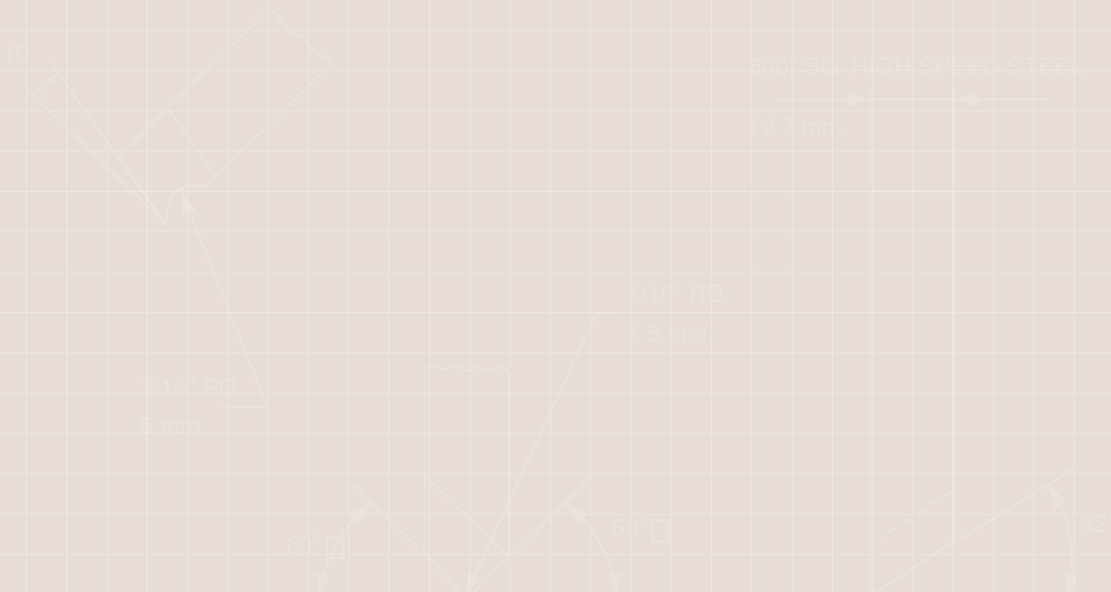


Marine Bearing

INSTALLATION MANUAL

Version: 2024.1

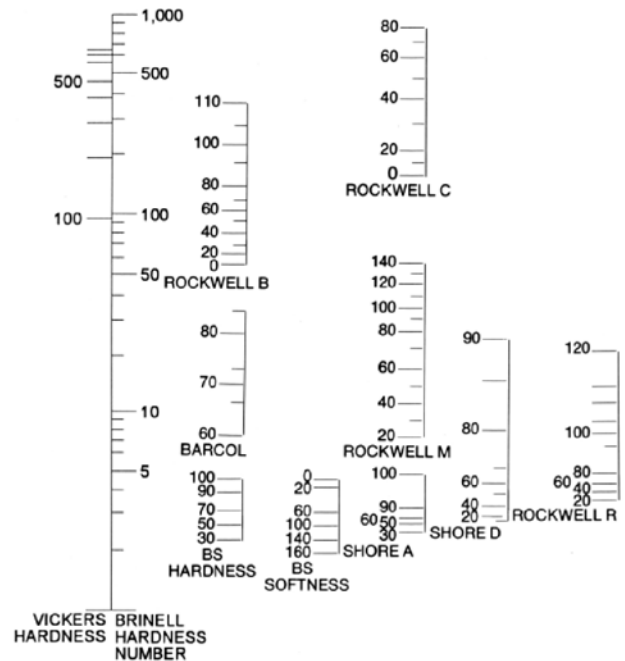


THORNDON

SYMBOLS & UNITS

SYMBOLS	UNITS	
	Metric	Imperial
Ct = Thermal Expansion Allowance	mm	inches
Cs = Absorption Allowance	mm	inches
d = Shaft diameter	mm	inches
Eo = Modulus of elasticity	MPa	psi
I.D. = Inside diameter of bearing	mm	inches
O.D. = Outside diameter of bearing	mm	inches
L = Length of bearing	mm	inches
N = Shaft speed	R.P.M.	R.P.M.
P = Pressure	MPa	psi
Ta = Machine Shop Ambient		
Temperature (Nominally 21°C (70°F))	°C	°F
To = Operating temperature	°C	°F
W.T. = Wall thickness of bearing	mm	inches
a = Coefficient of Thermal Expansion	°C	°F
μ = Coefficient of Friction	-	-
V = Velocity	m/ sec.	ft./min.
g = Poisson's Ratio		

APPROXIMATE COMPARISON OF VARIOUS HARDNESS SCALES



FREEZE FIT COOLANT TEMPERATURES

Dry Ice: -78°C (-109°F)

Liquid Nitrogen: -196°C (-320°F)

NOTE: All clearances referred to in this manual are diametrical clearances

METRIC CONVERSION TABLE

Length

1 Metre (m) = 39.37 Inches (in.)

1 Millimetre (mm) = 0.03937 Inches (in.)

Force

1 Newton (N) = 0.2248 lbs.

1 Kilogram (kg) = 2.205 lbs.

Pressure

* 1 kg/cm² = 14.223 psi (lbs./in.²)

** 1 Mega Pascal (MPa) = 145 psi (lbs./in.²)

1 N/mm² = 145 psi (lbs./in.²) = 1 MPa

1 MPa = 10.195 kgf/cm²

1 Bar = .981 kg/cm²

1 Mega Pascal (MPa) = 10 Bar

* Kilo = 1,000

** Mega = 1,000,000

OTHER THORDON TECHNICAL INFORMATION AVAILABLE

- Thordon Elastomeric Bearings Engineering Manual
- ThorPlas Bearings Engineering Manual
- Thordon Bearing Sizing Calculation Program

Please contact your local Thordon Distributor or Thordon Bearings Inc. if you require any of the above.

ThorPlas® is a registered trademark owned by Thordon Bearings Inc.

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INTRODUCTION

Thordon Bearings Inc. develops and manufactures synthetic polymer bearings for use as a high performance bearing material, particularly in marine applications. Thordon bearings provide long life and offer a unique combination of low friction, high elasticity and good mechanical properties (abrasion and shock resistance). Thordon bearings are homogeneous. They have a relatively high coefficient of thermal expansion that facilitates freeze fitting. They are also resilient and shock resistant. Thordon marine bearings are much easier to handle and install than other traditional marine bearings.

The important thing to remember is that Thordon elastomeric bearings are different from other bearing materials and therefore require slightly different handling. Anyone accustomed to working with bronze or other metallic bearing materials will find that the recommended amounts of interference and running clearance for Thordon elastomeric bearings are greater than for metals. The securing methods common for bronze or bronze-shelled bearings must also be re-considered when fitting Thordon elastomeric bearings. For example, flanged fitting, set screwing along the outside diameter (O.D.) and welding near the bearing are not acceptable with Thordon elastomeric bearings. Alternate methods of axially securing the bearing such as bolted retaining rings must be used. Thordon is a very easy material to machine. It is non-toxic and machines dust free. Therefore there are no health hazards involved.

Thordon elastomeric bearings are available in four grades for marine bearing system installations: XL, SXL, COMPAC and Composite. XL is the standard grade used in general marine applications. SXL is accepted as the preferred rudder bearing material, especially for highly loaded rudder applications, because of its lower coefficient of friction and ability to run dry. SXL is also used in propeller shaft bearings. COMPAC is a uniquely designed grade specified for propeller shaft applications to promote early formation of a hydrodynamic film between the shaft and the bearing. RiverTough/Composite is specially designed to provide long life in extremely abrasive conditions such as river boats, or suction cutter head dredges. These Thordon grades are similar in their basic chemical composition, and the same approach can be taken to installing any of them. Where differences do exist, they will be pointed out in this manual.

Thordon Bearings has recently introduced a new bearing grade: ThorPlas, a proprietary engineered thermoplastic. ThorPlas is a homogeneous, self-lubricating polymer material capable of working at dynamic pressures up to 45 MPa (6527 psi). It is not as abrasion resistant as the other Thordon elastomeric materials. The primary marine applications for ThorPlas are in highly loaded bearings where lubrication is difficult, such as fairleads, tiller arm bushings, ride control mechanisms, sheaves and davits. It is approved by most Classification Societies for use in ride control mechanisms at pressures up to 45 MPa (6527 psi). This manual is designed to provide the necessary information to install Thordon marine bearings of any size. For detailed technical information about Thordon Bearings refer to the Thordon Elastomeric Bearings Engineering Manual, or the ThorPlas Bearings Engineering Manual. If you have any questions or concerns please contact your local Thordon Distributor, or Thordon Bearings Inc., for further information or design assistance. For easy reference we have divided the manual into chapters as follows:

1. Propeller Shaft Bearings
2. Rudder Bearings and Other Marine Bearings
3. Operational Requirements
4. Dimensioning
5. Machining and Measuring Thordon Bearings
6. Installation Methods

Ch.1 PROPELLER SHAFT BEARINGS

1.1. GENERAL

1.1.1 INTRODUCTION

Thordon propeller shaft bearings are available to fit any size of shaft from 20mm (3/4") to 2000mm (80"), and larger if required. A standard range of bearings is available for shafts up to 305mm (12"). Custom made bearings can be supplied to suit any size of shaft and housing. Thordon bearings are available in a variety of forms that are described in the following sections of this chapter. Thordon propeller shaft bearings are normally fitted using an interference fit to hold them in place, however, where the orientation of the bearing is critical, anti rotation devices should be used. Thordon bearings may also be bonded in place in certain circumstances. Axial retention is recommended for all Thordon bearing installations. Water lubrication is most commonly used with Thordon propeller shaft bearings but comments on oil lubrication are provided in section 1.4.2.

1.1.2 BEARING LENGTH

Bearing length is dictated by Classification Societies based on load, operating speeds, and bearing design. Conventional water lubricated propeller shaft bearings are normally supplied with an L/D ratio (ratio of bearing length to shaft diameter) of 4:1 for the bearing next to the propeller (shorter lengths are used for FWD bearings). Fully grooved XL, SXL and RiverTough/Composite grades are normally designed to the 4:1 L/D standard. RiverTough at 3:1 L/D ratio has been used and approved for use on pushboats. Thordon COMPAC is approved by all major marine Classification Societies for use with an L/D ratio of 2:1 next to the propeller. This means that Thordon COMPAC bearings can be half the length of conventional water lubricated marine bearings. Comments that relate specifically to the shorter length option will be provided where appropriate in this manual.

Since Thordon bearings can be supplied in standard lengths, it will often be necessary to use a number of segments to make one marine bearing. The multiple segment concept is common with Thordon bearings. During installation, please ensure that:

- 1) the lubrication grooves are aligned
- 2) part of the axial expansion allowances are allocated to gaps between segments rather than leaving it all on the ends.

In view of the risk of misalignment on installation, Thordon Bearings recommends an annular groove (approximately the width and depth of the longitudinal grooves) be machined on one end of each segment where it will meet another bearing segment. The annular groove, as shown in Figure 1, allows water to flow from one segment to the next even if the grooves are not perfectly aligned. The annular groove can be added easily when machining the I.D. of the bearing. The machining sizes for Thordon bearings can be determined by using the Thordon Bearing Sizing Calculation Program.

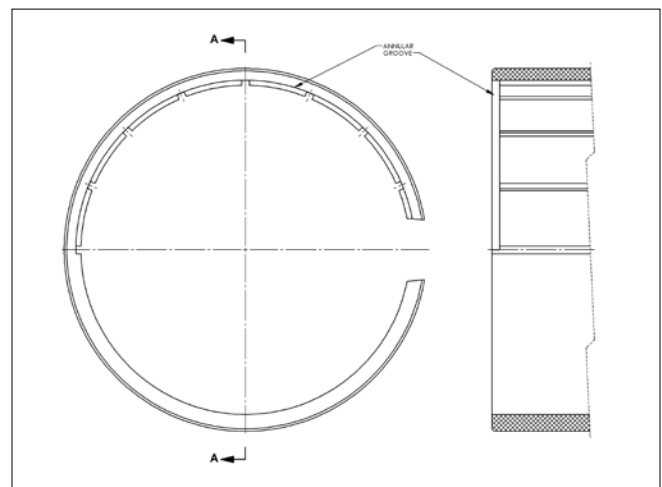


Figure 1: Drawing Showing Annular Groove in COMPAC Bearing

1.1.3 HYDRODYNAMIC OPERATION

Thordon propeller shaft bearings are designed to operate under hydrodynamic principles, where the shaft has to rotate faster than a threshold value to develop a hydrodynamic water-film between the shaft and bearing. The threshold speed is predominantly influenced by the bearing load and bearing configuration. Different configurations (length/diameter ratios, grooved or smooth, etc.) have different threshold speeds.

Through testing, Thordon has developed constants for various styles and configurations of Thordon bearings. These values are used to estimate the hydrodynamic thresholds for the bearings. When designing a vessel, the appropriate thresholds can be considered to ensure that the vessel's minimum continuous shaft speed is high enough to generate the hydrodynamic film. This should avoid prolonged operation at speeds where hydrodynamic film is not properly formed and where the sliding contact between shaft and bearing can accelerate wear.

PROPELLER SHAFT BEARINGS Ch.1

1.2 CYLINDRICAL BEARINGS

1.2.1 FULLY FINISHED

Any Thordon bearing can be provided in fully finished form, ready to install. Such bearings may be machined by Thordon Bearings Inc., by the shipyard, or by your local distributor. Fully finished bearings can be supplied to meet any inch or metric housing and shaft combination.

Fits and Clearances

Thordon bearings are normally designed for a press or shrink (interference) fit into the strut or stern tube. Sufficient oversize is allowed on the outside diameter (O.D.) of the bearing to prevent bearing movement, provided that the housing has not been pitted, corroded or rebored beyond its nominal diameter. Fully finished bearings are designed for an interference fit to suit specific shaft and housing dimensions. If actual shaft and housing dimensions vary from the original dimensions used to calculate the fully finished sizes, the bearing size may need to be recalculated using the Thordon Bearing Sizing Calculation Program. Fully finished bearings suitable for bonding into place can also be provided on request. Final dimensions for machining Thordon bearings can be easily determined by using the Thordon Bearing Sizing Calculation Program. Setscrews, which press against the bearing O.D., are not recommended for securing the bearing in place.

1.2.2 SEMI FINISHED

Semi finished bearings have similar dimensions to the fully finished bearings mentioned in section 1.2.1, but they have an oversize allowance on the outside, and undersize allowance on the inside as shown in Figure 2. This extra material is added to give flexibility to allow onsite machining should there be alterations in the shaft or housing dimensions. All semi finished propeller shaft bearings have moulded or machined lubrication grooves. Semi finished bearings are also supplied with some extra length to be used as a chucking allowance. It should be noted that the water grooves may not extend the full length of this chucking allowance. For propeller shaft bearing applications, **it is essential that the lubrication grooves extend along the full length of the final bearing.** Custom made semi finished bearings can be supplied to suit any combination of shaft and housing. The O.D., I.D. and length of Thordon semi finished bearings must be machined before installation. Refer to chapter 4, or the Thordon Bearing Sizing Calculation Program. Refer to Chapter 5 for machining instructions.

The "oversize" dimensions of semi finished bearings are based upon the calculated dimensions from the Thordon Bearing Sizing Calculation Program, not on nominal shaft and housing sizes. For example, the I.D. of a small semi finished bearing will be approximately 1.5mm (0.06") smaller than the calculated I.D., not the nominal I.D. (shaft size).

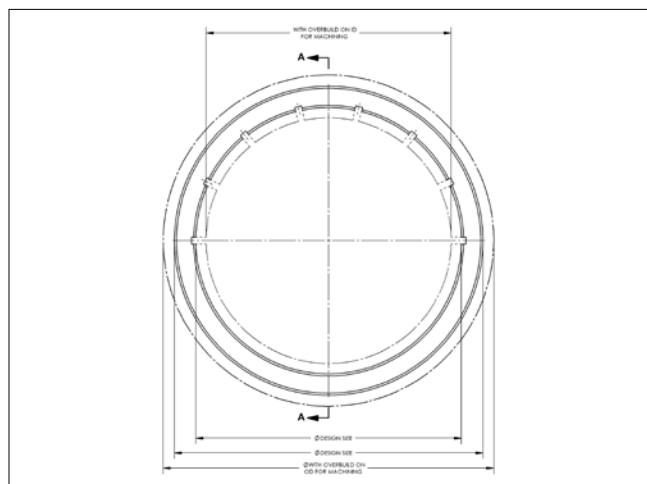


Figure 2: Semi Finished COMPAC Bearing with Overbuild

The use of semi finished bearings is an excellent way to make provision for "surprises" that may arise when the shaft and housing measurements are verified. With a semi finished bearing, sizes can be adapted on site to actual measured shaft or housing dimensions that may vary from those shown on drawings available before the vessel is docked.

1.2.3 MACHINED FROM STOCK TUBE

Thordon bearing material is available from stocking distributors in standard tube form. These tubes are 1 metre (39.4") long and come in a variety of inside and outside diameters to suit any application. However, using stock tubes for propeller shaft bearing installations requires machining lubrication grooves in the tube. These grooves must be machined prior to installation.

Line boring of the grooves in interference fitted bearings after fitting must be avoided because it has a negative impact on the interference pressure. The Thordon Bearing Sizing Calculation Program will provide groove dimension details. Groove machining is normally done by using the boring bar on the lathe as a "shaper". Custom moulded large bearings are often supplied without water grooves because they can be produced and delivered more quickly than grooved bearings.

Ch.1 PROPELLER SHAFT BEARINGS

1.3 STAVE CONSTRUCTION

1.3.1 STAXL SEMI FINISHED STAVES

Thordon STAXL staves are preformed profile sections, each designed to cover a range of housing and shaft diameters with a minimum of machining. All STAXL sections are supplied 1000mm (39.4") long. The profile of STAXL staves shown in Figure 3 is designed so that, in most cases, the only machining required is the boring of the I.D. after the staves have been installed in the housing, carrier or machine shop rig. Alternatively, the I.D. of each stove can be fly cut to the appropriate radius before fitting. In the fitting process, it is often necessary to adjust the width of one or two staves to achieve the required circumference and interference.

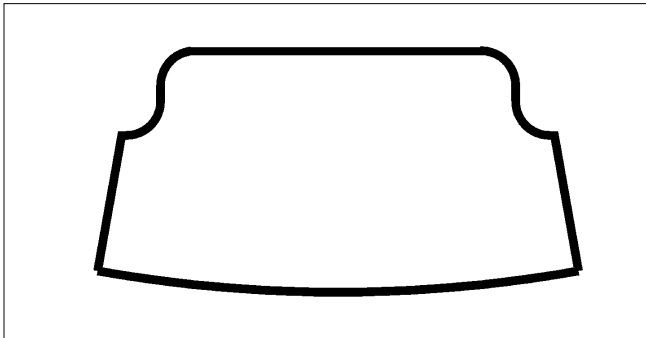


Figure 3: Thordon STAXL Stave Profile

STAXL staves are available in eleven different standard sizes as shown in Figure 4 below. For each cross section, the suitable range of shaft and housing sizes is shown. This information should be used as a guide to the suitability of a specific STAXL stave segment for a particular combination of shaft and housing. In addition, the thickness of the stave should be checked to ensure that there is sufficient material to machine to the required bore size without eliminating the preformed lubrication grooves. **It should be noted that, in all cases, the I.D. of the STAXL staves must be machined to the appropriate radius** (some rubber staves are designed for tangential contact between stave and liner. This does not apply to Thordon staves).

If a standard STAXL segment is not suitable for a given installation "as supplied", it is normally possible to adapt one by machining the side angles and exterior/back radius. If a very thin stave is required, it may be necessary to machine the back of the stave, or deepen the lubrication grooves as machining of the I.D. only may eliminate the lubrication grooves. If staves are being fitted with interference, but without keeper strips, the minimum wall thickness required for an interference fit must be retained, similar to interference used for tubular bearings. Refer to section 4.6 or the Thordon Bearing Sizing Calculation Program for minimum wall thickness requirements.

STAXL STAVES - 1000mm (39") LENGTH

Segment	Housing Diameter (mm)	Shaft Diameter (mm)	Chordal Width (mm)	Thickness (mm)	Housing Diameter (inches)	Shaft Diameter (inches)	Chordal Width (inches)	Thickness (inches)
G22	275 - 320	232 - 288	50	22	10.8 - 12.5	9.17 - 11.3	1.968	0.866
F27	320 - 365	270 - 325	58	27	12.5 - 14.3	10.6 - 12.7	2.283	1.063
E32	365 - 420	304 - 380	66	32	14.3 - 16.5	11.9 - 14.9	2.598	1.260
D42	420 - 480	340 - 430	75	42	16.5 - 18.8	13.3 - 16.9	2.953	1.653
D35	420 - 480	355 - 430	75	35	16.5 - 18.8	13.9 - 16.9	2.953	1.378
C42	480 - 555	400 - 505	78	42	18.8 - 21.8	15.7 - 19.8	3.071	1.653
C35	480 - 555	415 - 505	78	35	18.8 - 21.8	16.3 - 19.8	3.071	1.378
B42	555 - 660	475 - 610	78	42	21.8 - 25.9	18.7 - 24.0	3.071	1.653
B35	555 - 660	490 - 610	78	35	21.8 - 25.9	19.2 - 24.0	3.071	1.378
A42	660 - 790	580 - 740	84	42	25.9 - 31.1	22.8 - 29.1	3.307	1.653
A35	660 - 790	595 - 740	84	35	25.9 - 31.1	23.4 - 29.1	3.307	1.378

Figure 4: Thordon STAXL Stave Dimensions

PROPELLER SHAFT BEARINGS Ch.1

The number of staves required for an installation will vary with the actual size of the housing and the L/D ratio of the bearing. It also will vary with the number and size of keepers used (if any). The number and type of staves to make a complete circle can be determined using the Thordon Bearing Sizing Calculation Program. When the Input Screen is open, select "STAXL Stave" as the type of installation. Enter the shaft and housing details and confirm the temperature parameters. The Thordon Bearing Sizing Calculation Program will determine if the dimensions are suitable for a STAXL stave installation, make recommendations for changes, and then provide the reference to the appropriate stave cross section and the number of staves required to make a complete bearing. The number of staves must be increased appropriately for bearing lengths greater than one meter (39").

The number of staves required to make a complete circle for a specific installation can also be estimated manually by using the following formula:

$$\frac{C-K}{W} = \text{number of staves}$$

- where **C** = Calculated bearing O.D. with interference, converted to circumference
K = Total width of all keepers
W = Chordal width of stave to be used

NOTE 1: The number of staves is rounded up to the next whole number when one keeper strip is used, or to the next even number when two keeper strips are used.

NOTE 2: To make a complete circle, the above number must be increased appropriately for bearing lengths greater than one meter (39"). Avoid using multiple small pieces to make up the stave lengths.

NOTE 3: Figure 4 gives the chordal width of each STAXL stave cross section.

1.3.2 CUSTOM MOULDED STAVES

Thordon staves are also available in a fully moulded form. In this case full details of the housing and shaft, including drawings where possible, must be provided to Thordon Bearings in advance. Fully moulded staves are designed to be fitted directly into the housing. Machining of the O.D or I.D. is not required. It may, however, be necessary to machine the width of the last stave during fitting. The staves would normally be fitted using the freezing method (see Section 1.6). When installing fully moulded staves Thordon recommends that the I.D. of the bearing be checked after assembly of the staves to ensure that it is consistent with the calculated I.D. from the Thordon Bearing Sizing Calculation Program results. When fitting staves, either by freezing or with a press fit, the staves should be tapped frequently with a rubber mallet to ensure that they are well seated against the housing.

The "housing" referred to in this section can be either the stern tube or strut itself, or a metallic carrier. In either case, the housing must be in good condition, and the dimensions must be as indicated in the drawings provided to Thordon Bearings, or the fully moulded staves will not fit correctly. In view of this requirement, and the fact that production time for fully moulded staves may be 6-8 weeks, this type of stave is more suited to a planned docking.

Fully moulded staves are available in XL, SXL or Composite grades.

1.3.3 DOVETAIL STAVES

Thordon staves are also available in dovetail form, as shown in Figure 5, for installation in slotted housings.

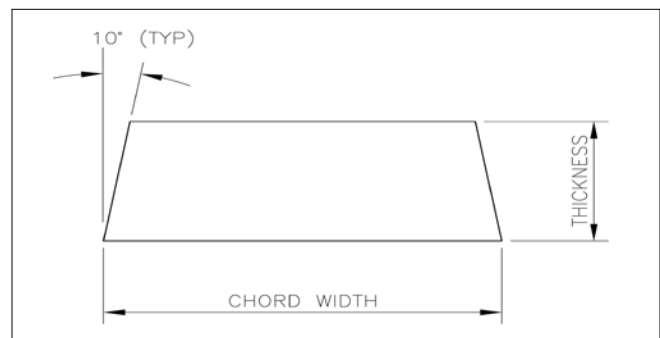


Figure 5: Thordon Dovetail Stave Profile

Ch.1 PROPELLER SHAFT BEARINGS

Ten sizes are available for standard dovetail groove and housing dimensions. All staves are supplied with a flat top to be machined or bored after assembly and a standard 10° side angle. (15 ° side angle staves are available on special order). Thordon dovetail stave dimensions are shown in Figure 6.

DOVETAIL STAVE DIMENSIONS

US NAVY Standard No.	Width of Slot (mm)	Thickness (mm)	Width of Slot (inches)	Thickness (inches)
001	43	22.2	1.687	7/8
002	46	22.2	1.812	7/8
003	49	23.8	1.937	15/16
004	52	23.8	2.062	15/16
005	56	23.8	2.187	15/16
006	59	23.8	2.312	15/16
007	70	26.9	2.750	1 1/16
008	75	26.9	2.937	1 1/16
009	78	30.1	3.062	1 3/16
010	81	30.1	3.187	1 3/16

Figure 6: Thordon Dovetail Stave Dimensions
- Supplied in 1 metre (39") Lengths

Thordon dovetail staves are designed to be freeze fitted into the dovetail slots in the housing or carrier. After installing all the staves, they must be line bored to the correct I.D. Many rubber type staves are designed with flat interior surfaces to facilitate hydrodynamic development. This concept works with soft rubber, but will not work with harder Thordon grades. A contoured inside surface is essential in all cases where Thordon dovetail staves are used. One acceptable alternative to line boring is fly cutting of each stave to the correct radius prior to installation.

1.4 GRADE SELECTION

1.4.1 COMPAC

This orange coloured bearing is specifically designed to provide the lowest friction in operation. This is achieved by using the Thordon elastomeric bearing that has the lowest friction, by not having grooves in the bottom half of the bearing (see Figure 7), and by reducing the bearing length relative to fully grooved bearings. The L/D ratio of the COMPAC bearing adjacent to the propeller can be as short as 2:1 versus the conventional water lubricated bearing ratio of 4:1 L/D. The length may be increased to accommodate low speed operation, but COMPAC is not normally used with an L/D ratio greater than 3:1. COMPAC is designed mainly for blue water operation. It is not recommended when the vessel will operate more than 10% of the time in abrasive water unless the water entering the bearing is cleaned.

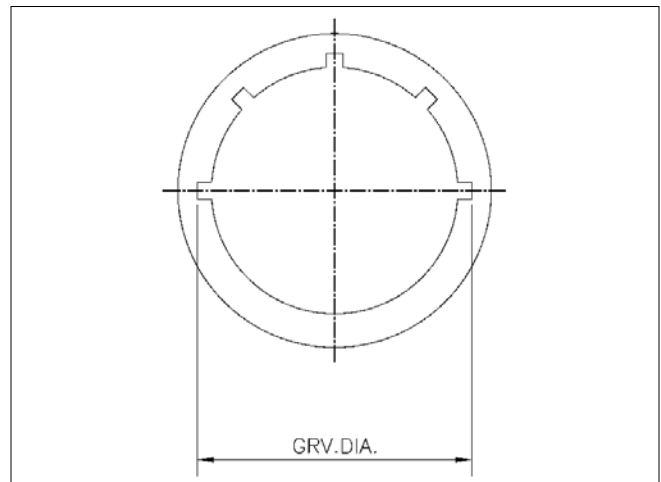


Figure 7: Thordon COMPAC Bearing Profile

PROPELLER SHAFT BEARINGS Ch.1

1.4.2 XL

The black XL grade provides good abrasion resistance, relatively low friction and good shock resistance (see Figure 8). Fully grooved XL propeller shaft bearings are normally designed with an L/D ratio of 4:1 for the bearing closest to the propeller. XL is not recommended if the vessel will operate more than 15% if its time in abrasive waters.

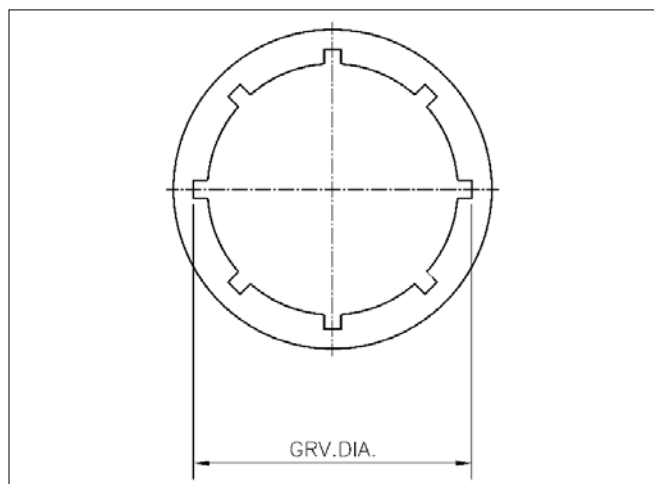


Figure 8: XL and SXL Fully Grooved Bearing Profile

1.4.3 SXL

This off-white Thordon grade has a low coefficient of friction. Being slightly softer, it is also slightly more tolerant of abrasion than XL. SXL can be used in vessels operating up to 20% of their time in abrasive waters. SXL is normally designed with a L/D ratio of 4:1 for the bearing closest to the propeller, and is fully grooved as shown in Figure 8.

1.4.4 RiverTough/COMPOSITE

RiverTough/Composite (see Figure 9) is a two-component bearing (yellow outside and black inside). The black inside material (known as GM2401) is softer and tougher than the other Thordon grades. As a result, RiverTough/Composite is the most abrasion resistant material of all Thordon grades and is designed for vessels operating over 20% of their time in abrasive operating environments. To ensure the optimum performance of RiverTough bearings, they should be used in conjunction with a very hard shaft or shaft liner. See section 3.5 for additional comments on mating materials. RiverTough is typically designed with an L/D ratio of 4:1 for the bearing closest to the propeller, however, RiverTough bearings at a 3:1 L/D ratio have been used and approved for use on riverboats.

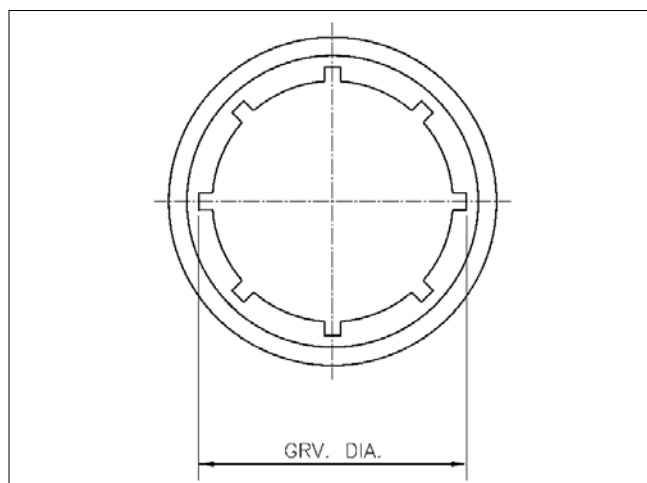


Figure 9: Thordon RiverTough/Composite Bearing Profile

Ch.1 PROPELLER SHAFT BEARINGS

1.5 LUBRICATION

1.5.1 SEAWATER

Water is the most common lubricant used with Thordon propeller shaft bearings. Water serves three purposes in the operation of the bearing. First, it forms a thin layer of hydrodynamic film between the shaft and bearing which reduces wear. Second, a flow of water removes heat generated during rotation of the shaft. Third, the water flow facilitates the removal of abrasive particles which can accelerate bearing wear. In order to accomplish this, a positive flow of cooling water from a pump source is recommended. **The minimum flow rate required is 0.15 litres per minute per mm (1 U.S. gallon per minute per inch) of shaft diameter.** The water pressure should be sufficient to overcome hydrostatic pressure from the draught of the vessel and flow losses, and to ensure positive flow at the aft end of the stern tube when the vessel is fully loaded. If vessel has two stern tubes, two water supply pipes are preferable to one large supply pipe that is split. The cooling water should be as close as possible to the temperature of the water in which the vessel is operating. Water which has already been used to cool the main engine, gear box or other machinery before it reaches the bearings may not be suitable. Water over 40°C (104°F) should not be used as it may have a detrimental effect on the Thordon bearing.



Figure 10: Thordon Water Quality Package

A pumped flow of water to a Thordon strut bearing is not normally required. Movement of the ship provides sufficient flow. Fairwaters and rope guards must be arranged so as not to impede water flow to the bearings. However, if the vessel spends a significant amount of time with the shaft turning and little or no forward or aft movement of the vessel (as in dynamic positioning or station keeping), a pumped flow of water to the strut bearings is recommended. Such a flow will also impede ingress of abrasive water when the vessel operates in shallow water. Water should be injected ahead of the inboard bearing in a stern tube. Thordon bearings can run without water flow for a limited time, but any sign of heating should be investigated immediately and corrected. For larger installations, water flow monitoring (see section 3.4 of this manual) is recommended to ensure that an adequate flow of cool water is being maintained. If a vessel equipped with Thordon elastomeric bearings spends a significant amount of time manoeuvring in very shallow or dirty water, consideration should be given to providing a source of clean water for bearing lubrication. A strainer or cyclone separator system can be used. Thordon Bearings manufactures a self contained Water Quality Package to ensure an adequate supply of clean water is consistently being delivered to both the forward seal and the bearings – see Figure 10. The life of the bearings will be extended if clean lubricating water is supplied to the bearings.

1.5.2 OIL

Although Thordon can operate in oil lubrication, it is not the preferred lubricant for propeller shaft bearings because it does not have the heat dissipation capacity of water.

1.5.3 GREASE

Grease lubrication of Thordon propeller shaft bearings is not recommended because grease cannot facilitate heat dissipation readily.

PROPELLER SHAFT BEARINGS Ch.1

1.6 FITTING OPTIONS

1.6.1 TUBULAR BEARINGS

Tubular bearings are normally interference fit using a freeze or press fit into a "housing". The "housing" can be the stern tube or strut of the vessel. It can also be a bronze or metallic carrier which is in turn fitted into the strut or stern tube. Thordon bearings can even be fitted into the bronze carriers of rubber-type bearings. In this case, the rubber is machined out to provide a smooth round bronze housing so the Thordon bearing can be fitted. Care should be taken to ensure there is enough bearing wall thickness to accommodate the stresses of an interference fit. If not, the Thordon bearing may have to be bonded into place.

With some water lubricated propeller shaft bearing installations such as naval or cruise ships, there is a requirement for being able to remove the bearings without removing the shaft. Shaft withdrawal of long shafts can be expensive and time consuming. The traditional configuration to facilitate removal of bearings with the shaft in place is by using split bronze carriers. The carriers are split on a taper to facilitate installation. Thordon bearings can be fitted into split carriers using split Thordon tubes either by using an interference fit and keepers along the edges of each half, or by bonding each half into the carrier. Detailed instructions are provided in Section 6.2.4 of this manual. There is also usually a second carrier permanently fixed in the strut or stern tube, into which the split carrier is fitted.

Thordon has developed a simpler approach that allows bearing removal with the shaft still in place. This involves using split Thordon bearings (typically COMPAC), a set of tapered keys, and a single non-split tubular metallic carrier which is permanently bolted or chocked into the strut or stern tube. One half of the tapered key set is fixed to the I.D. of the carrier, usually at the 3 or 9 o'clock position. The other half of the tapered key set is a sliding fit. First, the split Thordon bearings are installed in the housing. They are dimensioned using a normal interference fit. Second, the sliding half of the tapered key set is installed. As the key is inserted, it generates the interference. To remove the bearings, the sliding key is 'pulled' to remove the interference. Then the split bearing halves can be easily removed for inspection or replacement. This approach has also been used with stave type bearings. A more detailed overview is presented in Appendix 1 – Thordon COMPAC with Single Tapered Keyset Installation Manual.

Bonding of Thordon bearings is an alternative to press or freeze fitting. Bonding is used when the wall thickness of the bearing is not sufficient for an interference fit – for example when re-lining small bronze-backed rubber bearings. Bonding may also be used when the housing is not suitable for an interference fit – if it is not round, or not machined to provide full support along the full length of the bearing. Detailed instructions for bonding are in Chapter 6 - Installation Instructions and in Appendix 2: Bonding with TG-75.

1.6.2 STAVE TYPE BEARINGS

Thordon STAXL stave bearings can be fitted into tubular housings with or without the use of keepers. For repair or conversions, Thordon staves typically replace existing phenolic laminate or lignum vitae staves. These are usually fitted with keepers, so Thordon staves are usually fitted into the same configuration.

In the case of an installation where there are no keepers, consideration should be given to using Thordon tubular bearings rather than staves. Thordon tubes are easier and quicker to fit.

Ch.2 RUDDER BEARINGS & OTHER MARINE BEARINGS

2.1 GENERAL

Thordon has over 4000 rudder bearings installed on all sizes and types of vessels. The bearings can be supplied in either tube or stave form, and designed to operate with any type of lubrication - water, grease, oil, or, in the case of SXL, dry. This allows Thordon bearings to be installed without the need for lubrication lines and eliminates the pollution associated with grease. Where Thordon rudder bearings are expected to run dry, Thordon SXL grade should be used rather than XL because SXL has a lower dry coefficient of friction. SXL is also recommended for highly loaded submerged rudder bearings because its lower coefficient of friction provides better performance when high pressure reduces or eliminates the lubricating properties of water.

Thordon elastomeric bearings can be specified in all rudder bearing locations including stock, pintle and carrier bearings, while ThorPlas bearings can be used for tiller arm and steering gear linkage bushings. ThorPlas marine bearings are designed to withstand radial loads as high as bronze in relatively non-abrasive dry or wet applications. On some spade rudder designs for military vessels, ThorPlas bearings are also recommended due to the high pressures generated by extreme maneuvers at high speeds.

Thordon SXL rudder bearings are approved by all major Classification Societies for pressures of 10 to 12 MPa (1450 to 1740 psi). This high pressure approval allows the designer to match bearing pressure limits more closely to the bending and torsion requirements for the rudder stock. Significant weight and cost savings can often be achieved as well as a more slender rudder profile.

2.2 CYLINDRICAL BEARINGS

2.2.1 COMPLETE TUBE

Thordon SXL and XL tubular bearings are recommended for the pintle, stock and neck bearings, while SXL can be also be used as a carrier disc bearing. Because rudders move very slowly over a limited range, there is no need for a forced cooling water system, and therefore no need for the water grooves normally found in propeller shaft bearings. A full range of Thordon SXL rudder bearings in nominal diameters from 300mm (12") to 950mm (37") and an L/D ratio of 1.5:1 are available. Larger custom sizes can be supplied to suit many combinations of shaft and housing dimensions. Thordon rudder bearings can also be made from Thordon standard stock 1 metre (39.4") long tubes. Thordon rudder bearings are normally supplied in rough moulded form for local machining to the final dimensions required. Use the Thordon Bearing

Sizing Calculation Program for calculating dimensions, or refer to Chapter 4 for further dimensioning information. Chapter 5 contains machining instructions. Bearings can be machined by Thordon Bearings, by the local distributor, or most commonly by the shipyard where the bearings will be installed. It is preferable to machine the bearings on site so the dimensions can be adapted to suit actual measured shaft and housing dimensions which may vary from those on the vessel drawings.

2.2.2 SPLIT BEARINGS

It is sometimes preferable to use split tubular bearings rather than complete tubes. Split bearings facilitate installation without removing the complete rudder, or completely dismantling the steering gear. Any Thordon tubular bearing can be split to facilitate installation. A standard milling machine is normally used for this purpose, although Thordon Bearings has developed technology for splitting rudder bearings without a saw cut, thus leaving no gap. If the split is made by milling or cutting a tube, the bearing can still be fully machined before splitting. See Chapter 5 for detailed instructions. Split bearings can be fitted into split carriers, or can be held in place by an interference fit developed when the housing is bolted back together.

2.3 STAVE CONSTRUCTION

Stave type bearings are sometimes used in large rudders, particularly for retrofit when it is desirable to avoid unshipping the rudder assembly or steering gear. Thordon XL or SXL can be supplied in stave form. Working with staves usually requires more time and labour than working with tubes, so the use of tubes is recommended when feasible. If Thordon is replacing laminated phenolic staves for example, just because the phenolic bearing was made in stave form is no reason to make the replacement Thordon bearing from staves. Thordon cylindrical tubes would be recommended, as they are much easier to work with.

2.3.1 SEMI FINISHED STAVES

A standard range of semi finished Thordon rudder bearing staves has not been produced because of the general preference for tube type bearings. Some sizes are available, however, for particularly large diameters. Details are available from Thordon Bearings. Other sizes can be produced on request. Semi finished rudder staves are moulded to suit the required O.D., but must be machined on the I.D. to suit the specific stock dimensions and clearance requirements. The difference between rudder bearing staves and STAXL propeller shaft bearing staves is that the rudder bearing does not have lubrication grooves.

RUDDER BEARINGS & OTHER MARINE BEARINGS Ch.2

2.4 GRADE SLECTION

2.4.1 SXL

Thordon SXL (off-white) has a low coefficient of friction with high resistance to shock loading and vibration in rudder and other marine bearing applications. SXL can operate dry or with water lubrication, thus eliminating the need for greasing systems. Thordon SXL is approved by most Classification Societies for bearing pressures between 10 and 12 MPa (1450 to 1740 psi). Thordon Bearings Inc. offers a 15-year wear life guarantee for SXL rudder bearings in newbuild Classed vessels. In conversions, Thordon offers a wear life of twice the life of the non-Thordon bearing replaced, up to a maximum of 10 years.

2.4.2 XL

Thordon XL (black) has a low coefficient of friction with high resistance to abrasion but is not suitable for dry running in rudders. Thordon XL is approved by most Classification Societies for maximum bearing pressures between 5.5 to 7.5 MPa (800 to 1090 psi).

2.4.3 THORPLAS (FOR HIGHLY LOADED, NON-STANDARD APPLICATIONS)

ThorPlas-Blue is a proprietary engineered thermoplastic capable of withstanding operating pressures up to 45 MPa (6527psi) installed in a full form, interference-fit bearing configuration. It has a very low coefficient of friction similar to SXL and can operate dry without grease. Its properties make it an ideal bearing for highly loaded marine applications such as tiller arms, jockey bars and ride control mechanisms, where grease lubrication is difficult and sporadic causing failure of bronze and other metallic bearings. A separate ThorPlas Engineering Manual is available from Thordon Bearings or your authorized Thordon Distributor.

2.5 LUBRICATION

2.5.1 SEAWATER

Rudder pintle bearings are immersed in the water under most loading conditions. Rudder stock bearings may operate wet or dry. SXL is also recommended for highly loaded rudder bearings.

2.5.2 GREASE

Grease lubrication can be used with any type of Thordon rudder bearing if the assembly is designed for grease lubrication. However, since one of the advantages of Thordon SXL is its ability to run dry, removal of an existing greasing system tends to make the Thordon installation more cost effective. It eliminates a potential source of pollution and the associated cost of grease and labour. Using grease will also leech out the bearings internal lubricant, so if grease is used, it must always be used.

2.5.3 DRY RUNNING

If a rudder bearing is expected to run dry, Thordon SXL should be used. Liquid soap can be used to facilitate assembly and initial bedding in of the bearing.

2.6 OTHER MARINE APPS

There are numerous applications other than propeller shaft and rudders for Thordon bearings on ships. The dry running capabilities of SXL, and the load carrying capacity of ThorPlas offer unique advantages. The following is a partial list of applications:

- **Stern Roller Bearings** – either SXL or ThorPlas-Blue with greasing for extreme loading
- **Fairlead and Davit Bearings** – dry running with either SXL or ThorPlas-Blue depending on the bearing pressure
- **Ride Control Mechanisms on Fast Ferries** – ThorPlas-Blue not greased at pressures up to 45 MPa (6527 psi)
- **Stabilizer Bearings** – either SXL or ThorPlas-Blue not greased depending on pressures
- **Diving Plane Bearings on Submarines** – SXL not greased
- **Suction Cutter Head Dredge Bearings and Intermediate Lineshaft Bearings** – Composite with flushing water flow
- **Dredge Ladder Pivot Bearings** – SXL
- **Pumps** – SXL, XL, Composite or ThorPlas-Blue

The dimensioning, machining and fitting instructions provided in chapters 4, 5 and 6 are applicable to these applications except for ThorPlas-Blue, which is covered in a separate manual. The Thordon Bearing Sizing Calculation Program can be used for dimensioning of any of these bearings.

Ch.3 OPERATIONAL REQUIREMENTS

3.1 ALIGNMENT

Good alignment between the shaft and the bearing assists in ensuring satisfactory wear life. As the angle between shaft and bearing increases from misalignment, the load will be distributed over a smaller bearing area. This leads to localized high pressure on the bearing, increased speed necessary to develop hydrodynamic lift and a possible increase in adhesive wear.

It is recommended for design that the maximum misalignment between the shaft and bearing be limited to 3×10^{-4} radians. Due to the visco-elastic properties of Thordon elastomers, the actual misalignment that can be tolerated and still provide satisfactory service can be greater than this and is dependent upon the magnitude of the misalignment, direction and loading. For consideration of misalignment greater than 3×10^{-4} radians, Thordon Bearings should be consulted.

3.2 HOUSING BORE

All Thordon bearings require radial support around the circumference and along the full length. It is important that the housing be circular, consistent along its length and properly aligned. The bearing material will conform to the shape of the housing and transmit any irregularities in circularity or shape to the bearing surface.

For out-of-round or misaligned housings, there are three alternatives:

1. The preferred option is to repair the housing either by boring it, or for small local areas, by using epoxy and grinding.
2. The bearing can be bonded into place using TG-75 adhesive available from Thordon Bearings, or an epoxy resin.
3. The last, and least preferable option is that the bearing can be pressed into the housing and then bored to ensure it is round and aligned. Boring after fitting of an ungrooved rudder bearing should be limited to 5% of the wall thickness. Boring of a grooved propeller shaft bearing should be limited to no more than 10% of the wall thickness, or 25% of the groove depth, whichever is less. Removal of more wall than indicated above will have an adverse effect on the interference fit as stresses are concentrated on the I.D. of the bearing. Machining of lubrication grooves for propeller shaft bearings must always be done before the bearing is fitted into the housing. It is recommended that the housing be machined to within an ISO H7 tolerance and have a surface finish of 3.2 micro-metres (126 micro-inches) Ra.

Offset line boring of interference fit Thordon bearings to correct misalignment is not recommended because of the negative impact such boring can have on the actual interference. Offset boring of Thordon bearings before fitting is feasible, but great care must be taken to index the bearing correctly so that final fitting achieves correct alignment. In any offset boring operation, care must be taken to ensure that the minimum required wall thickness (wall behind grooves) for the interference fit is maintained at the thinnest point in the bearing. The use of mechanical anti rotation devices (keys or pins) is required for offset bored bearings to ensure that rotation does not change the orientation of the bearing (see Section 3.10).

3.3 PRESSURES

Nominal bearing pressures are calculated using:

$$\text{Pressure} = \text{Bearing Load} / (\text{Bearing Length} \times \text{Shaft Diameter})$$

3.3.1 PROPELLER SHAFT BEARINGS

The maximum allowable pressure is limited by the Classification Societies. Information on particular Classification Society requirements may be obtained directly from Thordon Bearings or your authorized Thordon Distributor. Most Classification Societies have approved all Thordon elastomeric grades for propeller shaft applications at pressures up to 0.6 MPa (87 psi).

3.3.2 RUDDER BEARINGS

Because rudder bearings are not exposed to continuous high shaft rotation speeds, they can accept much higher loads. Thordon SXL is approved by most Classification Societies for bearing pressures between 10 and 12 MPa (1450 to 1740 psi). Part of the reason for this high pressure approval of SXL is its low coefficient of friction. Thordon XL is approved for maximum pressures from 5.5 to 7.5 MPa (800 to 1090psi).

3.4 MONITORING

3.4.1 TEMPERATURE

Temperature probes are usually not installed in water lubricated bearing systems. However, for large Thordon propeller shaft bearing installations, temperature monitoring near the aft end of the aft bearing can be installed. Due to the thermal insulating qualities of Thordon, temperature sensors installed within the bearing wall will have a significant time lag in identifying problems. A probe can be inserted in the bottom of the bearing. The probe should be as close as possible to the I.D. of the bearing after allowing for maximum bearing wear. Typically the probe would be 8 to 10mm (0.315" to 0.394") below

the bearing I.D. Because of the low probability of heat generation, temperature monitoring for rudder bearings is unusual.

3.4.2 WATER FLOW

To achieve optimum life with Thordon propeller shaft bearings it is essential that an adequate flow of cooling water be supplied to stern tube bearings under all operating conditions. Monitoring of the flow of water is recommended, especially for larger vessels. Simple flow alarms are acceptable. The alarm should be set at 90% or more of the recommended minimum flow required for the bearings. Any reduction or stoppage of flow should be immediately investigated. Thordon's Water Quality Package incorporates a flow alarm to alert the operator to any low water flow condition to the bearings.

3.5 MATING SURFACES

3.5.1 BRONZE

Bronze is the most commonly used shaft liner material in marine service. It resists seawater corrosion, is easily machined, commonly available, and can be shrunk onto shafts. Nickel aluminum bronze is not recommended because experience has shown that it can lead to high bearing wear rates. Static cast bronze should be avoided for similar reasons.

There is a vast range of materials commonly called bronze. Two specific types which have given good service with Thordon bearings, and that are fully approved by Classification Societies, are Gunmetal (88% Cu, 10% Sn, 2% Zn) and "70-30 Copper Nickel". Both are relatively hard. In conjunction with Thordon bearings, bronze liners are acceptable for propeller shaft service as long as the vessel is not operating continually in abrasive conditions. In abrasive water environments, a harder liner material should be used.

When operating in significant abrasive environments, the theoretical optimum mating surfaces are the hardest practical surface on the shaft combined with the softest bearing material that will support the load and resist the abrasion. For severe, abrasive environments, a Thordon RiverTough bearing and a mating surface with a hardness of at least 40 Rockwell C are recommended. Nickel chrome boron coated liners can achieve 60+HRC.

For rudder bearing applications, bronze or stainless steel are acceptable liner materials. Lower pintle bearing positions for vessels operating in dirty environments should be equipped with a harder liner if wear has been experienced in this position.

3.5.2 CARBON STEEL

Carbon steel shafts are relatively inexpensive in smaller sizes. As long as there is not a corrosion problem, (i.e. fresh water service) these shafts can be fitted without liners. If, however, the vessel experiences a layover during which corrosion occurs on the shaft in way of the bearing, a high bearing wear rate may occur upon start-up. This high wear is a result of the rough, corroded shaft surface effectively "machining away" the Thordon bearing. Carbon steel shafts should not be used in salt water unless fitted with appropriate liners in way of the bearings and appropriate corrosion protection between the liners.

3.5.3 HARD METAL SLEEVES

Sleeves manufactured from hard, corrosion and abrasion resistant steels are particularly common on tug or push boats operating in dirty river environments. These operating conditions are usually very abrasive and a hard liner material is necessary for long life operation. There are many alloys available. Cost and availability play a role in selection. Some hard sleeves use a carbide coating such as boron carbide or tungsten carbide. The typical hardness would be in the range of 50-60 Rockwell C. A flame sprayed coating of a nickel chrome boron alloy over a stainless steel substrate and Thordon Composite bearings provide consistently good wear performance in abrasive water conditions in propeller shaft applications.

3.5.4 INCONEL 625

The U.S. Navy, and several other navies have experienced excellent results with submerged arc welded Inconel 625 alloy coatings. This alloy is a high nickel content (60%), corrosion resistant alloy that can be applied by cladding or in the form of a tubular liner or sleeve.

NOTE: Some Classification Societies will not permit welded liners, but many Naval authorities do.

3.5.5 STAINLESS STEEL

Most stainless steel alloys are not particularly good wear resistant materials; this is especially true of its easily machinable alloys. A liner should offer both good corrosion and abrasion resistance. This combination is often difficult to achieve; the most corrosion resistant alloys often offer poor abrasion resistance. Thordon has observed stainless steel shafts exhibiting substantial wear when running against a Thordon bearing. It is probable that the vessels were operating in abrasive water conditions. Some types of stainless steel shafting are good under abrasive conditions. Alloys with hardness higher than 30 Rockwell C would be the most appropriate. In

Ch.3 OPERATIONAL REQUIREMENTS

very abrasive conditions, however, a separate hard liner should be fitted, (see 3.5.3 above).

3.5.6 UNACCEPTABLE MATING MATERIALS

Neither Aluminum nor Titanium should be used with Thordon bearings. Soft stainless steels should be avoided if there are any abrasives present in the water. As mentioned above, Thordon does not recommend the use of nickel aluminum bronze. Non-metallic shaft liners should also be avoided.

3.6 MATING SURFACES - FINISH

Thordon bearings operate better with a highly polished mating surface. Badly corroded or scored shafts or liners should be avoided. The optimum surface finish is 0.4 to 0.8 micro-metres (16 to 32 micro-inches) Ra.

3.7 CORROSION PROTECTION

Thordon bearings are non metallic and avoid the type of electrolytic corrosion normally found between a metallic bearing and the housing. Thordon bearings, installed with an interference fit, normally press against a housing tightly enough to avoid penetration of corrosive water between the bearing O.D. and the housing. Additional protection of carbon steel housings can be achieved by painting the interior of the housing with a corrosion resistant epoxy paint prior to installation of the Thordon bearing. Freeze fitting of the bearing will minimize damage to the paint during bearing installation. The stern tube I.D. between housings should also be painted with corrosion resistant epoxy paint

Propeller shafts, which are subject to corrosion in seawater, must be protected between the liners by a corrosion resistant coating. The most common coatings used are vulcanized rubber and epoxy fiberglass. Both have disadvantages, and consequently the shaft survey interval for open systems depends on the Class Society.

3.7.1 Thor-Coat or ThorShield SHAFT COATING

Thor-Coat and ThorShield are epoxies modified to enhance dynamic performance. Thor-Coat and ThorShield are designed primarily for the protection of propeller shafts exposed to seawater from corrosion. Easily applied on a rotating lathe to a thickness of 2mm (0.08"), application is straightforward, (Figure 11). Thor-Coat and ThorShield are flexible, shock resistant, and in the event of coating damage where corrosion can then occur, the corrosion

is limited to the damaged area only and will not migrate along the shaft under the coating to unexposed areas. Localized damage can be easily repaired if necessary. Other uses such as coating stern tubes, rudder stocks and trunk surfaces are also possible. Detailed information on Thor-Coat and ThorShield can be obtained from Thordon Bearings or your local authorized Thordon distributor.



Figure 11: Easy Application of Thor-Coat & ThorShield

3.8 MARINE GROWTH

Marine growth is a problem typically associated with, but not limited to, propeller shafts in warm water. If marine growth occurs on the shaft or bearing surface, it can easily cut the bearing when the shaft is turned. Any shaft immersed in water should be rotated a few revolutions every second day. Flushing with fresh water will also help to reduce the amount of marine growth.

3.9 CATHODIC PROTECTION – CATHODIC CHALK

Cathodic protection is a normal part of any ship. Thordon Bearings has observed some examples of high levels of impressed cathodic protection causing the buildup of cathodic chalk on the shaft liners. This white chalk has been the cause of accelerated wearing of bearings. If white chalk appears on the shaft liner, the level of cathodic protection should be reviewed.

3.10 ANTI ROTATION DEVICES

Interference is normally sufficient to prevent rotation of a bearing in a housing, however, where the orientation of the bearing is critical (COMPAC bearings, for example) an anti rotation device should be fitted.

Some options for providing positive anti rotation are listed below:

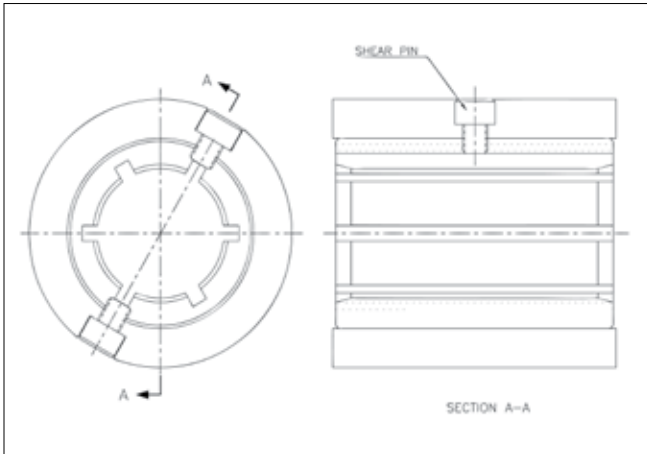


Figure 12: Radial Pin or Screw

Grub screws are not accepted as anti rotation devices. Shear pins or screws will work if fitted properly. Any radial pin must be fitted into a hole drilled completely through the full wall thickness of the bearing as shown in Figure 12. If fitted into blind holes, there is a significant risk that they will deform the wall of the bearing. The length of the actual pin in the bearing should typically be half of the wall thickness.

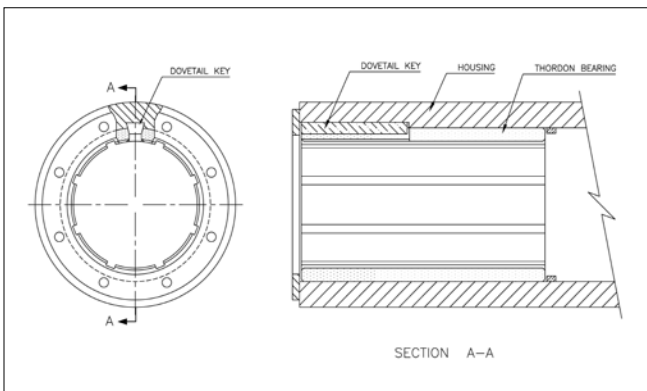


Figure 13: Dovetail Key (partial length)
Cannot be used for multi piece bearings.

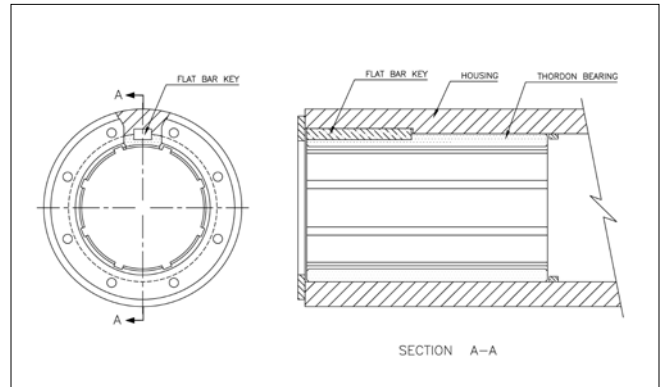


Figure 14: Flat Bar Key (partial length)
Cannot be used for multi piece bearings.

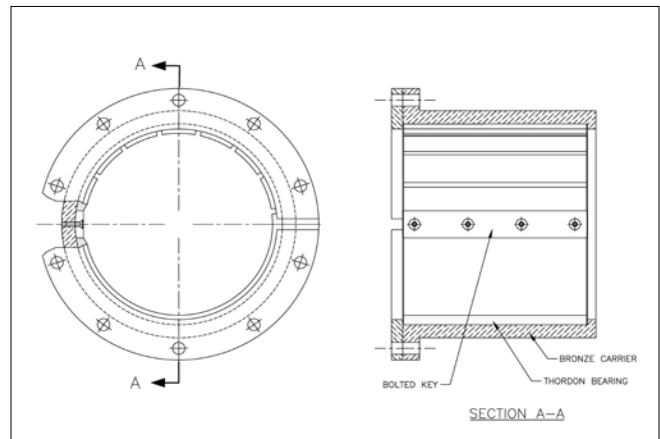


Figure 15: Bolted Key (full length)

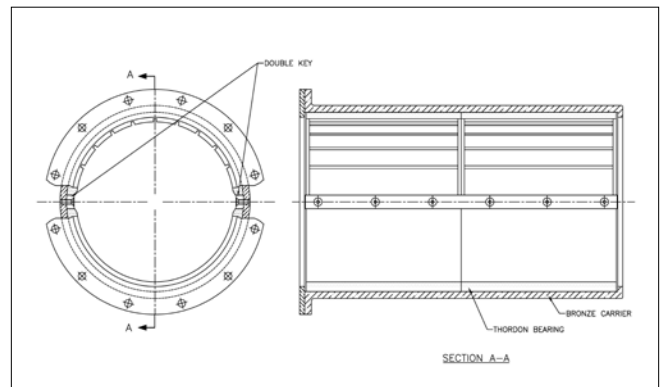


Figure 16: Traditional Double Key

Ch.4 DIMENSIONING

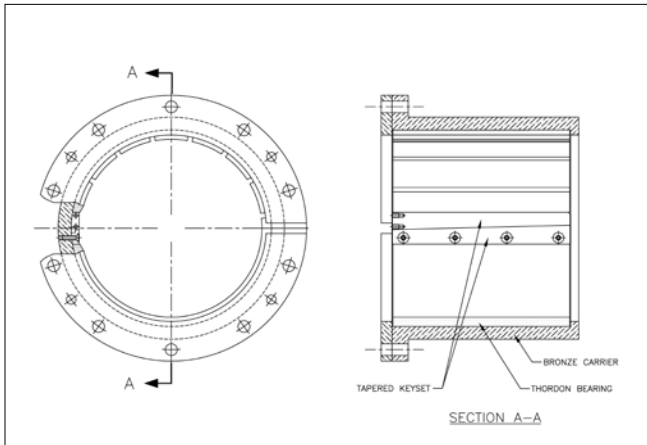


Figure 17: Tapered Keyset

3.11 MAXIMUM CLEARANCES

Bearings, when properly designed, installed and maintained, will provide many years of satisfactory service. However, in service, the bearings will wear either as a result of abrasive or adhesive conditions. The maximum wear can be a function of either a physical limitation of the bearing or a limit of the application.

As wear normally increases the maximum clearances in the bearing and as clearance is normally easier to measure than wear, the maximum clearances for different applications will be used.

As Thordon materials are homogeneous, the bearing material properties will not change as wear occurs in the bearing wall. The first limitation is the wall thickness of the polymer material to ensure that there is no metallic material contact between the shaft and the housing parts. This applies equally whether the bearing is a freeze fit bearing or a thin walled bonded bearing. In any case, maximum possible wear would be the wall thickness of the bearing as shown in Figure 18.

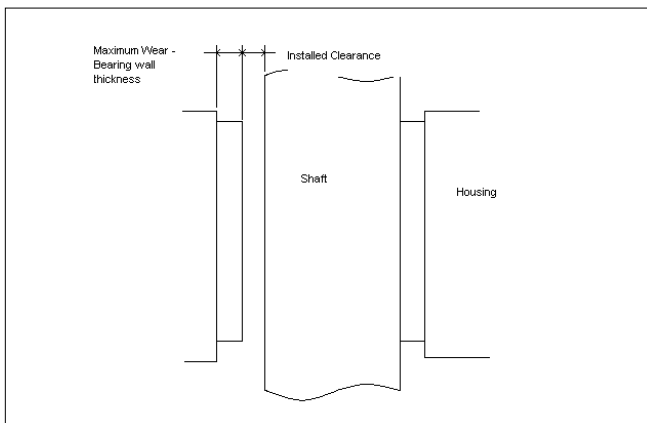


Figure 18: Maximum Wear is Wall Thickness of Bearing

As most freeze fit bearings are fit with axial retaining rings the first metallic contact would be between the shaft and the retaining rings as the bearing wears. The maximum wear would then be the wall thickness of the bearing proud of the retaining ring I.D. as shown in Figure 19.

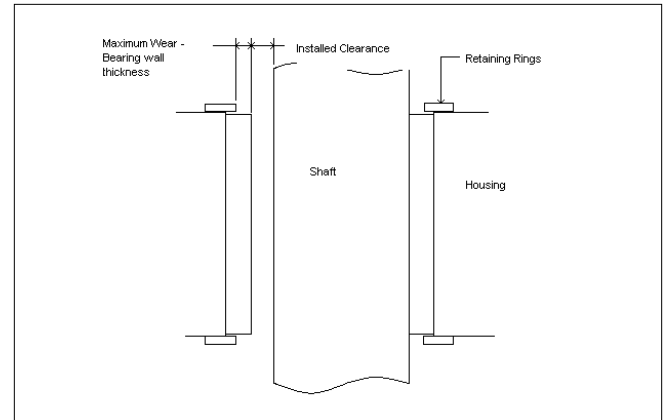


Figure 19: Maximum Wear is I.D. of Retaining Ring

In addition to physical constraints listed above, the maximum wear in a bearing may be limited by regulatory authorities or in the case of marine applications, Classification Societies. Each Classification Society will have guidelines on the maximum wear (or maximum clearances) that would be allowed in rudder or propeller shaft bearings. The following guidelines are general in nature and provide a basis for acceptable practice.

3.11.1 RUDDER BEARINGS

The maximum clearances for rudder bearings will vary slightly depending upon the Classification Society and the rudder arrangement. As a general rule, the maximum clearances for a rudder bearing can be calculated from the following formula:

Metric: Maximum Clearance =
shaft diameter (over liner) \times 0.002 + 5mm

Imperial: Maximum Clearance =
shaft diameter (over liner) \times 0.002 + 0.20"

3.11.2 PROPELLER SHAFT BEARINGS

The maximum clearances recommended for water-lubricated propeller shaft bearings is dependent upon the bearing design and the shafting arrangement. Bearing design includes bearing wall thickness, bearing configuration (grooved or ungrooved), loading, and shaft size. Shafting arrangement dictates the positional relationship between the bearing and the propulsion machinery. The maximum allowed bearing clearance is normally governed by the Classification Society involved. The graphs below show the typical maximum recommended clearance for propeller shafts. If no Classification Society is involved, then the groove depth can be used as an indication, i.e. replace bearings when groove depth has reduced to 0.5 - 1mm or 0.02" - 0.04". For COMPAC bearings with no grooves on the bottom wear area, the maximum wear can be calculated using the upper grooves.

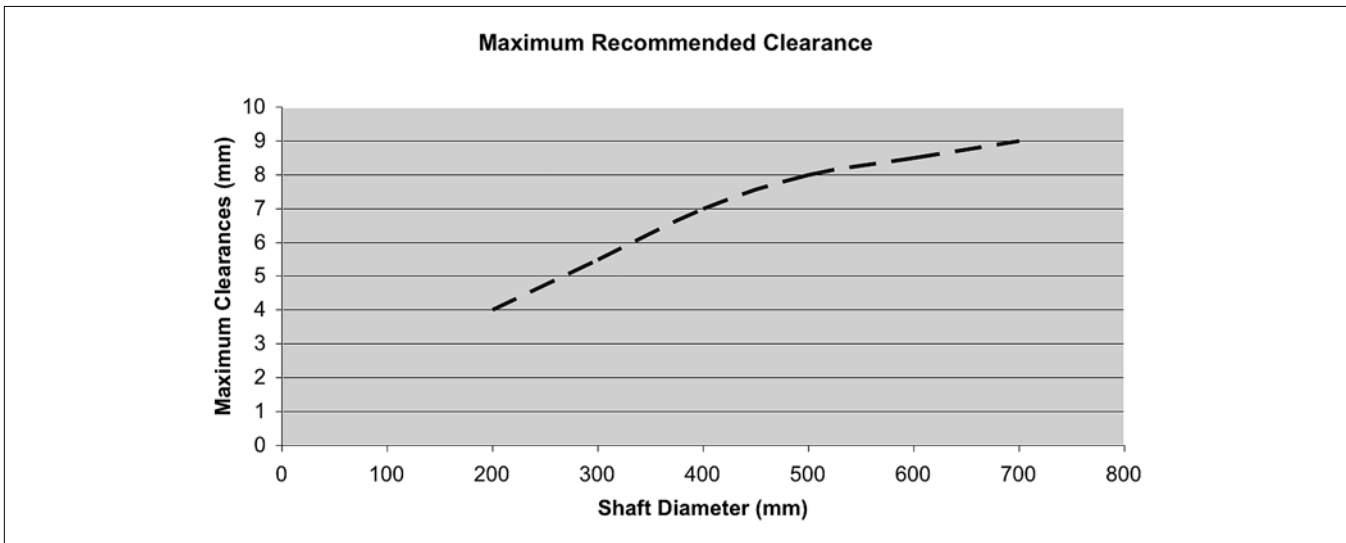


Figure 20: Typical Maximum Clearance (metric) for Stern Tube and Strut Bearings



Figure 21: Typical Maximum Clearance (imperial) for Stern Tube and Strut Bearings

Ch.4 DIMENSIONING

4.1 GENERAL

Dimensioning procedures for Thordon bearings are different from traditional bearing materials. Thordon bearings cannot be made to the same dimensions as the bronze, rubber, wood or other bearing materials they may be replacing. This chapter will provide the information necessary to dimension Thordon bearings. The process should be followed in the sequence indicated.

4.2 INFORMATION REQUIRED

The following information is required for dimensioning a Thordon bearing:

- Housing:** Maximum diameter
Minimum diameter
Length
- Shaft:** Maximum diameter
- Temperature:** Minimum expected operating temperature
Maximum expected operating temperature
Ambient temperature in the machine shop
- Lubrication:** Water or dry
- Application:** Propeller shaft, rudder, or other
- Type of Installation:** Interference or bonded

It is important to check that the housing is round and has not been worn or pounded into an oval shape. Thordon elastomeric bearings will adapt to the shape of the housing. The preferred solution is to machine or repair the housing, but if this is not possible, Chapter 6 provides installation instructions for an out-of-round housing.

Prior to calculating bearing dimensions, the housing should also be checked for alignment. Correction of misalignment by reboring of the housing is preferable to line boring of the bearing after installation. Once the housing is rebored, the bearing O.D. can be sized to the new housing dimensions. If reboring is not appropriate, Chapter 6 provides alternative installation procedures.

4.3 DIMENSIONING USING THORDON BEARING SIZING CALCULATION PROGRAM

The recommended way to calculate the dimensions of a Thordon bearing is to use the Thordon Bearing Sizing Calculation Program. The program is available from Thordon Bearings or your local Thordon distributor. Once the application parameters indicated in section 4.2 above are entered, the Program will provide the dimensions for machining. Manual calculations are also feasible; refer to the Thordon Bearings Engineering Manual or the ThorPlas Engineering Manual for detailed instructions.

The current version of the Thordon Bearing Sizing Program calculates all dimensions using an ambient temperature of 21°C (70°F). The program then provides adjusted values for different ambient temperatures. It also provides a reference chart that provides machining dimensions for a range of ambient temperatures allowing easy adjustment for changes in ambient temperature – from day to night for example. When machining Thordon bearings, use the bearing O.D. and wall thickness dimensions instead of the O.D. and I.D.

4.3.1 SAMPLE CALCULATIONS USING THORDON BEARING SIZING PROGRAM

The following are examples of the Thordon Bearing Sizing Program used to calculate typical bearing dimensions:

(see next page)

SAMPLE CALCULATION - METRIC

Given Data

- | | |
|---|---|
| 1. Type of Service Marine Propeller Shaft | 6. Shaft Diameter 100mm +0.00 / -0.13mm |
| 2. Grade of Thordon XL | 7. Housing Diameter 150mm +0.08mm / -0.00 |
| 3. Lubrication Water | 8. Housing Length 400mm |
| 4. Type of Installation Interference Fit | 9. Operating Temp. Min. -2°C Max. 45°C |
| 5. Grooved Bearing Style . . . Grooved | 10. Ambient Temp. 21°C |

Once the information above is entered, the Bearing Sizing Program gives the following results:

<p>Thordon Bearings Sizing Calculation Program No: 901263BM33 V 2006.2 Printed Date: 6/14/2007</p>	<p>THORDON BEARINGS INC. 3225 Mainway Drive, Burlington, Ontario, Canada L7M 1A6 Tel: 905-335-1440 Fax: 905-335-0209, www.thordonbearings.com</p>																																																																												
<p>General Information</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">Thordon Distributor:</td> <td>Thordon Head Office</td> </tr> <tr> <td>Customer:</td> <td></td> </tr> <tr> <td>Project Reference:</td> <td>Marine Bearing Installation Manual</td> </tr> <tr> <td>Calculated By:</td> <td>C. Carter</td> </tr> <tr> <td>Checked By:</td> <td></td> </tr> <tr> <td>Comments:</td> <td>Sample Calculation-Metric</td> </tr> <tr> <td>Drawing Number:</td> <td></td> </tr> <tr> <td>MRP Number:</td> <td></td> </tr> </table>		Thordon Distributor:	Thordon Head Office	Customer:		Project Reference:	Marine Bearing Installation Manual	Calculated By:	C. Carter	Checked By:		Comments:	Sample Calculation-Metric	Drawing Number:		MRP Number:																																																													
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<p>Results</p> <p style="text-align: center;">== ATTENTION ==</p> <p>Means of axial retention required. Positive flow of lubricant is required.</p> <table style="width: 100%; border: none;"> <thead> <tr> <th style="width: 40%;"></th> <th style="width: 20%; text-align: center;">Designed at 21 °C</th> <th style="width: 20%; text-align: center;">Machined at 21 °C</th> <th style="width: 20%;"></th> </tr> </thead> <tbody> <tr> <td>Machined Bearing Inside Diameter:</td> <td style="text-align: center;">102.30</td> <td style="text-align: center;">102.30 mm</td> <td style="text-align: center;">+0.13, -0.00</td> </tr> <tr> <td>Machined Bearing Outside Diameter:</td> <td style="text-align: center;">151.00</td> <td style="text-align: center;">151.00 mm</td> <td style="text-align: center;">+0.13, -0.00</td> </tr> <tr> <td>Calculated Machined Bearing Length:</td> <td style="text-align: center;">396.26</td> <td style="text-align: center;">396.26 mm</td> <td style="text-align: center;">+0.00, -0.5</td> </tr> <tr> <td>Bearing Wall Thickness:</td> <td style="text-align: center;">24.35</td> <td style="text-align: center;">24.35 mm</td> <td style="text-align: center;">(For reference only)</td> </tr> <tr> <td>Amount Of Interference:</td> <td style="text-align: center;">0.92 mm</td> <td></td> <td></td> </tr> <tr> <td>Bore Closure Factor:</td> <td style="text-align: center;">1.380</td> <td></td> <td></td> </tr> <tr> <td>Bore Closure Amount:</td> <td style="text-align: center;">1.42 mm</td> <td></td> <td></td> </tr> <tr> <td>Minimum Installed Diametrical Clearance:</td> <td style="text-align: center;">0.89 mm</td> <td></td> <td></td> </tr> <tr> <td>Diametric Running Clearance:</td> <td style="text-align: center;">0.32 mm</td> <td></td> <td></td> </tr> <tr> <td>Diametric Thermal Expansion:</td> <td style="text-align: center;">0.20 mm</td> <td></td> <td></td> </tr> <tr> <td>Diametric Absorption Allowance:</td> <td style="text-align: center;">0.37 mm</td> <td></td> <td></td> </tr> <tr> <td>Axial Thermal Expansion:</td> <td style="text-align: center;">1.74 mm</td> <td></td> <td></td> </tr> <tr> <td>Axial Absorption Allowance:</td> <td style="text-align: center;">2.00 mm</td> <td></td> <td></td> </tr> <tr> <td>Number of Grooves:</td> <td style="text-align: center;">8</td> <td></td> <td></td> </tr> <tr> <td>Width of Grooves:</td> <td style="text-align: center;">6.00 mm</td> <td></td> <td></td> </tr> <tr> <td>Depth of Grooves:</td> <td style="text-align: center;">5.00 mm</td> <td></td> <td></td> </tr> <tr> <td>Outside Diameter After Dry Ice Cooling:</td> <td style="text-align: center;">149.69 mm</td> <td></td> <td></td> </tr> <tr> <td>Outside Diameter After Nitrogen Cooling:</td> <td style="text-align: center;">148.12 mm</td> <td></td> <td></td> </tr> </tbody> </table>			Designed at 21 °C	Machined at 21 °C		Machined Bearing Inside Diameter:	102.30	102.30 mm	+0.13, -0.00	Machined Bearing Outside Diameter:	151.00	151.00 mm	+0.13, -0.00	Calculated Machined Bearing Length:	396.26	396.26 mm	+0.00, -0.5	Bearing Wall Thickness:	24.35	24.35 mm	(For reference only)	Amount Of Interference:	0.92 mm			Bore Closure Factor:	1.380			Bore Closure Amount:	1.42 mm			Minimum Installed Diametrical Clearance:	0.89 mm			Diametric Running Clearance:	0.32 mm			Diametric Thermal Expansion:	0.20 mm			Diametric Absorption Allowance:	0.37 mm			Axial Thermal Expansion:	1.74 mm			Axial Absorption Allowance:	2.00 mm			Number of Grooves:	8			Width of Grooves:	6.00 mm			Depth of Grooves:	5.00 mm			Outside Diameter After Dry Ice Cooling:	149.69 mm			Outside Diameter After Nitrogen Cooling:	148.12 mm		
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Shaft RPM:	0																																																																												

Figure 22: Output Sheet From Metric Example - Thordon Bearing Sizing Calculation Program

Ch.4 DIMENSIONING

SAMPLE CALCULATION - IMPERIAL

Given Data

- | | | | |
|-----------------------------------|------------------------|-------------------------------|----------------------|
| 1. Type of Service | Marine Propeller Shaft | 6. Shaft Diameter | 4" +0.000" / -0.005" |
| 2. Grade of Thordon | XL | 7. Housing Diameter | 6" +0.003" / -0.000 |
| 3. Lubrication | Water | 8. Housing Length | 16" |
| 4. Type of Installation | Interference Fit | 9. Operating Temp. | Min. 28°F Max. 113°F |
| 5. Grooved Bearing Style . . . | Grooved | 10. Ambient Temp. | 70°F |

Once the information above is entered, the Bearing Sizing Program gives the following results:

Thordon Bearings Sizing Calculation Program No: 901263BM33 V 2006.2 Printed Date: 6/14/2007		THORDON BEARINGS INC. 3225 Mainway Drive, Burlington, Ontario, Canada L7M 1A6 Tel: 905-335-1440 Fax: 905-335-0209, www.thordonbearings.com	
General Information			
Thordon Distributor:	Thordon Head Office		
Customer:			
Project Reference:	Marine Bearing Installation Manual		
Calculated By:	C. Carter		
Checked By:			
Comments:	Sample Calculation-Imperial		
Drawing Number:			
MRP Number:			
Results			
- = ATTENTION = -			
Means of axial retention required.			
Positive flow of lubricant is required.			
	Designed at 69.8 °F	Machined at 70 °F	
Machined Bearing Inside Diameter:	4.092	4.092 in	+0.005, -0.000
Machined Bearing Outside Diameter:	6.040	6.040 in	+0.005, -0.000
Calculated Machined Bearing Length:	15.850	15.851 in	+0.000, -0.020
Bearing Wall Thickness:	0.974	0.974 in	(For reference only)
Amount Of Interference:	0.037 in		
Bore Closure Factor:	1.382		
Bore Closure Amount:	0.057 in		
Minimum Installed Diametrical Clearance:	0.035 in		
Diametric Running Clearance:	0.013 in		
Diametric Thermal Expansion:	0.008 in		
Diametric Absorption Allowance:	0.015 in		
Axial Thermal Expansion:	0.070 in		
Axial Absorption Allowance:	0.080 in		
Number of Grooves:	8		
Width of Grooves:	0.250 in		
Depth of Grooves:	0.188 in		
Outside Diameter After Dry Ice Cooling:	5.988 in		
Outside Diameter After Nitrogen Cooling:	5.925 in		
Input Data			
Dimension Scale:	Imperial		
Temperature Scale:	Fahrenheit		
Maximum Operating Temperature:	113 °F		
Minimum Operating Temperature:	28 °F		
Machine Shop Ambient Temperature:	70 °F		
Maximum Shaft Diameter:	4.000 in		
Maximum Housing Diameter:	6.003 in		
Minimum Housing Diameter:	6.000 in		
Housing Length:	16.000 in		
Type of Lubrication:	Water		
Grade of Thordon Used:	XL		
Type of Service:	Marine Propeller Shaft		
Type of Installation:	Interference Freeze Fit		
Grooved Bearing Style:	Grooved		
Load on Bearing:	0 lb		
Shaft RPM:	0		

Figure 23: Output Sheet From Imperial Example - Thordon Bearing Sizing Calculation Program

4.3.2 TEMPERATURE CHART

As part of the Thordon Bearing Sizing Calculation Program, a Temperature Chart (see Figure 24) is available to facilitate adjustment of machining dimensions when the machine shop temperature varies from that used for the original calculation. The chart can be found by clicking the [T] on the top of the RESULTS page of the program.

The default chart covers a 5 to 35°C (41 to 95°F) range of machine shop ambient temperatures. For temperatures outside this range, the chart temperatures can be adjusted by clicking the "Options" button at the top of the screen and selecting "Customize Temperature Chart". By shifting the "Start Temperatures on Chart" up to 21°C (70°F) the Temperature Chart is able to show a range up to 51°C (123.8°F). This option also provides a box to print a longer chart (select Print Long Temperature Chart) which prints the entire chart shown on the screen while the short chart provides a "window" to print only the interested temperature range near 21°C (70°F).

The recommended procedure is to calculate the machined bearing dimensions either using Thordon Bearing's default temperature of 21°C (70°F) or using the expected actual ambient temperature in the machine shop at time of machining. A Temperature Chart should be printed along with the dimension calculation results sheet. Both should be provided to the machine shop. Prior to final machining,

the machinist should first check the temperature of the bearing by using a calibrated temperature gun or confirm that the bearing temperature is the same as that of the machine shop.

The machinist should then select the appropriate dimensions from the temperature chart based on the recorded bearing temperature. The Temperature Chart should always be consulted if the bearing temperature is different than the ambient temperature used for the original calculation. The Temperature Chart is particularly important in situations where machine shops are not climate controlled and where there are significant changes in temperature during the day, or from day to night.

NOTE: Should the machine shop temperature change significantly between when the bearing O.D. is machined and when the I.D. is to be machined, the wall thickness line in the Temperature Chart used for the O.D. dimension must be used to control the I.D. dimension. Do not attempt to machine the I.D. using a different temperature from the chart than that used for the O.D.

EXAMPLE: If machining the bearing O.D. at 12°C (54°F) in morning and the machine shop temperature rises to 24°C (75°F), the bearing wall thickness should be machined to the 12°C (54°F) dimensions (from the Temperature Chart) used for machining the O.D. and not the 24°C (75°F) dimensions.

Ch.4 DIMENSIONING

Thordon Bearings Sizing Calculation Program

V 2006.2

Printed Date: 11/14/2007

THORDON BEARINGS INC.

3225 Mainway Drive, Burlington, Ontario, Canada L7M 1A6

Tel: 905-335-1440 Fax: 905-335-0209, www.thordonbearings.com

General Information

Thordon Distributor:
Customer:
Project Reference:
Calculated By:
Checked By
Comments:

Thordon Head Office
Marine Bearing Installation Manual

Temperature Chart

Drawing Number:

MRP Number:

TEMPERATURES		METRIC DIMENSIONS (MM)					IMPERIAL DIMENSIONS (INCHES)				
Deg.(°C)	Deg.(°F)	O.D.	I.D.	Length	Wall Thk.	MIC	O.D.	I.D.	Length	Wall Thk.	MIC
5	41	150.72	102.05	395.02	24.33	1.03	5.934	4.018	15.552	0.958	0.040
6	42.8	150.74	102.07	395.08	24.34	1.02	5.935	4.018	15.554	0.958	0.040
7	44.6	150.76	102.08	395.14	24.34	1.01	5.936	4.019	15.557	0.958	0.040
8	46.4	150.79	102.10	395.20	24.35	1.01	5.937	4.020	15.559	0.958	0.040
9	48.2	150.81	102.11	395.26	24.35	1.00	5.937	4.020	15.561	0.959	0.039
10	50	150.83	102.13	395.32	24.35	0.99	5.938	4.021	15.564	0.959	0.039
11	51.8	150.86	102.14	395.38	24.36	0.98	5.939	4.021	15.566	0.959	0.039
12	53.6	150.88	102.16	395.44	24.36	0.98	5.940	4.022	15.568	0.959	0.038
13	55.4	150.90	102.17	395.50	24.36	0.97	5.941	4.023	15.571	0.959	0.038
14	57.2	150.92	102.19	395.56	24.37	0.96	5.942	4.023	15.573	0.959	0.038
15	59	150.95	102.20	395.62	24.37	0.95	5.943	4.024	15.575	0.960	0.038
16	60.8	150.97	102.22	395.68	24.38	0.95	5.944	4.024	15.578	0.960	0.037
17	62.6	150.99	102.24	395.74	24.38	0.94	5.945	4.025	15.580	0.960	0.037
18	64.4	151.02	102.25	395.80	24.38	0.93	5.945	4.026	15.582	0.960	0.037
19	66.2	151.04	102.27	395.85	24.39	0.93	5.946	4.026	15.585	0.960	0.036
20	68	151.06	102.28	395.91	24.39	0.92	5.947	4.027	15.587	0.960	0.036
21	69.8	151.08	102.30	395.97	24.39	0.91	5.948	4.027	15.590	0.960	0.036
22	71.6	151.11	102.31	396.03	24.40	0.90	5.949	4.028	15.592	0.961	0.036
23	73.4	151.13	102.33	396.09	24.40	0.90	5.950	4.029	15.594	0.961	0.035
24	75.2	151.15	102.34	396.15	24.40	0.89	5.951	4.029	15.597	0.961	0.035
25	77	151.18	102.36	396.21	24.41	0.88	5.952	4.030	15.599	0.961	0.035

ATTENTION:

1. Means of axial retention required.
2. Always use Temperature Chart and Data Sheet together.
3. Bearings to be machined by controlling outside and inside diameter for ID less than 330 mm.
4. Standard tolerances to be applied.
5. This Temperature Chart was created automatically with calculated results!

Input Data

Dimension Scale: Metric
 Temperature Scale: Celsius
 Maximum Operating Temperature: 45 °C
 Minimum Operating Temperature: -2 °C
 Machine Shop Ambient Temperature: 21 °C
 Maximum Shaft Diameter: 100.00 mm
 Maximum Housing Diameter: 150.08 mm
 Minimum Housing Diameter: 150.00 mm
 Housing Length: 400.00 mm
 Type of Lubrication: Water
 Grade of Thordon Used: SXL
 Type of Service: Marine Propeller Shaft
 Type of Installation: Interference Freeze Fit
 Grooved Bearing Style: Grooved
 Load on Bearing: 0 kg
 Shaft RPM: 0

Figure 24: Temperature Chart

4.4 CALCULATION DETAILS

4.4.1 BEARING OUTSIDE DIAMETER (O.D.)

TUBE TYPE BEARINGS

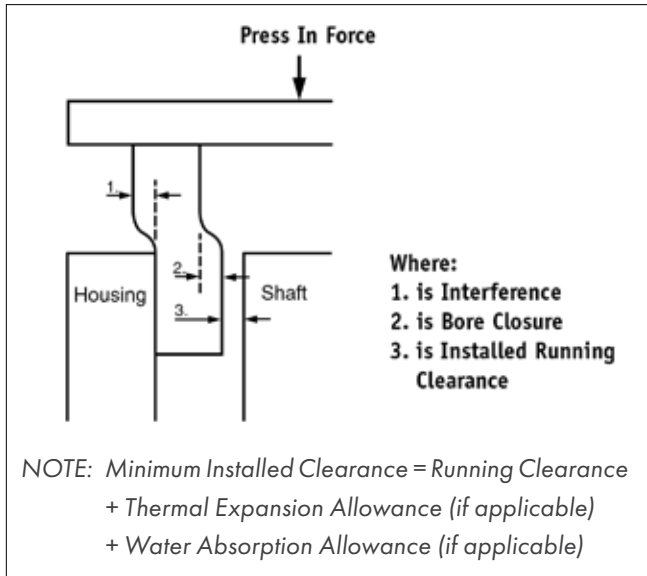


Figure 25: Interference Fit Parameters

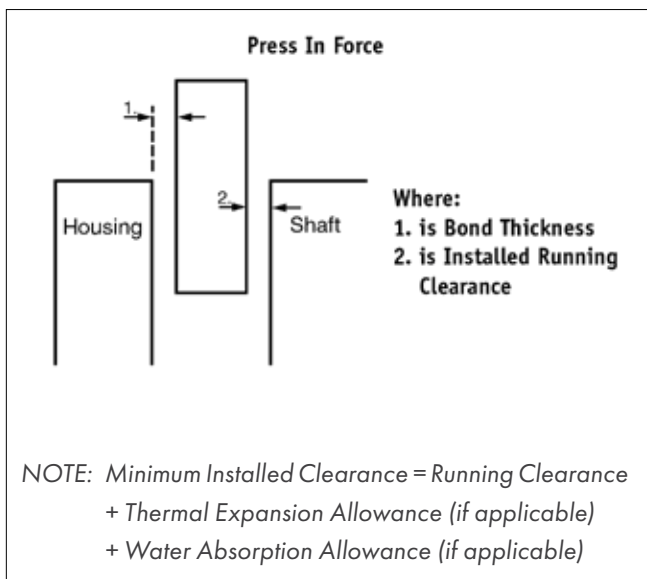


Figure 26: Bond Fit Parameters

4.4.1.1 INTERFERENCE

Thordon bearings are normally installed with an interference fit (Figure 25). The amount of interference will vary with the size of the bearing and with the minimum temperature at which it will operate. Additional interference is required for cold operation. Additional interference causes no harm, but insufficient interference for cold operations could cause the bearing to come loose in the housing. The amount of interference required is added to the maximum housing diameter to give the minimum bearing outside diameter. The normal minimum temperature used by Thordon bearings for propeller shaft applications is -2°C (30°F). For rudder stock bearings that operate out of the water, a minimum temperature of -25°C (-38°F) is often used to allow for possible operation in cold environments.

Thordon bearings can be installed with an interference fit by either press or freeze fit. An entry chamfer on the bearing and/or a rounded corner on the housing will facilitate press fitting. Remember however, that the bearing will not be able to support load in way of the chamfer. If the "Interference Press Fit" type of installation option is selected in the Thordon Bearing Sizing Calculation Program, the press in force required for a bearing is provided in the results output.

When freeze fitting a Thordon bearing, the selection of a suitable cooling agent depends on the temperature differential for which the bearing's interference fit is designed. [Temperature differential is the difference between ambient machine shop temperature and the coldest temperature to which the installed bearing will be exposed during operation.] If the differential is 40°C (100°F) or less, then dry ice can normally be used. If the differential is greater than 40°C (100°F), the use of liquid nitrogen is recommended. The Thordon Bearing Sizing Program provides O.D. dimensions for freezing in dry ice or liquid nitrogen. This can be compared with the housing diameter to see which freezing option is appropriate.

The theoretical amount of liquid nitrogen required to cool a Thordon bearing for installation can be calculated as follows:

Metric: Litres of liquid nitrogen required =
 $1.78 \times \text{Weight of bearing (kg.)}$

Imperial: US Gallons of liquid nitrogen required =
 $0.21 \times \text{Weight of bearing (lbs.)}$

The actual amount of liquid nitrogen required may be greater than this amount depending on the sizing of the container used, how well insulated it is, etc.

Ch.4 DIMENSIONING

4.4.1.2 MACHINING TOLERANCE

The Thordon Bearing Sizing Calculation Program provides the appropriate machining tolerance.

4.4.1.3 BONDING

An alternative to an interference fit bearing is bonding a bearing into the housing. If bonding is used, interference is not used (Figure 26). The bearing O.D. will be the housing I.D. less an allowance for the thickness of the bonding agent. The Thordon Bearing Sizing Program provides dimension calculations for bonded bearings including a reference to the thickness of the bonding agent.

4.4.2 BEARING INSIDE DIAMETER (I.D.)

4.4.2.1 BORE CLOSURE

Bore closure is the diametric reduction of the bearing I.D. that occurs when it is installed in a housing using an interference fit to hold it in place. (Bore closure does not occur with bonded bearings, and is therefore not a factor in calculating bearing I.D. for bonded bearings.) The interference oversize is transferred to the bearing I.D. A bore closure factor is applied to the interference amount to calculate the effect on bearing I.D. Actual bore closure may vary +/-15% from the calculated amount. Since the volume of a Thordon bearing at any given temperature remains constant, constraining the O.D. results in a reduced I.D. and may result in an increase in bearing length.

4.4.2.2 RUNNING CLEARANCE

The recommended running clearance for Thordon bearings is calculated based on the type of application. Different running clearances are used for propeller shaft and rudder bearings. Rudder bearing clearance can be less because the movement is oscillating rather than full rotation. Low frequency, oscillating motion generates less frictional heat.

4.4.2.3 DIMENSIONAL CHANGES DUE TO ABSORPTION

When immersed in water or other lubricants, Thordon only increases in volume 1.3% under normal conditions. Some of this expansion simply increases the amount of interference, but there is also an effect on the I.D. and length of the bearing. The Thordon Bearing Sizing Calculation Program calculates the effect of absorption on the bearing I.D. and length.

Axial absorption is important when calculating the gap to leave between the last bearing segment and the ring keeper, and between segments of multi piece bearings. Refer to section 6.2.2.1.

For rudder stock bearings that are usually above the water line, the absorption allowance should still be used because the bearings will be exposed to water. If a Thordon XL bearing is being installed with oil lubrication, the same absorption allowance will be used.

4.4.2.4 THERMAL EXPANSION

In cases where the maximum operating temperature of a bearing exceeds the ambient temperature in the machine shop where it is machined, an allowance for Thermal Expansion is included in the bearing I.D. and length calculations.

NOTE: Thordon Bearings uses a standard maximum operating temperature of 45°C (113°F) for the design of propeller shaft bearings. This temperature provides for the removal of heat generation with standard water flow and seawater temperature of 32°C (90°F). This temperature can be increased if the bearings are exposed to warmer waters.

4.4.2.5 MINIMUM INSTALLED DIAMETRICAL CLEARANCE

After installation, a Thordon bearing has a "Minimum Installed Diametrical Clearance" which is the difference between diameters of shaft and the bearing bore. This is composed of three factors: 1) The design running clearance 2) an allowance for thermal expansion of the material and 3) an allowance for water (or other lubricant) absorption by the material.

As the operating temperature of the bearing increases, the material expands and the bearing bore reduces - this is accommodated by the thermal expansion allowance. The material also expands due to water (or other lubricant absorption) causing a reduction in the bearing bore - this is accommodated by the lubricant absorption allowance. For example, after all water or lubricant absorption has occurred (may take several months), and the bearing is operating at the maximum design temperature, the bearing clearance is equal to the design running clearance value. The design running clearance is calculated as a function of shaft diameter and type of service.

Minimum Installed Diametrical Clearance is used as an important final check before putting the Thordon bearing into service. Early examination of clearances may show negative wear - this is due to the growth in water or lubricant absorption exceeding bearing wear.

4.5 WATER GROOVES

4.5.1 PROPELLER SHAFT BEARINGS

Thordon propeller shaft bearings must always have lubrication grooves to facilitate an adequate flow of cooling water or lubricant. Most small propeller shaft bearings are supplied with lubrication grooves already moulded or machined in place (Figure 27). When lubrication grooves must be machined into an ungrooved tube, the Thordon Bearing Sizing Calculation Program provides the necessary lubrication groove design information.

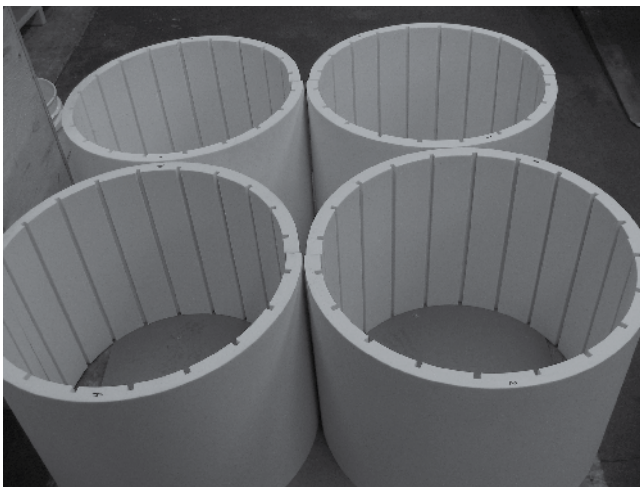


Figure 27: Thordon Propeller Shaft Bearings with Water Grooves

For Thordon SXL, XL and RiverTough propeller shaft bearings, grooves are evenly spaced around the whole circumference of the bearing. COMPAC 2:1 L/D ratio bearings have lubrication grooves in the upper half only. This design improves hydrodynamic performance. If a propeller shaft bearing is made up of more than one segment, an annular groove should be machined in one end of each segment where it meets the next segment. The groove should be the same width and depth as the axial grooves. This annular groove facilitates passage of cooling water from one segment to the next if there is any misalignment of the grooves.

4.5.2 RUDDER BEARINGS

There is no need for lubrication grooves in Thordon rudder bearings because there is no flow of lubricant through the bearings.

4.6 STAXL STAVES

4.6.1 INTRODUCTION

In the past Thordon has used several different methods for dimensioning Thordon STAXL staves. As a result of extensive field experience in recent years, a more precise dimensioning method has evolved that is recommended for all installations.

4.6.2 PRE-ASSEMBLY

We believe that pre assembly is the most accurate method of dimensioning Thordon STAXL staves. In this method the staves, at room temperature, are placed in the housing until a gap of less than one stave width is left. For most installations with two keeper strips, each half of the bearing would be dimensioned separately. Once the staves have been placed in the housing, use threaded jacking bars, a small Enerpac® jack, or other similar means to press them together to eliminate any gaps. With the staves pressed together, measure the gap between the last stave and the keeper. Note this measurement.

4.6.3 INTERFERENCE CALCULATION

Use the Thordon Bearing Sizing Calculation Program to determine the amount of circumferential interference. For Type of Installation, select "STAXL Staves", and the program will provide the circumferential interference. In the typical case of two axial keeper strips, where each half of the bearing is dimensioned separately, divide the circumferential interference by two.

4.6.4 FINAL STAVE WIDTH

Add the calculated circumferential interference in Section 4.6.3 for the full or half bearing as appropriate to the measured gap noted in section 4.6.2 to determine the required width of the final stave. Mill the last stave to this width.

4.6.5 STAVE ASSEMBLY (I.D.)

IN ALL CASES THE I.D. OF THORDON STAXL STAVES MUST BE MACHINED TO THE APPROPRIATE DIAMETER. STAVES ARE SUPPLIED FLAT ON THE I.D., BUT UNLIKE SOME RUBBER STAVES, THEY CANNOT BE USED WITH THE FLAT I.D. IT MUST BE CONTOURED.

Normally staves are line bored after installation in the housing, carrier, or machine shop dummy housing. The I.D. dimensions can be obtained from the Thordon Bearing Sizing Calculation Program. It is also possible to mill the I.D. of each stave to the appropriate radius and thickness.

Ch.4 DIMENSIONING

4.6.6 LONGITUDINAL EXPANSION ALLOWANCES

End keepers or stops are always recommended with Thordon bearings as added security to prevent axial movement in the event of unbalanced loads, excessive vibration, or other unanticipated factors. A gap should be left between the end keeper and the staves to allow for axial water absorption and thermal expansion. The Thordon Bearing Sizing Calculation Program will indicate the required length of the staves.

4.6.7 ENCAPSULATED KEEPER STRIPS

Occasionally, stave installations are designed so that keeper strips fit into machined grooves in the back of staves rather than between staves. In this case dimensioning should be the same as for an installation using no keeper strips. Grooves should be machined in the backs of the appropriate staves. These grooves should provide ample clearance over the keepers so that a proper fit can be achieved even when the staves are frozen.

4.7 DOVETAIL ASSEMBLIES

Thordon staves are also available in dovetail form for dovetail (slotted) housings.

Thordon dovetail staves are designed for interference fitting into slotted carriers as shown in Figure 28. This ensures a snug fit throughout the length of the stave. To dimension dovetail staves, select "Type of Installation" as "Dovetail Staves-Standard or Custom" in the Thordon Bearing Sizing Calculation Program. For standard staves, the Thordon Bearing Sizing Calculation Program will select the appropriate stave, and give the required width of the slot. This width must be verified. The standard side angle of Thordon dovetail staves is 10° . If a standard stave is not suitable, then select "custom" and the Thordon Bearing Sizing Calculation Program will indicate the options available. If the carrier has a 15° side angle, then the staves should be milled to suit. Thordon staves must fit well into the grooves. If the grooves have been damaged or widths are uneven, the staves may vibrate in service and suffer hysteresis.

The I.D. of the Thordon dovetail stave assembly must be machined. Although a flat interior surface is acceptable for some rubber staves, it is not acceptable for Thordon staves. The Thordon Bearing Sizing Calculation Program will calculate the I.D. of the Thordon dovetail stave assembly at the same time as it calculates the stave details above.

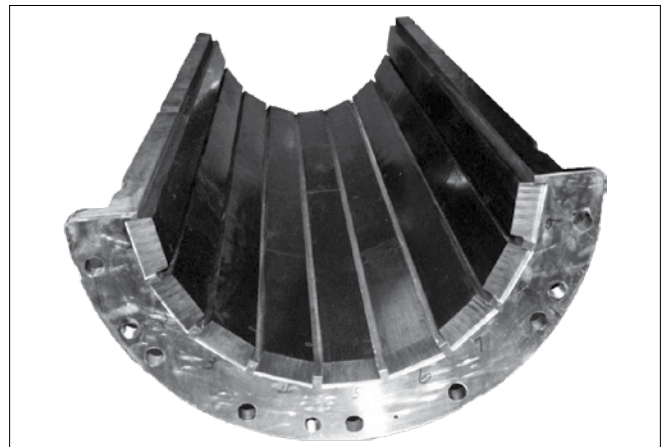


Figure 28: Side View of Dovetail Stave Assembly

4.8 KEYED TUBULAR BEARINGS

Thordon bearings are often installed with both an interference fit and a set of locking keys. To size the Thordon bearings and split gap widths to obtain the correct interference for a keyed bearing application, the following procedure should be used.

1. Calculate the bearing dimensions based on a normal tube, and an interference fit using the Thordon Bearing Sizing Calculation Program.
2. Machine the bearing according to the calculated dimensions.
3. Measure the circumferential width of the key(s) and measure or approximate the width of the cut on the side opposite the key in the case of a single key as illustrated in Figure 29.

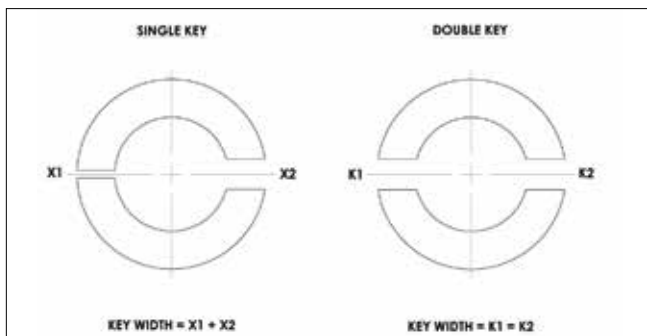


Figure 29: Measuring Key Widths

4. Cut the slot(s) in the bearing so the total width of material removed equals the width of the keys/ keyset plus the width of the cut if any. Ensure that the combined circumferential interference of bearing and key(s) is the same as for a non-split bearing.

For an installation with two keys or key sets, the same basic approach should be used. The bearing should be dimensioned as if it were not split. Then each cut in the bearing should be machined to the exact width of one of the keys. Again, this is done to ensure that the correct circumferential interference is maintained.

4.9 SPLIT BEARINGS WITH NO KEEPERS

In some applications such as rudder bearings, it may be necessary to split a Thordon bearing to facilitate fitting without removing the complete rudder assembly. In this case bearing dimensions should first be calculated as if the bearing were a normal non split tubular bearing. Then an allowance should be added to the calculated machined bearing I.D. and O.D. to allow for material lost in the cutting process. This allowance should be the total thickness of the splitting cuts divided by π (3.1416). The resulting bearing will be slightly oval, but will become round when interference is applied from the housing.

Ch.4 DIMENSIONING

4.10 WORKING WITH THE THORDON BEARING SIZING CALCULATION PROGRAM

4.10.1 METRIC SIZING CALCULATION EXAMPLE – BEARING MACHINED AFTER FITTING INTO HOUSING

NOTE: See figure 30 on the next page

Given Data

1. Type of Service. Marine Propeller Shaft
2. Grade of Thordon SXL
3. Lubrication Water
4. Type of Installation. Interference Fit, machined after fitting in housing
5. Grooved Bearing Style . . Grooved
6. Shaft Diameter 100mm +0.00/-0.13mm
7. Housing Diameter 150mm + 0.08mm
8. Housing Length 400mm
9. Operating Temp. Min. 10°C Max. 45°C
10. Ambient Temp. 21°C

Use the Thordon Bearing Sizing Calculation Program to calculate the finished dimensions of the bearing. In this case the program gives the following results:

NEXT STEPS.

Assuming machine shop temperature is 21°C

- Step 1: Bearing O.D. is machined to 150.81mm as per Thordon Bearing Sizing Calculation Program
- Step 2: Machine bearing length to 395.97mm
- Step 3: Fit bearing into housing
- Step 4: Machine bearing I.D. to maximum shaft diameter plus Minimum Installed Diametrical Clearance $100 + 0.91 = 100.91\text{mm}$

(Thordon Bearing Sizing Calculation Program gives bearing I.D. including bore closure, which has already happened, when the bearing is fitted into the housing).

NOTE 1: If this procedure is used with interference fit ungrooved bearings, the machining of the I.D. after fitting in the housing should not be more than 5% of the wall thickness. Machining more than this amount may have an adverse effect on the interface pressure of an interference fit. If the procedure is used with grooved bearings, the amount of machining after fitting must be limited to 10% of the wall thickness or 25% of the groove depth, whichever is less. It may be necessary to pre-machine the bearing I.D. to remove enough material to allow for final machining of the I.D. after fitting within the above limits.

NOTE 2: Grooves must always be machined before fitting the bearing into the housing.

4.10.2 IMPERIAL SIZING CALCULATION EXAMPLE – BEARING MACHINED AFTER FITTING INTO HOUSING

NOTE: See figure 31 on the page after next.

Given Data

1. Type of Service. Marine Propeller Shaft
2. Grade of Thordon SXL
3. Lubrication Water
4. Type of Installation. Interference Fit, machined after fitting in housing
5. Grooved Bearing Style . . Grooved
6. Shaft Diameter 4" +0.000/-0.005"
7. Housing Diameter 6" +.003"/-0.000"
8. Housing length. 16"
9. Operating Temp. Min. 50°F Max. 110°F
10. Ambient Temp. 70°F

Use the Thordon Bearing Sizing Calculation Program to calculate the finished dimensions of the bearing. In this case the program gives the following results:

NEXT STEPS.

Assuming machine shop temperature is 70°F.

- Step 1: Bearing O.D. is machined to 4.077" as per Thordon Bearing Sizing Calculation Program
- Step 2: Machine bearing length to 15.845"
- Step 3: Fit bearing into housing
- Step 4: Machine bearing I.D. to maximum shaft diameter plus Minimum Installed Diametrical Clearance $4" + .0035" = 4.035"$

(Thordon Bearing Sizing Calculation Program gives bearing I.D. including bore closure which has already happened when the bearing is fitted into the housing).

NOTE 1: If this procedure is used with interference fit ungrooved bearings, the machining of the ID after fitting in the housing should not be more than 5% of the wall thickness. Machining more than this amount may have an adverse effect on the interface pressure of an interference fit. If the procedure is used with grooved bearings, the amount of machining after fitting must be limited to 10% of the wall thickness or 25% of the groove depth, whichever is less. It may be necessary to pre machine the bearing I.D. to remove enough material to allow for final machining of the I.D. after fitting within the above limits.

NOTE 2: Grooves must always be machined before fitting the bearing into the housing.

SAMPLE CALCULATION - METRIC

Thordon Bearings Sizing Calculation Program

No: 901263BM33 V 2006.2
 Printed Date: 6/25/2007

THORDON BEARINGS INC.

3225 Mainway Drive, Burlington, Ontario, Canada L7M 1A6
 Tel: 905-335-1440 Fax: 905-335-0209, www.thordonbearings.com

General Information

Thordon Distributor:	
Customer:	Thordon Head Office
Project Reference:	Marine Bearing Installation Manual
Calculated By:	C. Carter
Checked By:	
Comments:	Metric Results-Bearing Machined After Fitting into Housing
Drawing Number:	
MRP Number:	

Results

== ATTENTION ==

**Means of axial retention required.
 Positive flow of lubricant is required.**

	Designed at 21 °C			Machined at 21 °C
Machined Bearing Inside Diameter:	101.96			101.96 mm +0.13, -0.00
Machined Bearing Outside Diameter:	150.81			150.81 mm +0.13, -0.00
Calculated Machined Bearing Length:	395.97			395.97 mm +0.00, -0.5
Bearing Wall Thickness:	24.43			24.43 mm (For reference only)
Amount Of Interference:	0.73 mm			
Bore Closure Factor:	1.250			
Bore Closure Amount:	1.05 mm			
Minimum Installed Diametrical Clearance:	0.91 mm			
Diametric Running Clearance:	0.32 mm			
Diametric Thermal Expansion:	0.23 mm			
Diametric Absorption Allowance:	0.37 mm			
Axial Thermal Expansion:	2.03 mm			
Axial Absorption Allowance:	2.00 mm			
Number of Grooves:	8			
Width of Grooves:	6.00 mm			
Depth of Grooves:	5.00 mm			
Outside Diameter After Dry Ice Cooling:	149.44 mm			
Outside Diameter After Nitrogen Cooling:	147.76 mm			

Input Data

Dimension Scale:	Metric
Temperature Scale:	Celsius
Maximum Operating Temperature:	45 °C
Minimum Operating Temperature:	10 °C
Machine Shop Ambient Temperature:	21 °C
Maximum Shaft Diameter:	100.00 mm
Maximum Housing Diameter:	150.08 mm
Minimum Housing Diameter:	150.00 mm
Housing Length:	400.00 mm
Type of Lubrication:	Water
Grade of Thordon Used:	SXL
Type of Service:	Marine Propeller Shaft
Type of Installation:	Interference Freeze Fit
Grooved Bearing Style:	Grooved
Load on Bearing:	0 kg
Shaft RPM:	0

Figure 30: Metric Sizing Calculation Example – Bearing Machined After Fitting Into Housing

Ch.4 DIMENSIONING

SAMPLE CALCULATION - IMPERIAL

Thordon Bearings Sizing Calculation Program

No: 901263BM33 V 2006.2
 Printed Date: 6/25/2007

THORDON BEARINGS INC.
 3225 Mainway Drive, Burlington, Ontario, Canada L7M 1A6
 Tel: 905-335-1440 Fax: 905-335-0209, www.thordonbearings.com

General Information

Thordon Distributor:	
Customer:	Thordon Head Office
Project Reference:	Marine Bearing Installation Manual
Calculated By:	C. Carter
Checked By:	
Comments:	Imperial Results-Bearing Machined After Fitting into Housing
Drawing Number:	
MRP Number:	

Results

= ATTENTION =

Means of axial retention required.
 Positive flow of lubricant is required.

	Designed at 69.8 °F	Machined at 70 °F	
Machined Bearing Inside Diameter:	4.077	4.077 in	+0.005, -0.000
Machined Bearing Outside Diameter:	6.032	6.032 in	+0.005, -0.000
Calculated Machined Bearing Length:	23.767	23.767 in	+0.000, -0.040
Bearing Wall Thickness:	0.978	0.978 in	(For reference only)
Amount Of Interference:	0.029 in		
Bore Closure Factor:	1.250		
Bore Closure Amount:	0.042 in		
Minimum Installed Diametrical Clearance:	0.035 in		
Diametric Running Clearance:	0.013 in		
Diametric Thermal Expansion:	0.008 in		
Diametric Absorption Allowance:	0.014 in		
Axial Thermal Expansion:	0.113 in		
Axial Absorption Allowance:	0.120 in		
Number of Grooves:	8		
Width of Grooves:	0.250 in		
Depth of Grooves:	0.188 in		
Outside Diameter After Dry Ice Cooling:	5.977 in		
Outside Diameter After Nitrogen Cooling:	5.910 in		

Input Data

Dimension Scale:	Imperial
Temperature Scale:	Fahrenheit
Maximum Operating Temperature:	110 °F
Minimum Operating Temperature:	50 °F
Machine Shop Ambient Temperature:	70 °F
Maximum Shaft Diameter:	4.000 in
Maximum Housing Diameter:	6.003 in
Minimum Housing Diameter:	6.000 in
Housing Length:	24.000 in
Type of Lubrication:	Water
Grade of Thordon Used:	SXL
Type of Service:	Marine Propeller Shaft
Type of Installation:	Interference Freeze Fit
Grooved Bearing Style:	Grooved
Load on Bearing:	0 lb
Shaft RPM:	0

Figure 31: Imperial Sizing Calculation Example – Bearing Machined After Fitting Into Housing

5.1 GENERAL MACHINING

Thordon XL, SXL, COMPAC and RiverTough/Composite are hard, tough elastomeric polymer products that can be easily machined. ThorPlas-Blue is a thermoplastic and requires slightly different machining than the elastomeric grades and is covered in Section 5.5. It is necessary, however, to remember that Thordon elastomers and ThorPlas-Blue are non-metallic materials, and must be machined differently than metal. Due to the elastomeric nature of Thordon it has a tendency to “move away” from anything that exerts pressure on it, including machine tools of all types. Thordon cannot be burnished or chipped; it must be cut with a sharp tool. The importance of sharp cutting tools cannot be over emphasized if Thordon is to be successfully machined.

NOTE: Machining videos are available from Thordon Bearings Inc. or from your local distributor. This is an excellent tool for understanding the requirements for machining Thordon bearings.

When thin wall bearings are being machined it is important to recognize that the exertion of excess pressure may actually deform the bearing. In some situations it may be necessary to use modified chuck jaws, to support the tube using a spider, plug or a mandrel or to mount the tube using screws to fix it to a faceplate. For large, thin-walled tubular bearings, it is recommended to machine them on a vertical boring mill.

Cutting speeds are also important. Low feed rates combined with too low a turning speed tend to produce a rough cut due to the toughness and elastomeric nature of Thordon. High speeds combined with a low feed rate may produce excessive frictional heat, resulting in a gummy-galled finish. The most suitable speed/feed combinations are similar to those used when machining aluminum.

Clearances, as specified using the design information in this manual, may seem excessive in comparison to metals. Thordon, however, expands from temperature change and submersion in liquids. Thordon also exhibits bore closure shrinkage at a rate greater than 100% of interference. This is due to the incompressible nature of Thordon elastomers. The minimum installed clearance takes all of these factors into account. As well, clearance for a liquid lubrication film if the bearing is water or oil lubricated and safety clearance for frictional heat build up are also accounted for. The recommended running clearance should not be decreased without first consulting your Thordon distributor or Thordon Bearings Inc.

NOTE: If adequate running clearance is not provided, bearing failure is almost certain.

Virtually all operations that can be performed on metal, including machining, drilling, tapping, shaping, routing, sawing, milling and bonding, can be performed on Thordon. Thordon can also be worked or shaped with conventional hand tools, keeping in mind that carbide tipped cutting blades should be used to prevent heat build up when sawing.

5.2 MACHINING XL, SXL, AND COMPAC

5.2.1 CUTTING TOOL

To machine Thordon elastomers, it is critical that the correct cutting tool be used. The tool must be designed to slice the material and project it away from the machined surface. When machining Thordon properly, a continuous streamer is projected from the cutting tool. The cutting tool must be sharp. After grinding, the cutting tool should be honed with an oilstone to ensure a sharp cutting edge. Some of the new carbide cutting tools currently available provide excellent results machining Thordon. They are extremely sharp initially and hold their edge very well.

Thordon Bearings recommends a tool bit manufactured by Kennametal that is available worldwide. The tool bit is Titanium Nitride PVD coated carbide and is Kennametal part number: CPGT3251HP-KC730 as shown in Figure 32. The tool holder is part number: SCMPN-083V. There are a number of tool bits and holders offered in the Kennametal KC730 series. The applicable ISO standards are M05 - M20, S15 - S25. If you have trouble locating this, or a similar product, please contact Thordon Bearings or your local Thordon Distributor.



Figure 32: Kennametal® Tool Bit

Ch.5 MACHINING & MEASURING THORDON BEARINGS

It is important when machining Thordon and particularly when boring, to ensure that the machining streamer is removed from the work. If this is not done, it will interfere with the cutting tool and a rough finish will result.

NOTE: Due to the very elastic nature of the material, caution should be taken when removing cuttings from the work area.

The drawings on this page illustrate the proper cutting tool configuration when using conventional tool bits. High speed steel can be used for SXL and COMPAC; tungsten carbide tool bits are used with XL.

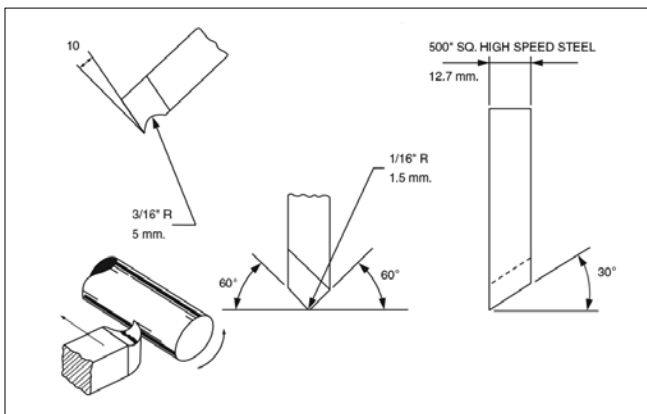


Figure 33: General Machining Tool Bit

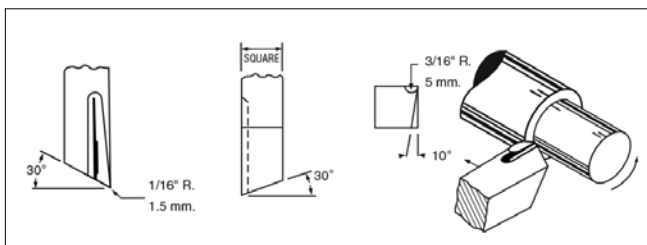


Figure 34: Step Machining Tool Bit

5.2.2 MACHINING SPEEDS AND FEEDS

Suggested turning speeds for bearings of various diameters are provided in the chart below.

Bearing Diameter		RPM	Coarse Feed	Fine Feed
(mm)	(inches)			
75mm	3"	600	0.6mm/rev.	0.4mm/rev.
150mm	6"	450	(0.025"/rev.)	(0.015"/rev.)
300mm	12"	300	for HSS tool	for HSS tool
450mm	18"	150	-	-
600mm	24"	120	0.3mm/rev.	0.2mm/rev.
750mm	30"	95	(0.012"/rev.)	(0.007"/rev.)
900mm	36"	80	for tipped tool	for HSS tool

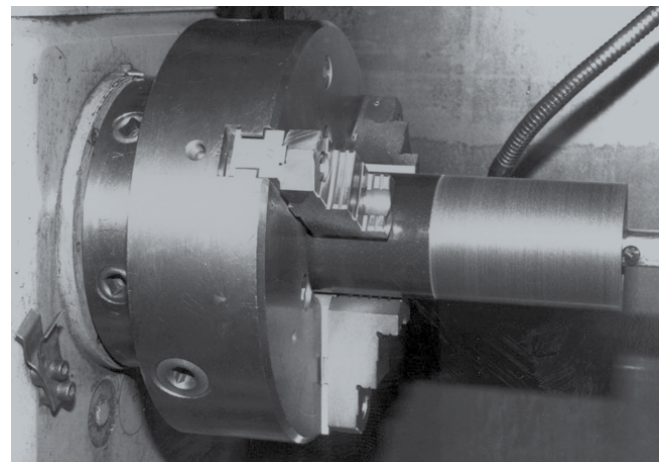
Figure 35: Typical Speeds and Feeds

NOTE 1: The turning and feed speeds are provided as a guide only. The optimum speed may vary higher or lower depending on such variables as the length of tube, the wall thickness, and how the bearing is being supported, i.e. simply chucked, spider at chuck or on a full length mandrel. As is common with all machining operations, some experimentation is required to obtain optimum results.

NOTE 2: Cutting lubricants are not required and are not recommended.

5.2.3 BEARING SET UP

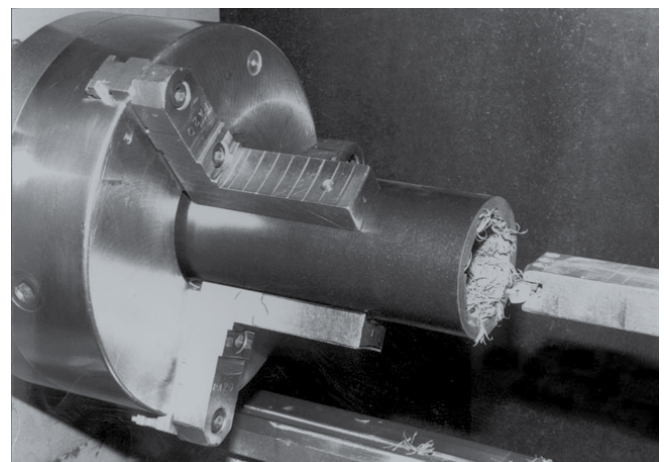
MACHINING - PARTIAL LENGTH FROM A TUBE



A bearing that is being made from the partial length of a tube can be chucked at one end in a normal 3 jaw chuck, the O.D. rough machined, the I.D. finish machined, the O.D. finish machined and then parted to length. Care must be taken not to over tighten the chuck and distort the tube.

MACHINING (I.D.)

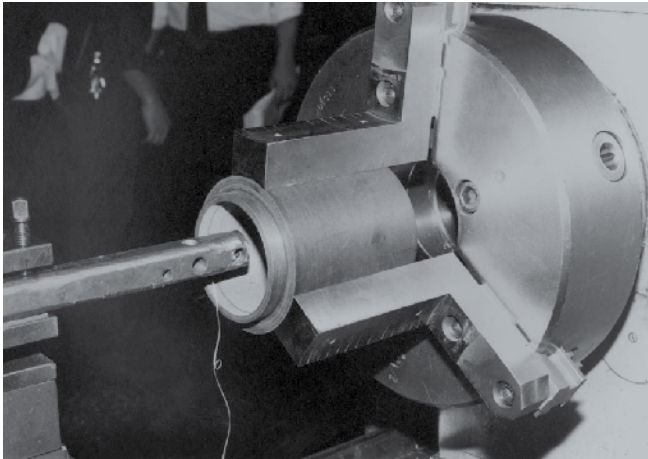
THIN WALL TUBE WITH SOFT JAW CHUCK



To machine the I.D. of a thin wall tube, the O.D. should be rough machined, the tube gripped in an extended soft jaw chuck and the I.D. finish machined. The extended chuck will grip and support the tube without deforming.

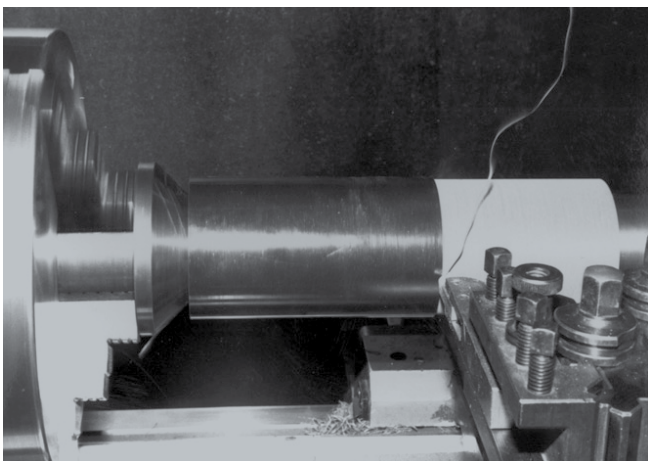
MACHINING & MEASURING THORDON BEARINGS Ch.5

MACHINING (I.D.) THIN WALL TUBE WITH EXTERNAL SLEEVE



A thin wall tube I.D. can also be machined by first machining the O.D. to size, lightly pressing the tube into a machined metal housing, chucking the housing and then machining the I.D. of the tube. It is possible to obtain tighter tolerances than those obtained with external soft jaws with this method but it is more complicated and typically not necessary.

MACHINING (O.D.) FULL LENGTH OF A LUBRICATION GROOVED BEARING - SUPPORTED ON CENTRES

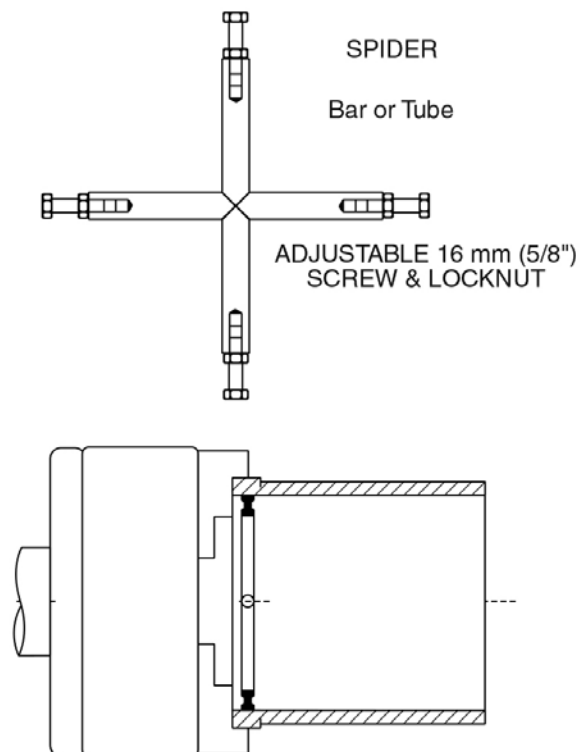


After the I.D. of a bearing with lubrication grooves has been finish machined, the bearing can be chucked on centres, driven by a key in one of the grooves and the O.D. finish machined. This method is acceptable for propeller shaft bearings, but will not yield the tight tolerances required for pump bearings.

MACHINING (O.D.) MACHINED STEEL PLUG OR ADJUSTABLE SPIDER



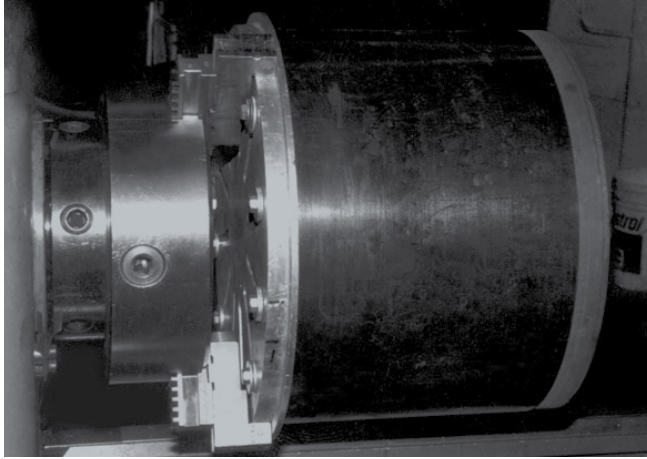
After the I.D. of a tube has been finish machined, a machined steel plug can be slip fit into the I.D. of the bearing. On larger tubes, a 3 or 4 arm spider can be set to the inside diameter of the tube and located opposite the chuck jaws. Both of these devices eliminate distortion from chuck jaw pressure. A simply constructed 4-arm spider is illustrated below. With either of these methods it is necessary to add a 50mm (2") chucking allowance to the required length of the bearing.



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MACHINING (O.D.)

PREFERRED MACHINING METHOD - O.D. & I.D.



Bearings larger than 380mm (15") O.D. are most easily mounted for machining by lag screwing them to a faceplate. The faceplate can then be set up on a vertical mill, or chucked in the lathe. An additional 50mm (2") must be added to the required length of the bearing as a chucking allowance. The faceplate is centered as accurately as possible and then screwed to the tube using lag screws into predrilled holes.

After mounting, the tube can be trued for machining, if required, by loosening the screws and adjusting the position of the tube using the slots in the faceplate.

The O.D. of the tube is rough machined first, then the I.D. finish machined, the O.D. finish machined and then the bearing is parted to length from the tube. If the bearing is too large to safely catch as it is parted off from the tube, the following procedure should be used. Part the tube approximately 80-90% of the way through, remove faceplate and tube from the lathe and knife cut the bearing from the tube.

If the bearing is mounted in a lathe, it should be completely machined without stopping for extended periods of time. This prevents the bearing drooping or going out of round under its own weight.

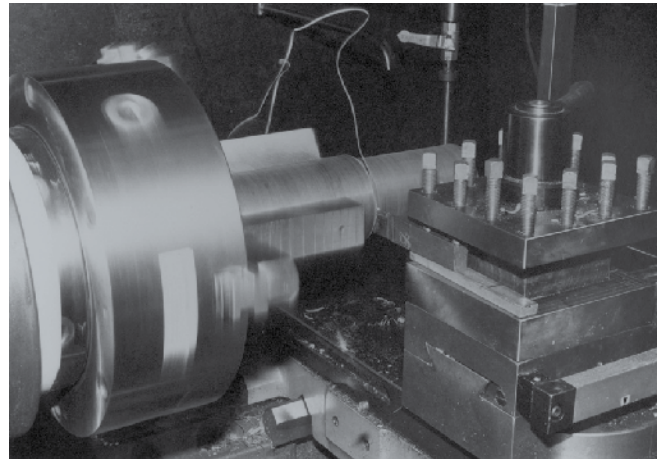
NOTE: Ensure that the tube is securely mounted to the faceplate before turning. Failure to mount the tube securely could result in the tube coming loose and causing personal injury.

5.2.4 PARTING TO LENGTH

Thordon can be parted to length with a standard parting tool, however, additional rake and side clearance are helpful to prevent heat generation resulting from the Thordon contacting the side of the parting tool. Cuttings from Thordon should be constantly removed during parting off, in order to achieve a uniform cut face.

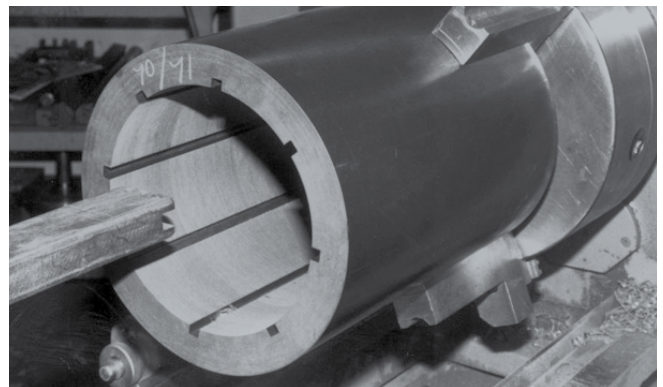
NOTE: Due to the very elastic nature of the material, caution should be taken when removing cuttings from the work area.

5.2.5 MACHINING LUBRICATION GROOVES

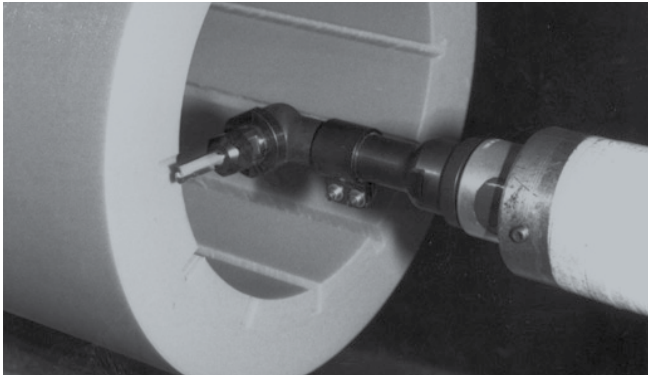


Lubrication grooves can be machined by hand or with a router.

To machine lubrication grooves by hand, a formed tool bit is mounted to the lathe boring bar and manually pushed through the bearing (broached). Several passes may be required to achieve the final groove depth.



The grooves can be machined much more easily by mounting a 90° router to the boring bar and then machining to the correct depth in one pass through the bearing.



The outside diameter of the chuck can be divided and marked to act as a guide for locating the grooves in the bearing.



NOTE: Lubrication grooves must always be machined before the bearing is fitted into the housing. Bearing I.D. can sometimes be machined after fitting into the housing, but grooves cannot.

5.2.6 GENERAL MACHINING TIPS

1. To obtain optimum dimensional and surface finish results, the final machining cut should be 1.5mm (0.060") to 2.5mm (0.100") and the cutting tool razor sharp.
2. If machining is not done in a temperature controlled environment, the Thordon Temperature Chart must be used to adjust the machining dimensions to suit the actual temperature at the time of machining. Changes in temperature can result in significant bearing dimensional changes.
3. Due to the elastomeric nature of Thordon bearings, if a machining error is made on the I.D. and if the wall thickness is still adequate, it may be possible to recalculate the O.D. of the bearing and still use it. Contact Thordon Bearings for corrected O.D. value.
4. Before making a final machining cut, the bearing should be checked to ensure that it has not retained any heat from previous cuts. If the temperature of the bearing is higher than the machine shop ambient temperature, the resulting final cut dimensions will not be correct.

5.2.7 MACHINING LARGE BEARINGS 1000mm (40") or LARGER

The easiest way to machine large Thordon elastomeric bearings is on a vertical boring mill. When machining on a vertical boring mill, the following basic steps should be followed:

- Use a two stage machining procedure (see below) to avoid significant dimensional issues after part off
- Machine on a vertical boring mill
- Use a PI tape for checking O.D. dimensions
- Use a ball micrometer to check wall thickness

A large Thordon bearing will change dimensions significantly with changes in temperature, so it is essential to monitor the temperature of the bearing during inspection. Use an accurate temperature gun to verify temperature of the bearing for all inspections. Take care when measuring temperature. Thordon streamers and the heat generated from the chuck can be misleading.

5.2.7.1 FIRST STAGE MACHINING

Rough machine O.D. and I.D. and leave overbuild on all diameters including stepping the length (flange) with a groove for final machining/clamping.

5.2.7.2 FINAL MACHINING

Clamp on grooved flange step as described above. Thordon recommends machining from chuck/flange up as Thordon streamers will generate heat and will cause difficulties determining actual bearing temperatures for getting finish cuts. Also, material streamers around the cutting tool will tend to push the tool and may cause a very rough finish or issues holding tolerances.

- Skim O.D. and I.D.
- Finish O.D. - use temperature charts. Check O.D. at a minimum of three positions (top, middle and bottom)
- Finish I.D. by measuring the wall thickness - use temperature charts. Check wall thickness. Machine a partial part-off, and knife cut.

Recommend flipping and facing to length. Holding method needs to be determined by the machine shop (best method available) as part off will result in the end collapsing and clamping stress which may lead to gouging.

Re-check O.D. at 3 positions and wall thickness at both ends.

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5.3 MACHINING RiverTough/ COMPOSITE

Machining Thordon RiverTough or Composite is different from machining Thordon XL, SXL or COMPAC because of the softer (black) bearing wear surface material, GM2401. The O.D. or yellow shell, can be machined using the same techniques as outlined in section 5.2. The I.D. (black), however, machines differently and is covered in this section.

5.3.1 CUTTING TOOL

The new Kennametal or equivalent Titanium Nitride PVD carbide coated tool bits described earlier in the section on machining XL, SXL or COMPAC are highly recommended for machining Thordon RiverTough/Composite bearings. With these tool bits, the black GM2401 I.D. of the bearing material can be finish machined to an acceptable surface finish without using a grinding hog as was recommended in the past.

If a conventional high speed cutting tool is used for machining the inner RiverTough/Composite bearing material it should be made to the configuration illustrated in Figure 36. As with other types of Thordon bearings, it is essential that the cutting tool is kept sharp.

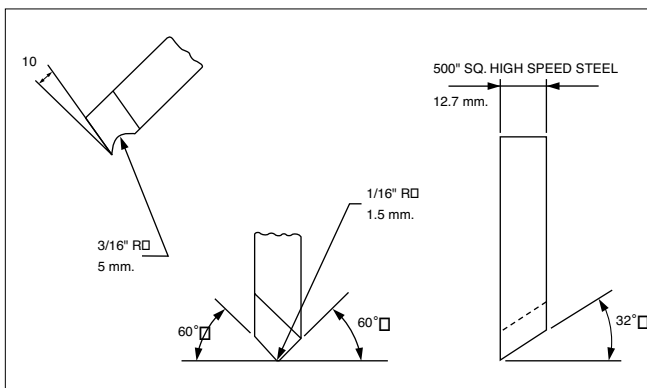


Figure 36: High Speed Cutting Tool

When using a conventional high speed tool bit to machine the I.D. of a Thordon RiverTough/Composite bearing some extra steps must be taken. Due to the nature of the GM2401 (black) wear surface material, conventional tool bits wear very quickly. In the course of one machining pass through the I.D., the tool bit will wear enough to produce a taper along the bearing I.D. This taper must be corrected for on a second pass, so the first step is to ensure that two final passes in a range of 2.0 to 3.0mm (0.080" to 0.120") deep are required to finish machine the I.D. of the bearing. The first pass is used to measure the amount of taper that is occurring (a taper of 0.15mm (0.006") over the length of a standard Thordon tube is common) and then this taper must be corrected for on the second pass.

NOTE: It is very important to note that the final pass must be made at the same depth, speeds and feed rate as the preceding one. Otherwise the wear on the tool bit producing the taper will change and the correction that is being made by hand will not be correct.

Machining the I.D. results in a burr at the lubrication grooves that can be removed using emery cloth or a deburring tool. The surface finish of the bearing will be somewhat rough but the bearing will bed in quickly and perform well.



Deburring tool

5.3.2 MACHINING SPEEDS & FEEDS

Suggested turning speeds for Composite bearings of various diameters are given in the chart below.

Bearing Diameter (mm)	Bearing Diameter (inches)	RPM	Feed HSS	Feed Tipped Tool
150mm	6"	250	0.5mm/rev.	0.25mm/rev.
300mm	12"	100	(0.020"/rev.)	(0.010"/rev.)
450mm	18"	75		
600mm	24"	60		
750mm	30"	50		
900mm	36"	40		

Figure 37: Typical Speeds and Feeds for Machining RiverTough/Composite

5.3.3 MACHINING PROCEDURE O.D. UP TO 250mm (10")

The procedure for machining Thordon RiverTough/Composite bearings up to 250mm (10") O.D. can be summarized in the following steps.

- Part the bearing oversize and face to the required finished length.
- Mount the bearing on centres and rough machine the O.D.
- Press the bearing (light press fit) into a housing to support it and finish machine the I.D.
- Lightly press the bearing onto a mandrel and finish machine the O.D.

5.3.4 MACHINING PROCEDURE O.D. LARGER THAN 250mm (10")

RiverTough/Composite bearings larger than 250mm (10") are best machined by mounting them to a faceplate and then machining the I.D., machining the O.D., parting oversize and facing to length.

NOTE: Ensure that the bearing is securely mounted to the faceplate before turning. Failure to mount the bearing securely could result in it coming loose and causing personal injury.

5.4 Machining ThorPlas-Blue

5.4.1 GENERAL MACHINING

ThorPlas-Blue is easily machined to fine tolerances. ThorPlas-Blue can be milled, sawed, planed, drilled, tapped and threaded. Depending on bearing sizes, allow for 25 to 40 mm (0.984" to 1.575") of material length for chucking and holding the part to any standard lathe.

GUIDELINES FOR SAFE MACHINING:

- Use sharp tools (carbide grade) with fast speed rates
- Provide good support to the part without over-clamping (to avoid cracking)
- Avoid sharp corners/edges
- Adequate material cuttings removal during machining
- Coolants may be considered for drilling holes

Typical cutting speeds for ThorPlas-Blue are between 150 to 300m/min (492 to 985 fpm) as shown in Figure 38.

Diameter	RPM
200mm (7.874")	350
300mm (11.811")	300
400mm (15.750")	200
500mm (19.685")	150
600mm (23.622")	100

Figure 38: Typical Cutting Speeds for Machining ThorPlas-Blue

Cutting Feeds used for rough turning are 0.38 mm to 0.5 mm (0.015" to 0.020") per revolution. For finish turning, 0.12 mm to 0.25 mm (0.005" to 0.010") per revolution are recommended.

As mentioned, fine tolerances can be achieved for ThorPlas, as shown in Figure 39.

See the ThorPlas Bearings Engineering Manual for more information.

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THORPLAS-BLUE MACHINING TOLERANCES

A - Bearing OD Machining Tolerances		
METRIC:		
Bearing OD	Bearing Length	Tolerance on OD (mm)
Up to 150mm	up to 100mm	+/- 0.03
	above 100mm	+/- 0.05
150 to 250mm	up to 150mm	+/- 0.05
	150 to 250mm	+/- 0.07
250mm and up	maximum L/D of 1:1	+/- 0.07
IMPERIAL:		
Bearing OD	Bearing Length	Tolerance on OD (in.)
Up to 6.00"	up to 4.00"	+/- 0.001
	above 4.00"	+/- 0.002
6.00" to 10.00"	up to 6.00"	+/- 0.002
	6.00" to 10.00"	+/- 0.003
10.00" and up	maximum L/D of 1:1	+/- 0.003
B - Bearing Wall Thickness Machining Tolerances		
METRIC:		
Bearing OD	Bearing Length	Tolerance on Wall (mm)
Up to 150mm	up to 100mm	+0.00
		-0.03
	above 100mm	+0.00
		-0.05
150 to 250mm	up to 150mm	+0.00
		-0.05
	150 to 250mm	+0.00
		-0.07
250mm and up	maximum L/D of 1:1	+0.00
		-0.07
IMPERIAL:		
Bearing OD	Bearing Length	Tolerance on Wall (mm)
Up to 6.00"	up to 4.00"	+0.000
		-0.001
	above 4.00"	+0.000
		-0.002
6.00" to 10.00"	up to 6.00"	+0.000
		-0.002
	6.00" to 10.00"	+0.000
		-0.003
10.00" and up	maximum L/D of 1:1	+0.000
		-0.003

C - Bearing LENGTH Machining Tolerances	
METRIC:	
Bearing Length	Tolerance on Length (mm)
Up to 150mm	+0.00
	-0.25
150 to 250mm	+0.00
	-0.50
250mm and up	+0.00
	-1.00
IMPERIAL:	
Bearing Length	Tolerance on Length (in.)
Up to 6.00"	+0.000
	-0.010
6.00" to 10.00"	+0.000
	-0.020
10.00" and up	+0.000
	-0.040
D - ThorPlas Washer Tolerances	
METRIC:	
Bearing Dimension"	Tolerance (mm)
OD	+0.00
	-1.00
ID	+1.00
	0.00
Thickness	+/- 0.50
IMPERIAL:	
Bearing Dimension"	Tolerance (mm)
OD	+0.000
	-0.040
ID	+0.040
	0.000
Thickness	+/- 0.020

Figure 39: ThorPlas-Blue Machining Tolerances

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5.4.2 GROOVE CUTTING

Water grooves, when required, are normally broached using a custom-made boring bar on the lathe. The boring bar and tools should be designed to produce the dimensions given in Figure 40 and 41. The following custom made tool bits can be ordered from Thordon Bearings or your Thordon distributor using the appropriate Part Numbers:

F99TB003: Toolbit with profile to machine 3mm (0.118") radius groove with 7 mm (0.276") radius edge

F99TB004: Toolbit with profile to machine 4mm (0.157") radius groove with 7 mm (0.276") radius edge

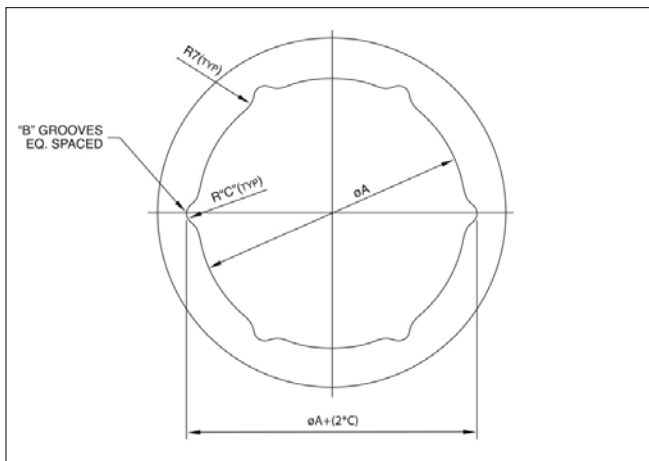


Figure 40: Typical Groove Configuration for ThorPlas-Blue Bearings

A	A	B	C	C
Shaft Diameter (mm)	Shaft Diameter (in.)	Number of Grooves	Groove Radius (mm)	Groove Radius (in.)
up to 30	up to 1.20	3	3	0.120
31 to 50	1.21 to 2.00	4	3	0.120
51 to 80	2.01 to 3.15	6	3	0.120
81 to 120	3.16 to 4.70	6	4	0.160
121 to 160	4.71 to 6.30	8	4	0.160
161 to 200+	6.31 to 7.90+	10	4	0.160

A, B and C refer to dimensions in Figure 40.

Figure 41: ThorPlas-Blue Water Groove Dimensions

NOTE: Water grooves are only used when there is a flow of water through the bearing such as a vertical pump. Grooves are not required when a bearing is immersed in water with no significant flow, as in a wicket gate bearing application.

5.4.3 CHAMFERS

Chamfers should be machined on the O.D. of each end of the bearing to facilitate installation following guidelines in Figure 38 and the dimensions in Figure 42.

METRIC:	
Bearing Length	Chamfer Detail
Below 25mm	1.5mm x 25°
25mm to 100mm	3.0mm x 25°
Over 100mm	5.0mm x 25°
IMPERIAL:	
Bearing Length	Chamfer Detail
Below 1 inch	1/16" x 25°
1 inch to 4 inches	1/8" x 25°
Over 4 inches	1/4" x 25°

Figure 42: Dimensions for Machining Chamfers

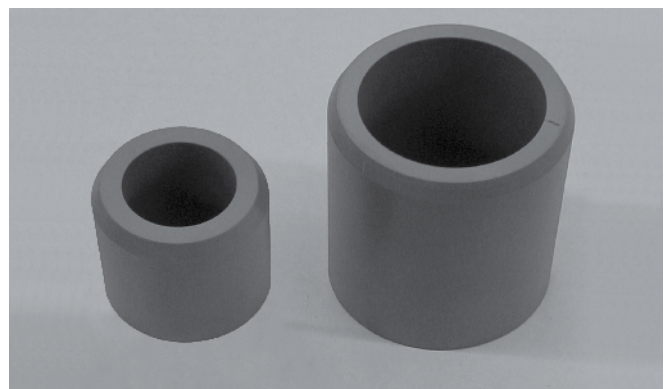


Figure 43: Chamfer on ThorPlas-Blue bearings

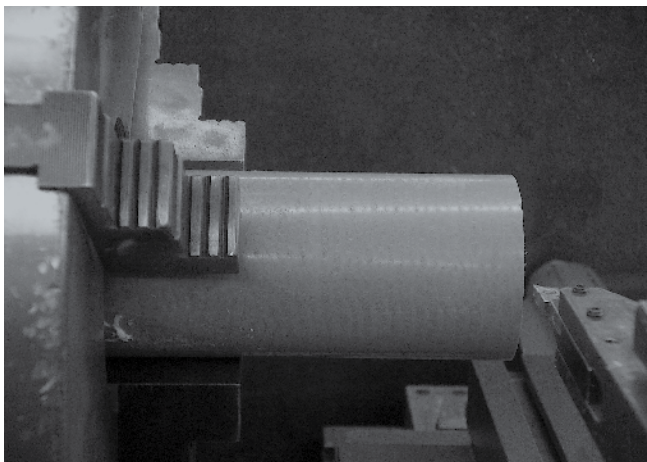
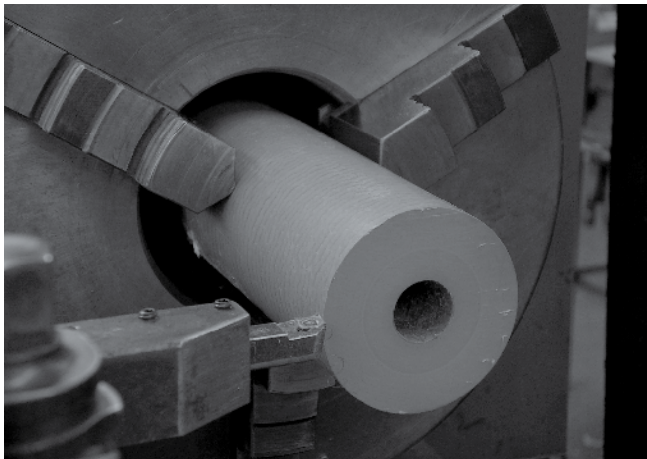
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5.4.4 STEP-BY-STEP MACHINING PROCESS

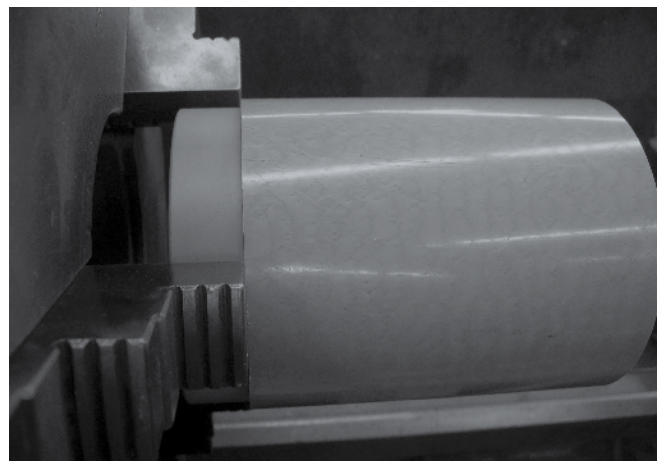
Steps 1 through 7 illustrate the machining process for ThorPlas-Blue in a standard lathe.

Step 1 Cut part allowing extra length for chucking, parting off and facing. Typically chucking lengths of 25mm (1") are sufficient for bearings up to 152mm (6") O.D. For large parts - O.D. in excess of 152mm (6"), thin wall bearings and/or for parts with tighter than standard tolerances, an internal plug or "chucking ring" is recommended to support the bearing in the chuck jaws.

Step 2a Set the part in the chuck jaws as shown below. These figures show a piece with sizes of 76.2mm O.D. x 25mm I.D. (3" x 1") squared in the chuck using a three-jaw configuration. Use light to moderate clamping forces. Do not over clamp as this can cause stresses in the material resulting in cracking.



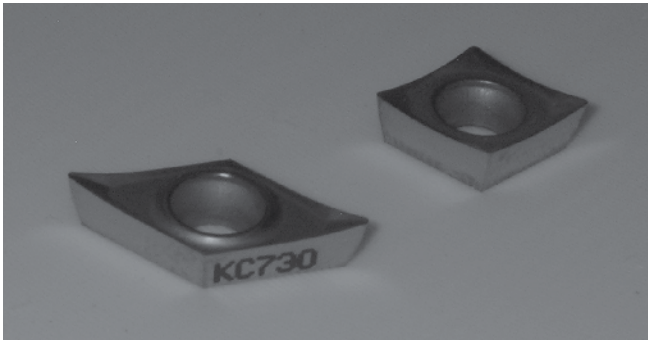
Step 2b For parts needing a metal chucking ring, machine slightly the O.D. to clean uneven surfaces and machine the I.D. so that the chucking ring has a slight interference with the ThorPlas-Blue - interference of 0.03mm (0.001"). Typical thickness of chucking rings vary from 12mm (0.5") for small parts to as high as 25mm (1.0") for parts with O.D. values in excess of 250mm (10"). Figures below show a ThorPlas-Blue bearing, size of 152mm (6.0") O.D., where a chucking ring is used for extra support.



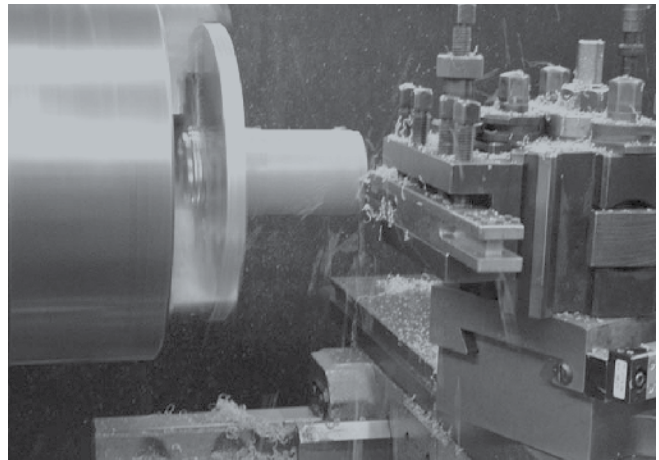
MACHINING & MEASURING THORDON BEARINGS Ch.5

Step 3 Sharp and smooth tool bits will ensure the best finish when machining ThorPlas-Blue. The photo below illustrates the tools used to machine ThorPlas-Blue – the bit on the left is used for machining the I.D. while the bit on the right is used for the O.D.

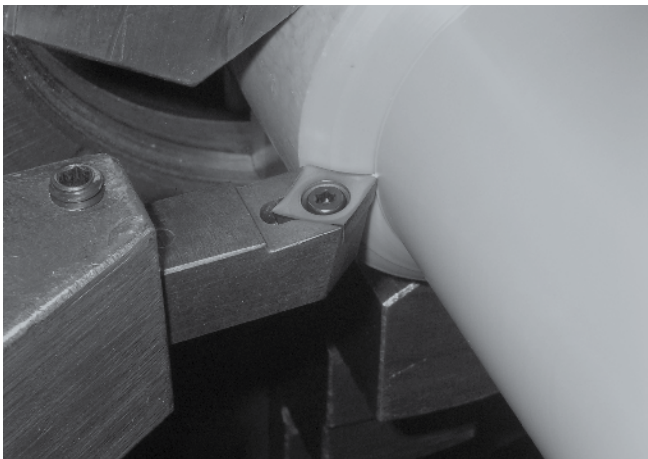
NOTE: Cutting feeds for rough turning are 0.38 to 0.50mm (0.015" to 0.020") per revolution. For finish turning, 0.12 to 0.25mm (0.005" to 0.010") feeds are recommended.



Step 5 Machine bearing O.D. using the appropriate tool.

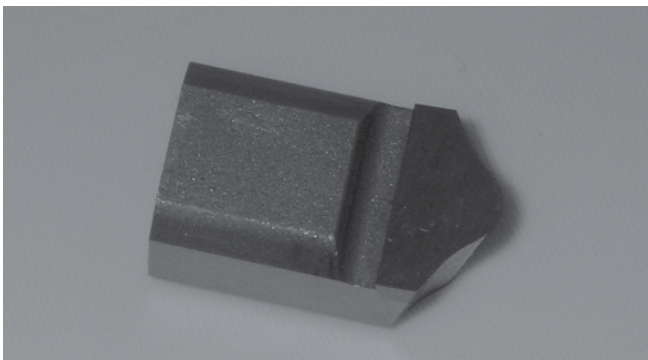


Step 6 Part bearing to length using the parting tool. Support the bearing as the cut is made so that it does not fall. As shown below, fine streamers are collected after machining ThorPlas-Blue.



Step 4 Proceed to machine bearing I.D. using the tool bit and the boring bar. Clearing of chips or shavings from bearing I.D. is important to reduce heat build up and to obtain desired tolerances. Finish the bearing O.D. prior to routing the grooves using the round edge tool shown below.

Step 7 Include chamfers on the end of the bearings to ease installation. Use Figure 42 to for proper dimension of chamfers based on bearing size.



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5.5 SPLITTING THORDON BEARINGS

There are two methods to split a Thordon elastomeric bearing, either using a saw blade or with a knife. These methods are explained further below.

5.5.1 SPLITTING A THORDON BEARING USING A SAW BLADE

The O.D., I.D., bearing length, lubrication grooves, and all chamfers must be fully machined prior to initiating the procedures to split the bearing segments.

A horizontal boring mill with an indexed rotating table is the best type of equipment to use to ensure proper location and accurate measurement of the splits. The pictures below illustrate the recommended process and equipment.

Depending on the length of the bearing, create two or three support disks that are the same diameter as the fully machined bearing I.D. The wooden inserts should be approximately 19.05mm or 0.75" thick. Two holes should be cut in each insert, 180° apart, to allow for two threaded rods to be placed through for securing purposes. Locate the support discs at the top and bottom (and mid section if required) of the bearing ID. These will keep the bearing "roundness" during the splitting process.



Centre the mill table and use four blocks to raise the bearing up from the surface of the mill table. Use the indicator so that the blocks are set to the centre of the table and the bearing is centered on the mill. The blocks should be positioned at approximately 90° apart from each other to support the bearing. The bearing is to be set on the blocks and oriented to place the cut on the split line shown on the Bearing Details Drawing.

NOTE: Measure the ID of the bearings at the temperature at which they are being machined and use these numbers to create the wooden inserts. Maintain the machine shop temperature constant as the splits are being machined. If the temperature changes drastically, the bearings may shrink or expand and the wooden inserts will not fit properly.



The bearing is clamped onto the table with 2 threaded rods secured with "T" nuts located in a groove on the table. Two metal bars are placed on the top of the bearing located directly over the metal support blocks on the mill table and clamped into position using a nut threaded onto the rod. Care is to be taken to ensure the clamps are not secured too tight.



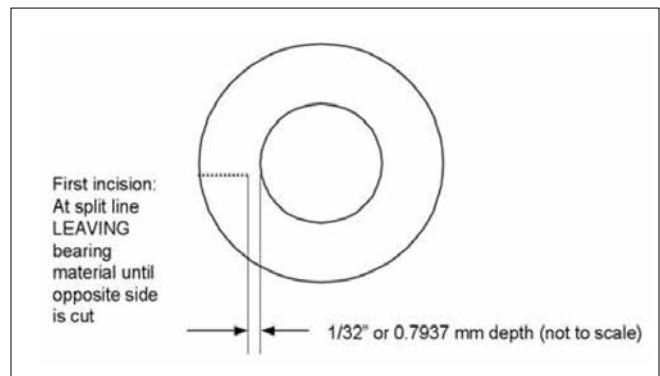
MACHINING & MEASURING THORDON BEARINGS Ch.5



Line the spindle of the machine to the split line indicated on the drawing and square to the bearing surface. A high-speed steel metal slitting saw 203.2 mm x 3 mm x 31.75mm (8" x 1/8" x 1 1/4") cutter is typically used by the Thordon Machine Shop (saws with side chip clearance) to do the splits. The cutting speed should be approximately 0.25 m/min (10 inches/min) at 140 RPM. The blade should be positioned with its saw teeth on the opposite direction of the bearing so that the saw is cutting away from the bearing.



Begin cutting the split line. Position the spindle to make the incision from the bottom up, cutting from the O.D. towards the I.D. of the bearing. The depth of the cut should leave a 0.794 mm (1/32") **section of material at the bottom of the cut for further cutting after opposite side is cut.** See figure below. If the bearing is cut all the way through, the material will have a tendency to spring back losing its roundness and making it very difficult to continue with the split on the opposite side (180°).



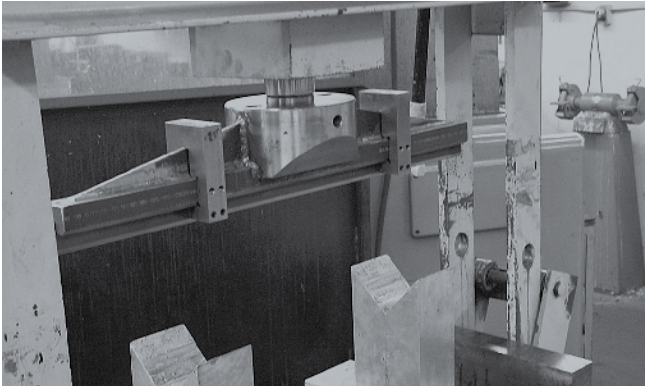
Rotate the table 180° and proceed with the second cut, again leaving approximately 0.794 mm (1/32") of bearing material behind. Ensure that both halves have the same arc length. Air should be used constantly during slitting to remove shavings. If shavings are not removed, the saw blade could get stuck and break. Take the bearing off the boring mill table. Using a sharp knife cut through the 0.794mm (1/32") gap of material that was left behind until the two segments are separated. Clean off the edges.

NOTE: Use compressed air to remove the material as it is being split away from the bearing. If the material is not removed it will tend to melt on the blade as the splitting process continues.

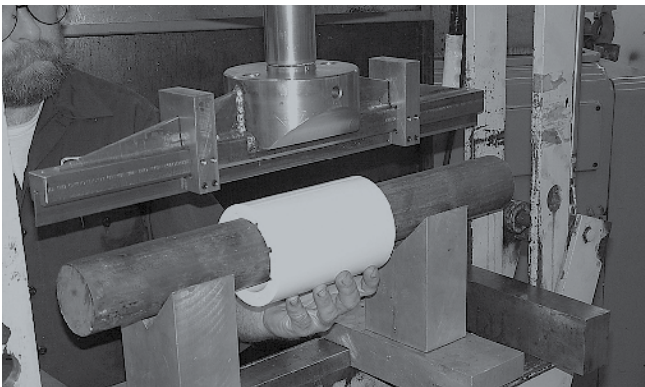
Ch.5 MACHINING & MEASURING THORDON BEARINGS

5.5.2 SPLITTING A THORDON BEARING USING A KNIFE

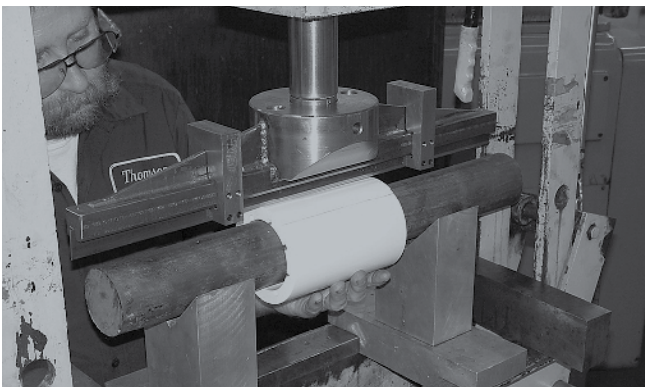
The O.D., I.D., bearing length and grooves of the bearing must be fully finished before proceeding with this technique. Mark the split before splitting.



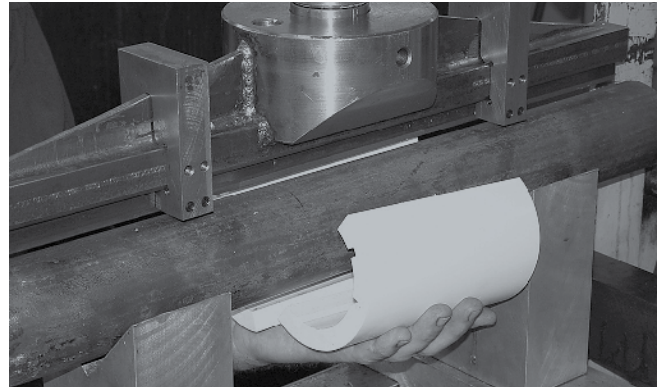
A Hydraulic Press is used to “knife” cut bearings without a gap. The knife or blade holder has been made in house to fit our press. The two holders at the bottom support the shaft used to position the bearing.



The shaft is placed inside of the bearing to be split and the assembly is located over the two stand supports.



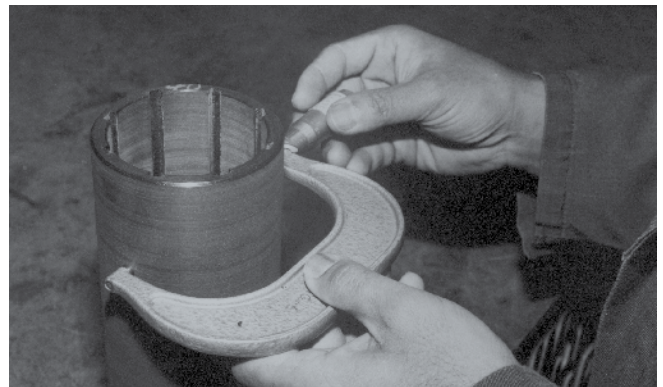
The first cut is made. Hold the bearing so that there is no movement while the blade is being lowered.



Rotate bearing 180°, and support the bearing so that there is no movement while the second cut is being made.

5.6 DIMENSIONAL & SURFACE FINISH MEASUREMENTS

5.6.1 DIMENSIONAL MEASUREMENTS



Outside micrometer

In most cases Thordon bearings can be measured using the same instruments and methods as any other material. It must be remembered that Thordon elastomeric bearings require a light touch when measuring because it is possible to deform the bearing out of round. In addition, Thordon elastomeric bearings have a high coefficient of expansion compared to metals, so measurements must be taken at machine shop temperature. If this is not possible then the dimensions must be corrected for the thermal expansion and contraction that has occurred because of the difference between the machine shop and ambient measuring temperatures.

In the case of larger diameter, relatively thin wall bearings that have been machined and removed from the lathe, it is typical to find that they show ovality. This deformation can be the result of the bearing sagging under its own weight or from being secured to a pallet for shipping. The bearing may appear to be out of tolerance due to the

MACHINING & MEASURING THORDON BEARINGS Ch.5

fact that it has become out of round. This is not a problem because when the bearing is pressed into a housing, it will conform to the shape of the housing and will be round. To accurately measure the bearing outside the housing, use a pi tape to measure the O.D. and then measure the wall thickness using a ball micrometer to obtain the correct I.D. dimension.



A pi tape is a precision steel tape calibrated to measure diameters by measuring circumference.

5.6.2 SURFACE FINISH AND TOLERANCES

Thordon, due to its non-metallic elastomeric nature, cannot be machined to as smooth a surface finish as metals. This is not a problem because the bearing goes through a normal break in period during which the initial surface roughness is worn smooth. It is important, however, to strive for as good a surface finish as possible to reduce friction and initial break in wear. The mechanics of obtaining a good surface finish have been covered in the machining section but it is important to know how to measure the surface finish of a Thordon bearing.

Due to the non-metallic nature of Thordon bearings, they will tend to feel smoother to the touch in comparison to metal than they really are. To measure accurately the Thordon bearing surface finish, a stylus type of surface finish gauge should be used. Practical experience has shown that the use of a comparator will usually result in a value that is less than the actual value. This is because Thordon bearings are softer than metal and feel smoother than they actually are when measured with a stylus.

The tolerances on surface finish are as follows:

XL, SXL, COMPAC, ThorPlas:

3.2 micro-metres (125 micro-inches) Ra

RiverTough/Composite:

4.2 micro-metres (175 micro-inches) Ra

NOTE: Due to the unique characteristics of Thordon bearings, compared to metals, optimal performance can still be obtained at relatively high (compared to metal) surface finishes.

5.6.3 MACHINING TOLERANCES

Thordon bearings are non-metallic and consequently cannot be machined to the same tight tolerances as bronze or other rigid materials. Conversely tight metallic tolerances are not necessary to obtain optimum performance. The standard machining tolerances for Thordon elastomers is shown in Figure 44.

Bearings up to 330mm (13.00")		
O.D.	+0.13mm, -0.00mm	(+0.005", -0.000")
I.D.	+0.13mm, -0.00mm	(+0.005", -0.000")
Bearings between 330 - 530mm (13.00 - 21.00")		
O.D.	+0.18mm, -0.00mm	(+0.007", -0.000")
W.T. (Wall Thickness)	+0.00mm, -0.13mm	(+0.000", -0.005")
I.D. (Composite only)	+0.18mm, -0.00mm	(+0.007", -0.000")
Bearings over 530mm (21.00")		
O.D.	+0.25mm, -0.00mm	(+0.010", -0.000")
W.T.	+0.00mm, -0.13mm	(+0.000", -0.005")
I.D. (Composite only)	+0.25mm, -0.00mm	(+0.010", -0.000")
Bearing Length Tolerance:		
For bearings shorter than 500mm (20") long	+0.00mm, -0.50mm	(+0.000", -0.020")
For bearings longer than 500mm (20") long	+0.00mm, -1.00mm	(+0.000", -0.040")

Figure 44: Machining Tolerances XL, SXL, COMPAC and RiverTough/Composite

NOTE 1: For Thordon XL, SXL and COMPAC bearings over 330mm (13"), machined I.D. tolerance should be controlled by controlling the wall thickness of the bearing. For RiverTough/Composite bearings over 330mm (13") only, the actual I.D. of the bearing should be controlled.

NOTE 2: If the wall thickness is less than 25mm (1") then there may be restrictions as to the length of bearing that can be properly machined. Consult Thordon Bearings for details.

NOTE 3: If an application requires tolerances that are tighter than those outlined in this manual please contact your Thordon distributor or Thordon Bearings for guidance.

Ch.6 INSTALLATION METHODS

6.1 GENERAL

Thordon bearings are generally fitted with an interference fit. Actual installation is very quick and easy, especially when freeze fitting is used. The housing should always be clean and dry. No grease or oil should be used to help press or drive fitting, as this will have a negative effect on the interference. The housing should be round and not tapered or bell mouthed. It should provide support to the Thordon bearing along its full length. Thordon bearings will not function properly when not fully supported. Gaps in the housing must be filled, or a sleeve fitted before installing the Thordon bearing.

The relatively light weight of Thordon bearings is a significant advantage in the installation of large bearings. Large tubular bearings can be handled and freeze fitted manually or with light lifting equipment. The interference fit is normally sufficient to prevent bearing rotation under normal conditions, but anti rotation devices should be fitted when the orientation of the bearing is critical (such as COMPAC bearings). A forward stop and an end keeper ring are recommended to avoid any possibility of axial movement. These keeper rings must be of adequate proportion and have an inside diameter equal to the maximum acceptable bearing/liner wear down plus 10%. The removable keeper ring should be retained with bolts rather than welded.

If the housing is cast or machined steel, it should be suitably protected from corrosion. The housing I.D. input used for bearing size calculations should take account of any coating thickness.

As an alternative to interference fitting, it is possible to bond Thordon bearings into housings. Bonding is used when the bearing wall is too thin for an interference fit and also when the housing does not provide a smooth round support for the bearing. Further information on preparation and bonding techniques is found in Section 6.4.

6.2 FREEZE FITTING

6.2.1 GENERAL

Because Thordon elastomers have relatively high coefficients of thermal expansion, they contract significantly when cooled. This makes freeze fitting the easiest way to install Thordon bearings. Dry ice is a common cooling agent, but liquid nitrogen is the optimum for XL, SXL, COMPAC and RiverTough/Composite. The amount of shrinkage during freeze fitting is calculated by the Thordon Bearing Sizing Calculation Program, or can be estimated as follows:

- Each 10°C decrease in temperature will result in an approximate decrease in diameter of 0.0014mm/mm of diameter.
- Each 10°F decrease in temperature will result in an approximate decrease in diameter of 0.0008 inches/inch of diameter.

Thordon elastomeric bearings do not become brittle at low temperatures. If a Thordon elastomeric bearing is dropped while frozen it will usually not shatter or crack. Simply clean and degrease any surfaces which came into contact with the ground, re-freeze the bearing and install it into the appropriate housing.

6.2.1.1 DRY ICE

When using dry ice, it should be in pelleted form or, if supplied in block form, the block must be broken into smaller pieces. The dry ice must make good contact with both the inside and outside surfaces of the bearing. The bearing should remain in the dry ice for a minimum of three hours and can then be checked to see if it has shrunk sufficiently for installation. If not, the bearing should be re-packed and checked in another hour.

SAFETY CAUTION: Use of dry ice in closed or poorly ventilated areas should be avoided, as the gases tend to displace the existing oxygen and can be fatal.

6.2.1.2 LIQUID NITROGEN

Liquid nitrogen can be used for fitting SXL, XL, COMPAC and RiverTough/Composite grades using a gas tight container where the liquid cannot leak out and cause harm. The bearings should be completely immersed (or as close to completely submerged as is practical) or evenly coated with liquid nitrogen. When the liquid nitrogen stops boiling, the bearing has reached -196°C (-320°F) and can be easily installed (approximately 5 to 30 minutes depending on the surface area of the bearing).

NOTE 1: ThorPlas-Blue bearings should not be exposed to liquid nitrogen. Freeze fitting of ThorPlas-Blue bearings should be done with dry ice only. See the ThorPlas Bearings Engineering Manual for more detailed installation instructions.

NOTE 2: Any Thordon bearing bonded in a metallic carrier must not be exposed to temperatures below 0°C (32°F) as the bond can fail.

Typically, freeze fitting tanks are designed to fit as large a variety of bearings as possible while using as little liquid nitrogen as possible as shown in Figure 45.

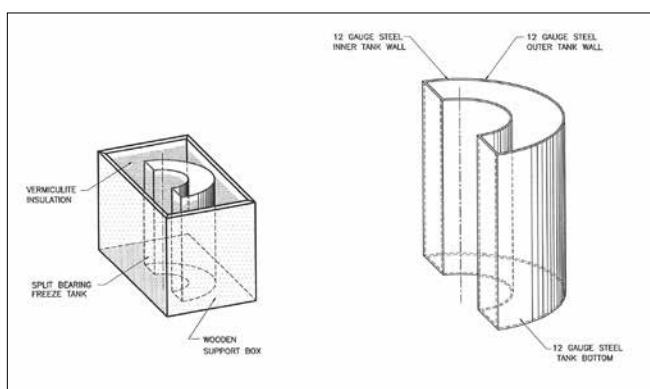


Figure 45: Typical Freeze Fitting Tanks

SAFETY CAUTION: Use of liquid nitrogen in closed or poorly ventilated areas should be avoided as the boiled off gasses tend to displace the existing oxygen and can be fatal. Do not let liquid nitrogen come into contact with exposed skin; the extreme cold will cause burns.

6.2.2 TUBULAR BEARINGS

Thordon tubular bearings, when frozen, can normally be slid into the housing without difficulty. It is possible, however, that a bearing may become stuck when only partially inserted. It is recommended that a hydraulic jack or rubber mallet be readily available to complete the installation – speed becomes important in such cases because the bearing will continue to warm up and expand. If any fitting force is applied, then the frozen bearing must be protected against localized damage.

For all tubular bearings, Thordon Bearings recommends a machined stop or ring at an appropriate point in the housing to prevent the bearing from moving too far when being installed. Frozen bearings can easily slide too far into the stern tube or rudder housing if a stop is not provided. Thordon also recommends a keeper ring at the other end to eliminate any possibility of axial movement. The designed interference fit is usually sufficient, but a tapered housing, or cyclical unbalanced loading may occasionally cause a large bearing to move axially if it is not secured.

To make handling and machining easier, Thordon bearings are often supplied in multiple segments to make up one length. Each segment can be installed and allowed to warm up before the next is fitted, or the segments can be fitted immediately after each other, however, care must be taken not to disturb the position of the previous segment. Each segment should be installed with its centre correctly positioned axially – the cooled segment will have also contracted in length and must be free to expand in the axial direction at each end as it warms. There will therefore be gaps between each end of the bearing and the keepers, and also between any bearing segments. Gaps should also be provided to allow for a portion of the axial absorption and thermal expansion to occur between segments.

Grooves of propeller bearing segments should be aligned to avoid restriction of the water flow. This can be done visually, or a piece of flat bar stock can be fitted so that it engages the grooves on adjoining segments. To avoid possible constriction problems from minor misalignment of water grooves, each section of a Thordon tubular bearing should be machined with a circular recess at one end (the same width and depth as the water grooves). This facilitates flow of water from one set of grooves to another even if there is groove misalignment. Care must be taken to ensure that these recessed ends are properly installed - in the middle, not the outside.

Ch.6 INSTALLATION METHODS

6.2.2.1 RECOMMENDED PROCEDURE FOR PROPELLER SHAFT BEARINGS

1. Freeze the Thordon tubular bearing as described in section 6.2
2. Slide the bearing section(s) into the housing.
If there are multiple sections:

- a. Immediately before each section is pushed into the housing, its length should be measured. The segment is then pushed into the housing until the centre of the segment is positioned correctly.

EXAMPLES: A bearing for a 600mm (23.6") housing would be machined to approximately 596mm (23.5") long (to allow for axial water absorption and thermal expansion). It would shrink to 584mm (23.0") after freezing in liquid nitrogen. The centre of the bearing should be 300mm (11.8") from the end of the housing, but the frozen bearing is only 584mm (23.0") long, so the gap to the internal keeper is $300 - 584/2 = 8\text{mm}$ ($11.8 - 23.0 / 2 = 0.315\text{"}$).

For two segments in a 1200mm (47.2") long housing, install the first segment as above. Install the second segment until it has passed the location of the external keeper by 8mm (0.31"). This will result in a gap between segments which is normal. The size of this gap cannot be predicted as the first segment will have warmed some amount and correspondingly expanded. Once the bearing is operational and water absorption and thermal expansion have occurred, all gaps will disappear.

- b. Place circumferential grooves (if any) towards the inside of the bearing.
- c. Ensure all lubrication grooves (if any) are aligned either visually or with a piece of bar stock
- d. Install the axial keeper ring at the open end. The keeper ring should not block the flow of water through a propeller shaft bearing.
- e. Allow bearings to warm to ambient temperature. As Thordon bearings are an effective thermal insulator, it can take considerable time for the core material to warm. It is recommended that at least 12 hours elapse before measurements are taken.
- f. Measure the bearing bore and record readings from throughout the bearing length and around its bore. The difference between bearing I.D. and shaft diameter should be checked against the calculated Minimum Installed Diametrical Clearance. If the measured clearance at any point in the bearing is less than the Minimum Installed Diametrical Clearance, this should be investigated and corrected.

6.2.2.2 RECOMMENDED PROCEDURE FOR RUDDER BEARINGS

The actual length of a Thordon rudder bearing will be less than the housing length by the amount of the allowances for thermal expansion and absorption. It is important that this amount be evenly distributed. If the bearing is a single tube, then the total of the allowances should be divided in two with half being allocated to the bottom of the bearing and half to the top. If the bearing is made up of two or more segments, then an appropriate portion of the total allowances should be allocated to gaps between the segments.

With freeze fitted rudder bearings, positioning of the bearing(s) is more difficult than in horizontal bearings because the bearings want to slide down to the stop. To avoid this, use shims made of wood or cardboard to hold the bearing in the correct position until it starts to warm up and establishes its "grip" on the housing. Then the shims can easily be removed. Do not use metal shims because, once the bearing has warmed up, they will be very difficult to remove. Similar shims should also be used to create the appropriate space between bearing segments in the case of a multi segment bearing.

6.2.3 STAVE BEARING INSTALLATION

1. Take care to ensure all staves are cooled by alternating layers of staves and dry ice. The staves should be left in dry ice for approximately 2-3 hours. A cylinder of liquid nitrogen large enough to immerse the staves can also be used. The staves should be immersed until bubbling of the nitrogen stops.
2. Frozen staves are placed side by side in the housing until all staves are assembled. When fitting staves on the upper half of the assembly they may be kept in place by using hoops, wooden discs or other devices. Once the staves begin to warm-up, no special support will be required.
3. Place machined staves next to the keeper strips. It is sometimes necessary to drive the last stave into the housing if the assembly has begun to warm up during the installation. Once the staves are fully warmed-up, they will be held tightly in place by their interference fit.
4. While frozen, Thordon staves, especially Composite staves, may twist or warp a little, but this should not unduly affect the assembly.
5. Any staves that come loose should be hammered back into place.
6. While it is warming up, the assembly should be checked to ensure that all staves are tightly seated against the housing.
7. A keeper ring should be used to prevent axial movement of the staves under unusual conditions

When staves of different lengths are used, an interlocking pattern is recommended; long and short and then short and long. Care should be taken to ensure the long and short machined staves are matched together against the keeper strips.

A forward stop and an end keeper ring should be used when installing stave bearings to eliminate any possibility of axial movement of the staves under unusual operating conditions.

6.2.4 SPLIT BEARINGS (SINGLE KEY, DOUBLE KEY)

6.2.4.1 SINGLE TAPERED KEYSSET DESIGN

The single tapered keyset design consists of a full form housing, a single keyset split into two tapered components and split Thordon bearing segments, normally COMPAC. One key segment is fixed to the carrier while the other half is loose as shown in Figure 46. One major advantage of this concept is that the bearings can be removed and replaced without removing the shaft. Complete installation instructions are found in Appendix 1: Thordon COMPAC Bearing with Single Tapered Keyset Installation Manual. A Bearing Technology Training CD containing videos on COMPAC bearing single tapered keyset design and installation is also available from Thordon Bearings.

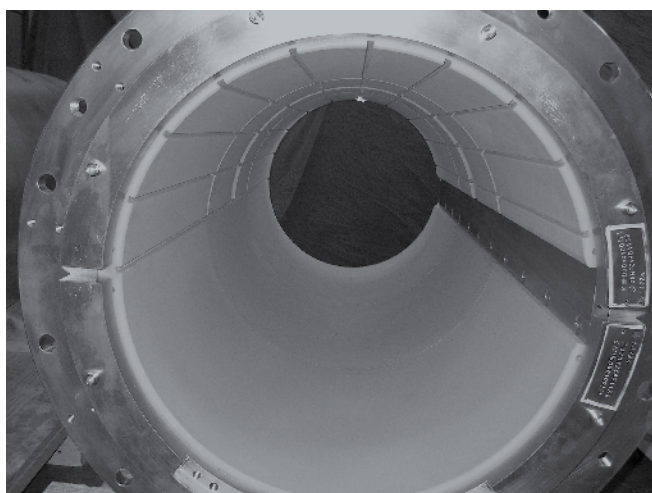


Figure 46: COMPAC Single Tapered Keyset Design Installation

6.2.4.2 DOUBLE KEY DESIGN (FIGURE 47)

1. Bearing segments can be installed individually. All the bearing halves do not have to be frozen at once.
2. Slide the bearing segments in place. Ensure each segment is in the correct spot (grooves on upper half for COMPAC bearing).
3. Leave space between the bearing segments for axial growth when the segments normalize to room temperature.
4. Install keeper ring.

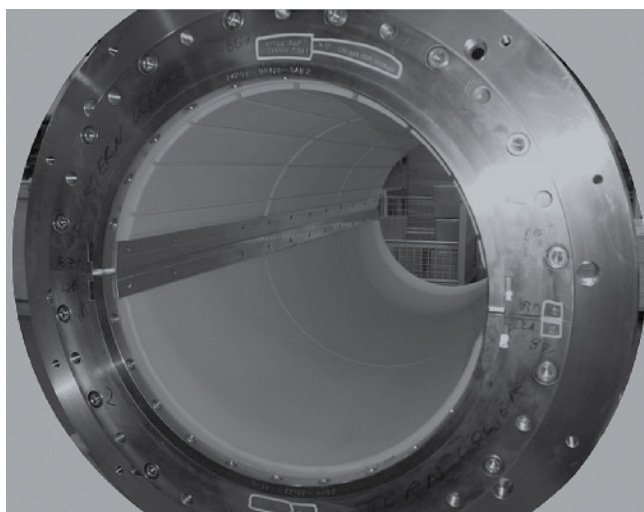


Figure 47: COMPAC Double Key Design Installation

Often, the spring force of the bearings against the keys will cause the carrier to become slightly oval. The carrier can easily be forced round by inserting it into the housing.

Ch.6 INSTALLATION METHODS

6.3 PRESS OR DRIVE FITTING

6.3.1 CYLINDRICAL BEARINGS

Although freeze fitting is the preferred way to install Thordon bearings, it is also possible to use a drive or press fit when freezing facilities are not available. Drive fitting is possible for small bearings. Hammer impact will not harm the bearings. Because of the significant amount of interference on Thordon bearings, considerable pressing force is required to install larger bearings. All press or drive fit bearings should be machined with an entry chamfer to facilitate entry into the housing. For multiple segment bearings, a piece of flat steel bar should be fitted into adjoining grooves to ensure proper groove alignment. To avoid possible constriction problems from minor misalignments of lubrication grooves, each segment of a Thordon tubular bearing should be machined with a circular recess at one end (the same width and depth as the lubrication grooves) This facilitates flow of water from one set of grooves to another, even if there is minor misalignment of the grooves. Care must be taken to ensure that these recessed ends are properly installed - in the middle, not on the outside. Pressing force required to fit a Thordon bearing is provided by the Thordon Bearing Sizing Calculation Program, or can be calculated as follows:

Press force (kg) =

$$\frac{\text{interference(mm)} \times \text{wall thickness(mm)} \times \text{length(mm)} \times 85}{\text{housing bore(mm)}}$$

Press force (N) =

$$\frac{\text{interference(mm)} \times \text{wall thickness(mm)} \times \text{length(mm)} \times 850}{\text{housing bore(mm)}}$$

Press force (lbs.) =

$$\frac{\text{interference(inch)} \times \text{wall thickness(inch)} \times \text{length(inch)} \times 120000}{\text{housing bore(inch)}}$$

NOTE: These are estimations, using a 0.3 friction coefficient and a nominal Compression Modulus to suit all grades of Thordon elastomeric polymer bearings.

6.3.2 SINGLE TAPERED KEYSSET DESIGN

The single tapered keyset design consists of a full form housing and a single keyset split into two tapered segments, and split tubular Thordon bearings (normally COMPAC). One half of the key is fixed to the carrier while the other half slides along it. The single key design allows the bearings to be removed easily from the carrier without removing the shaft. Detailed instructions for press fitting are provided in the Thordon COMPAC Bearing with Single Tapered Keyset Installation Manual in Appendix 1.

6.4 ALTERNATIVE METHODS: BONDING

6.4.1 DIMENSIONING FOR BONDING

When bearings are bonded in place, there is no interference on the O.D. of the bearing, and no bore closure allowance on the I.D. The allowances for running clearance, absorption and thermal expansion must still be considered. The Thordon Bearing Sizing Calculation Program will provide dimensions for a bonded fit. Consult with Thordon Bearings if the bearing will be bonded at a temperature different from where it was machined.

6.4.2 TG-75

TG-75 is a flexible, high strength, two-part epoxy based adhesive which has been specially selected by Thordon after extensive testing of a variety of adhesives. It cures with enough flexibility to accommodate the stresses generated by the thermal expansion and absorption of Thordon. It is used primarily to form strong bonds between cured elastomers and metals. It can fill gaps up to 3mm (0.125"). Detailed instructions for using TG-75 are found in Appendix 2. Alternative adhesives can be used in an emergency.

6.4.3 FILLING RECESSES

When gaps larger than 3mm (0.12") are encountered it is necessary to use a different type of adhesive. In such cases Thordon recommends the use of a chocking compound designed for marine applications.

6.4.4 CHOCKING COMPOUNDS

Chocking compounds can fill substantial gaps with minimal shrinkage. Pot life and viscosity can be such that they can be poured into the annular space between a bearing and its housing without difficulty as long as proper venting provisions are allowed.

Most chocking compounds have a significant exothermic curing process. When the wall of the chocking compound is thick, this heat may be sufficient to damage the Thordon bearing. In this situation, Thordon Bearings cautions that the temperature should be monitored when chocking with a wall thickness greater than 12mm (0.5").

Contact the chocking compound manufacturer or distributor for details about their chocking compound.

There are two installation methods using chocking compounds, one using the chock as an adhesive to bond the bearings into place, and the other using chock to form a housing into which a bearing can be interference

fitted. The use of chocking compounds is popular in new construction as an alternative to boring and aligning struts, and in repair when badly worn housings are encountered.

For any Thordon bearing installation involving chocking compounds, anti rotation devices (as described in Section 3.10) should be used to prevent relative movement between the chock and the housing and between the chock and the bearing. If using pins, then two pins per bearing segment are recommended.

6.4.4.1 BONDING DIRECTLY INTO THE HOUSING USING CHOCK

The bearing O.D. must be clean before bonding. Use a rag or cloth wetted with a solvent to clean the bearing O.D. Ensure the solvent is allowed to dry before chocking the bearing. The bearing must be correctly aligned using jacking screws, etc. Follow the chock manufacturer's instructions for venting and damming the assembly, and for mixing and pouring the chock. Avoid abrupt drops in temperature during curing of the chock as these may cause the bearing to shrink. This in turn can affect the integrity of the bond.

Chocking bearings directly into the housing can make the removal of worn bearings difficult. It is often necessary to chisel out the chock. An alternative is to use the chocking compound to make a housing into which a bearing can be freeze or press fitted. See instructions below.

6.4.4.2 MAKING A HOUSING FROM CHOCK

Making a housing from chock is an alternative to bonding. It may be more expensive initially, but replacement of worn bearings is much easier. The process involves using a "dummy bearing" which has the same O.D. as the nominal O.D. of the final Thordon bearing. The dummy bearing is coated with a mould release compound to prevent the chock from sticking to it. The dummy bearing is then aligned and installed following the procedures outlined in 6.4.4.1 above. Once the chock has cured, the dummy bearing can be removed, leaving a round aligned chock housing into which a Thordon bearing can be fitted using the normal interference fit methods described above.

6.4.4.3 CHOCKING STERN TUBES OR BEARING CARRIERS

Some shipyards fit Thordon bearings into carriers or stern tubes, and then chock the carrier or stern tube into position. This procedure is acceptable as long as the temperature on the inside of the carrier or stern tube does not exceed 55°C (130°F). The exothermic reaction from

some chocking compounds, especially if the wall is thick, can transfer sufficient heat through the carrier or stern tube wall to stress relieve the Thordon bearing, causing it to lose its interference fit. The preferred method is to chock the carrier or stern tube with the bearings removed.

6.5 INSTALLING CARRIERS FOR SINGLE TAPERED KEYSSET DESIGN

The carriers are supplied in accordance with customer requirements and can either be chocked or fit directly into the bearing housing provided in the ship structure (stern tube, strut, or other.)

All parts are finish machined, ready for installation, unless otherwise directed.

NOTE: COMPAC bearings segments are to be removed from the carrier prior to chocking and installed only after Chocking of the carriers is complete

Ch.6 INSTALLATION METHODS

6.6 REMOVAL OF THORDON BEARINGS

6.6.1 GENERAL

If Thordon bearings have to be removed, there are several acceptable procedures.

1. For smaller bearings it is often feasible to use a "come-along" to pull the bearings out. Fit a pulling plate behind the bearing to be removed and pull with a hydraulic jack. See Figure 48 below.

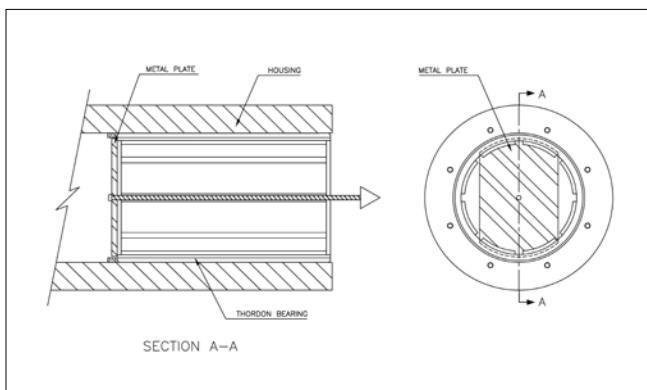


Figure 48: Technique For Removing Small Thordon Bearings

6.6.2 REMOVAL OF SINGLE TAPERED KEYSET BEARINGS – SEE APPX. 1

The tapered keyset concept allows removal of Thordon COMPAC bearings for inspection with the shaft in place. The removal of the tapered key and bearing is outlined in Appendix 1: Thordon COMPAC Bearing with Single Tapered Keyset Installation Manual. A Bearing Technology Training video on COMPAC bearing single tapered keyset design and installation is also available from Thordon Bearings.

2. It is also possible to pack a small bearing with dry ice and freeze it enough to be able to pull it with little force.
3. For larger bearings, the easiest way is to remove the interference fit. This can be accomplished by cutting a groove in the worn part of the bearing using a router or similar tool such as a circular saw or a chain saw. The groove should be 3-5mm (.01" - 0.2") wide. Recommended procedure is to cut the groove almost through the wall of the bearing leaving 1- 2mm (0.04"-0.08") of bearing wall that can then be cut with a sharp knife. This procedure minimizes the risk of damage to the bearing housing. Once the bearing wall has been completely cut, one side can be pried up and doubled over the other to completely remove the interference pressure. Then the bearing can be manually removed.
4. An alternative method is to heat the bearing to more than 70°C (158°F) for at least an hour, and then cool it. This will effectively stress relieve the bearing and it should be easily removed.

COMPAC INSTALLATION APPENDIX 1

THORDON COMPAC BEARING WITH SINGLE TAPERED KEYSSET INSTALLATION MANUAL

EQUIPMENT DESCRIPTION

The Thordon COMPAC with tapered keyset bearing system consists of the following items:

- a. A bronze or stainless steel bearing carrier.
- b. A bronze tapered keyset.
- c. Split COMPAC polymer bearing segment/segments.
- d. Bronze or Stainless Steel axial retaining rings.

The bearing assembly for all sizes of COMPAC bearings with tapered keyset is similar in construction. A brief description follows:

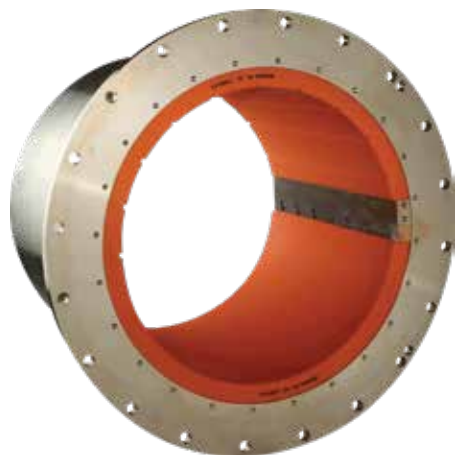
Each bearing assembly comprises an outer metallic carrier lined with Thordon COMPAC polymer bearing segments.

The bearing carrier is supplied in cylindrical form for permanent chocking or interference fitting into the ship. One end of the carrier is typically flanged to provide means for a positive location to the mating face of the housing.

The COMPAC polymer bearing is made up of segments; the top halves have lubrication grooves while the bottom halves have a smooth bore. The number of segments required per carrier is dependent upon the length and diameter of the bearing.

A single axial key provides the interference to retain the COMPAC bearing segments in the carrier. The key is split with a taper. The bottom half is bolted to the carrier and the top half is removable allowing easy extraction of the bearing without removing the shaft.

Retaining rings are bolted at the outer end of the carrier to prevent any possible axial movement of the bearing segments.



PRINCIPLE OF OPERATION

The bearings are designed using hydrodynamic theory. The smooth bore in the bottom half of the bearing allows, at lower shaft speeds, the quick development of a fluid film between the shaft and the bearing. Thus the bearings can operate more quietly and effectively at lower revolutions per minute. The Thordon COMPAC polymer bearings have inherent self-lubricating properties facilitating lower startup torques.

The bearings are cooled by a flow of water over the bearing surface. Pumped lubrication flow is recommended and the minimum recommended lubrication flow rate is 0.15 litres per minute per millimetre of shaft diameter. If pumped water lubrication is not provided such as in a strut bearing, the forward motion of the vessel must provide sufficient water flow to the bearings.

The elastomeric nature of the bearing also allows for the passage of abrasive particles through the bearing without causing excessive wear to the shaft.

Note: Shaft liners in way of bearings should be clean and smooth (0.8 µm surface finish) for optimum performance.

The bearings are retained in the bearing carrier by an interference force between the bearing and the carrier developed by fitting of the key. Removing the key releases the interference force allowing for easy removal of the bearing segments.

BREAK-IN OF NEW BEARINGS

A new bearing supplied from the factory or a replacement bearing machined on site will have machining marks on the wear surface.

During initial operation of the shaft, the peaks of the machining marks will be worn away and a smooth surface will be generated. This is normally accomplished during commissioning of the propulsion system on new ships and initial manoeuvring on existing ships.

For commissioning procedure, please refer to the "Generic Commissioning Procedure" attached at end of this document in Appendix A.

APPENDIX 1 COMPAC INSTALLATION

BEARING CARE & MAINTENANCE AFTER FITTING

To maximize bearing life and bearing performance, routine bearing maintenance and care should be undertaken.

Where a vessel is idle for periods lasting longer than two days, good marine practice is to slowly rotate the shaft on turning gear for 2 revolutions every 1-2 days to dislodge marine growth and salt deposits on journal surfaces.

Shaft surface roughness should be maintained at less than 1.6 micro-metres (63 micro-inches) Ra to prevent accelerated bearing wear.

CARRIER INSTALLATION INSTRUCTIONS

The carriers are designed to either be chocked or press fit into the bearing housing provided in the ship structure (stern tube, strut, or other.)

The carriers and bearings are shipped from the Thordon factory on cradles in wooden crates. All parts are finish machined, ready for installation, unless otherwise directed.

KEY AND BEARING INSTALLATION (SHAFT REMOVED)

The fixed key, lower half, is bolted into the required position in the carrier.

Place the beginning end of the removable key (thinnest end of the key) on the fixed key. Press the key into position using hand pressure. A non-metallic 5 kg mallet hammer may be required to tap the key into the position.

The COMPAC polymer bearing segments are delivered to the shipyard in a fully machined state ready for installation in the metallic carriers.

Note: COMPAC bearing segments are to be installed only after Chocking of the bronze carriers is complete

The recommended method to cool the bearing segments is using liquid nitrogen. To accomplish this, a holding tank as illustrated in Figure 1 should be used.

Note: COMPAC bearing grooves are to be on top half only.

Place one segment at a time in the tank and leave the segment in the tank for approximately 20 minutes or until the liquid nitrogen stops boiling. It is recommended that the bottom halves of the bearing are cooled first and fit in the carrier followed by the top halves. In lieu of liquid nitrogen, dry ice can be used as a cooling medium to cool the bearing segments

Slide the frozen bearing segments into the carrier starting with the bottom segments then slide the top halves in ensuring that the top and bottom segments are aligned.

Care must be taken to ensure that the segments are installed in the correct order making sure that:

- The lubrication grooves are on the top of the bearings
- The circumferential grooves are positioned towards the centre of the bearing

Install the retaining ring and retaining ring screws onto the carrier. Tighten the screws to the torque recommended on the arrangement drawing.

WARNING:

Nitrogen, although not a poisonous gas, will displace air and if the work is being conducted in a depressed area, the localized atmosphere may become devoid of oxygen even though the area in general may be well ventilated--adequate precautions must be observed to preserve personnel safety regarding oxygen depletion and the low temperature of the coolant.

KEY AND BEARING INSTALLATION (SHAFT INSTALLED)

Place the beginning end of the removable key (thinnest end of the key) on the fixed key. Press the key into position using hand pressure. A non-metallic 5 kg mallet hammer may be required to tap the key into the position.

Leave approximately 150 to 160 mm of the end of the key out and proceed to install the COMPAC bearing segments as detailed below.

With the shaft centered in the carrier, install the bottom segments one at a time and slide them into the bearing carrier. The upper edge of the bearing on the key side should be in contact with the stationary section of the key. When the bottom segments are fully in, the shaft should be lowered to allow insertion of the top segments. Each segment in turn is rested on the shaft and slid into the housing.

When all segments are fully inserted, the Extractor Rod is removed from the extraction tool and the extraction tool is threaded into the mounting holes in the housing. The Extractor Bar is positioned to allow the fitting of a hydraulic cylinder between the end of the key and the Extractor Bar. The hydraulic cylinder is pressurized pushing the key fully into the housing.

Install the retaining ring and screws and tighten in accordance with torques specified on the drawing.

COMPAC INSTALLATION APPENDIX 1

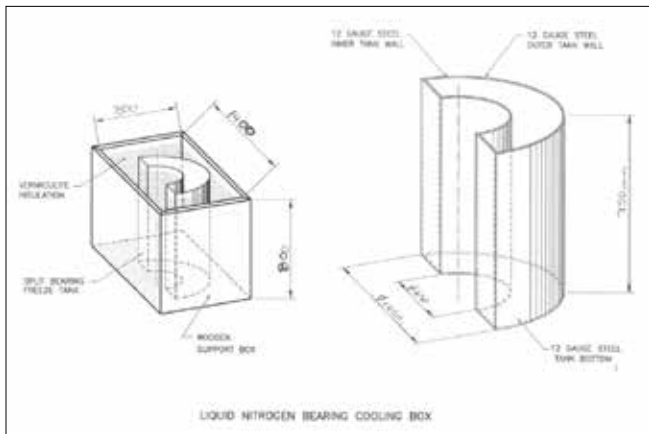


Figure 1. Dimensions are typical - vary to suit size of actual bearing segments being cooled

REMOVAL OF COMPAC BEARING SEGMENTS (SHAFT INSTALLED)

Key Removal

Centre the shaft in the bearing by lifting with block and tackle or other suitable securing method so that the shaft is no longer contacting the bearing.

Remove the retaining ring bolts and retaining ring. Store for re-installation later.

Remove the Wear Down Gauge, as it will impede the removal of the bearing.

Attach the key extraction tool supplied by Thordon Bearings shown in Figure 2. The tool must be firmly attached to the key. Place the cross bar on the adjustable rods so that it is extended from the key as far as possible, while still allowing for a minimum 25 mm engagement of the Extractor Nut over the Extractor Rod (puller) Figure 3.

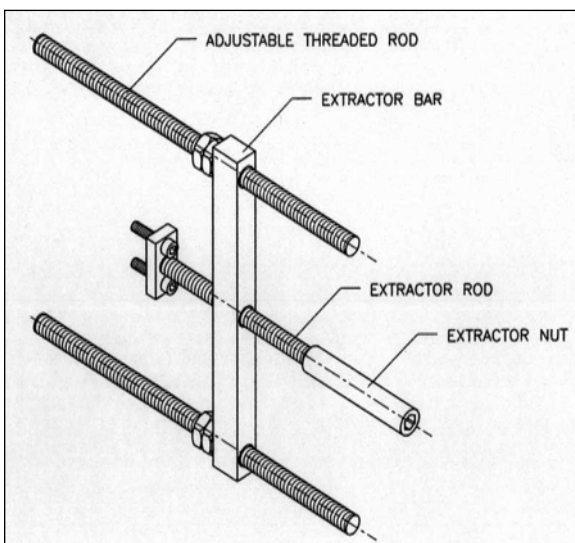


Figure 2. Illustration of the extractor key tool

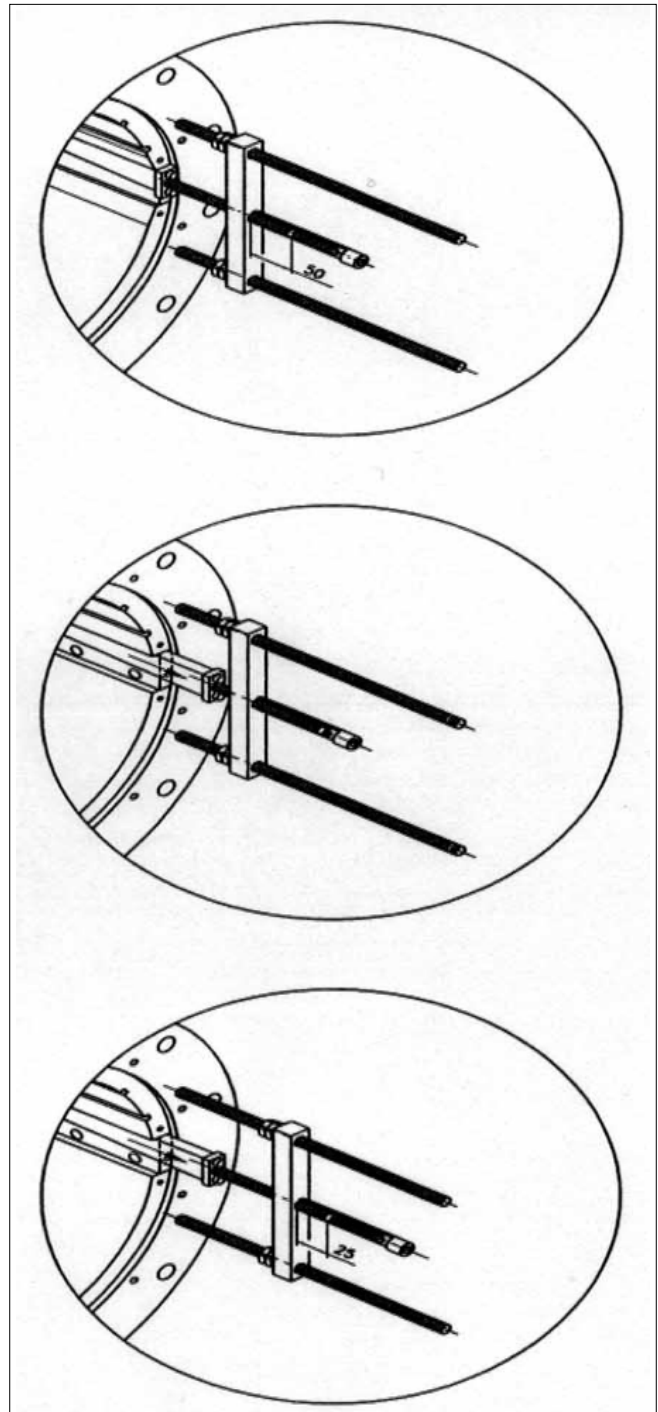


Figure 3. Extractor tool set up to begin detachable single key extraction.

Using the hex wrench turn the nut onto the puller to increase the nut engagement, which will extract the key.

APPENDIX 1 COMPAC INSTALLATION

When the Extractor Nut has bottomed out on the puller, set up the extraction tool as described in the previous section. Move the nuts outward along the adjustable rods to extend the distance between the crossbar and carrier. Turn the Extractor Nut again until it bottoms out. Repeat the procedure until the key can be removed by hand. Figure 4 illustrates what a typical key extraction procedure looks like.

Store the key for re-installation later. Store the extraction tool for later use.



Figure 4. Single Key removal using key extraction tool

Bearing Removal

Use a J-hook shown in Figure 5 to remove the top half of the bearing. Screw the J-hook to one of the ends of the fully threaded steel rod. The rod should be approximately 1 metre long with M6 thread (or similar).



Figure 5. J-hook and nut used to remove bearing segments (yard supply)

Insert the J-hook rod into the section between the permanent key (attached to the carrier) and the top section of the COMPAC bearing segment. The height of the J-hook is such that there is sufficient clearance to install the J-hook without becoming blocked.

See Figure 6 (below) for a sketch.

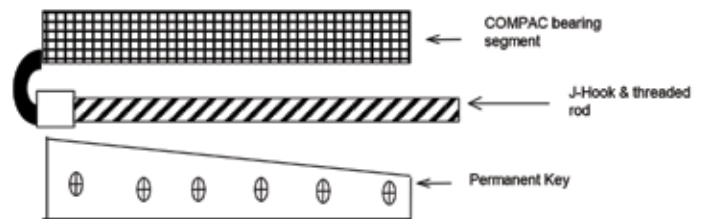


Figure 6. Illustration showing how the J-hook is used to remove COMPAC bearing segments.

Pull the J-hook rod and the COMPAC bearing segment will come out of the carrier. Proceed to remove the bottom section using the same device.

TG-75 EPOXY ADHESIVE INSTRUCTION MANUAL

Surface Preparation

The metal substrate and the Thordon material need to be properly prepared. Poor substrate preparation may result in loss of bond strength and the possibility of the bearings coming loose from their housings during operation.

Metal Preparation

Metal surfaces should be machined not smoother than 3.0 micrometers (125 micro-inches) Ra. The surface should be gritblasted to increase adhesion. For metals exhibiting corrosion, the surface should be clean blast to obtain a Near White Blast clean surface per Standard SSPC-SP No. 10/NACE No.2.

NOTE: Bonding should take place within 2 hours of surface preparation and cleaning. For Aluminum and Stainless Steel, reduce the exposure time to 30 minutes or less, as an oxidation layer may form very quickly in these materials after sandblasting.

The surface to be bonded needs to be cleaned after sandblasting with an organic solvent/degreaser such as Methyl Ethyl Ketone (MEK), isopropyl alcohol, or other equivalent non-residue degreaser, to remove any contamination prior to applying the TG-75 adhesive. Allow the degreaser to completely evaporate without further contamination before bonding. Do not touch the cleaned parts – if the parts need to be handled, use NEW latex gloves to protect the clean surface from contamination caused by oil in skin.

TG-75 Shear Strength for Bonding Thordon SXL and Metals

When bonding to a variety of metal substrates, such as copper, brass, stainless steel, cold rolled steel and aluminum, it is generally observed that TG-75 gives very high bond strength. When TG-75 was used to bond Thordon SXL and several types of metals such as bronze, stainless steel and carbon steel, shear strength level of over 14 MPa (2000 psi) were typically achieved, based on lapshear testing (per ASTM D1002). Typical bond shear strengths for Thordon SXL and metals are found in Table 1.

Material	Avg. Shear Strength (lap joint, ASTM D1002)
Bronze C90500	18.68 MPa (2709 psi)
Stainless Steel 316	19.04 MPa (2762 psi)
Mild Steel 1020	17.01 MPa (2467 psi)

Table 1. Average shear strength for various metal substrates bonded to Thordon SXL with TG-75.

Thordon Surface Preparation

Thordon bearings should be machined before bonding. The surface finish of the Thordon bearing to be bonded should be between 3.0 to 6.0 micrometers (125 to 250 micro-inches) Ra.

It is recommended that the bearing surface be wiped with a cloth or soft paper wetted with a small amount of solvent – ensure that no residue from the paper is left behind. A clean brush can also be used to clean the surface. Allow the solvent to dry completely before applying the adhesive. Note that the Thordon elastomeric bearing should NOT be soaked in the solvent.

APPENDIX 2 TG-75 INSTRUCTION

Mixing Adhesive Components

TG-75 adhesive is a two-part system consisting of an accelerator denoted as "TG-75A" and a resin "TG-75B". These two components should be mixed using the following VOLUME ratio:

Part A to Part B = 1:2

Improper mixing ratios may result in failure of the adhesive to cure (too little accelerator used, adhesive does not harden) or it could cure too quickly (if too much accelerator is used) resulting in significantly reduced curing times.

Temperature of the materials at the time of mixing is also very important for proper performance. For cartridges stored at low temperatures, the cartridge should be allowed to return to room temperature (minimum overnight) PRIOR to mixing of Parts A & B. See Storage section for more information.

Once mixed, the adhesive offers a maximum working time of 60 minutes at 23°C (73°F) and has a viscosity of approximately 50,000 cps. Increases in temperature will reduce the working time or pot life.

TG-75 adhesive is supplied in cartridges containing two tubes (TG-75A and TG-75B). One mixed cartridge yields 450 ml (15.22 US oz.) with typical coverage of 7000 cm² (1085 in.²) at a thickness of 0.25 mm (0.010 in.). Recommended adhesive thickness ranges from 0.25mm to 0.38 mm (0.010 in. to 0.015 in.). Exceeding the recommended adhesive thickness reduces the bond strength. Consult with Thordon Bearings if higher adhesive thickness values must be used.

Dispensing Procedure A – Pneumatic Gun (available from Thordon Bearings)

1. Fully retract the pistons manually: The pneumatic gun must be connected to the airline and the middle rod pulled back until the pistons are fully retracted.
2. Insert the cartridge assembly: Place the open end of the cartridge assembly over the piston pads. Be careful to align the pads in the centre of the cartridge plungers. If the pistons are not centred, the plungers may flip or be pushed unevenly resulting in improper mixing and leaking. Snap the front end of the cartridge assembly into position at the front of the gun. Manually push the piston forward until they bottom out against the inside of the cartridge plungers. See Figure 1.

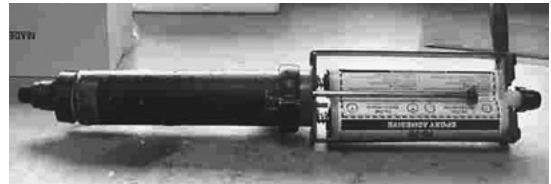


Figure 1: TG-75 cartridge properly inserted into pneumatic gun.

3. Phase the cartridge: use a pneumatic gun with a maximum pressure of 0.70 MPa (100 psi), turn the regulator knob counterclockwise to the stop. Remove the "D" shaped plugs from the cartridge - see Figure 2.



Figure 2: Plugs for TG-75 cartridge.

Hold the cartridge tips over a disposable surface. Depress the gun trigger and slowly open (turn the regulator knob clockwise) until compound extrudes evenly from the cartridge tips. Release the trigger.

4. Dispensing: open the pressure regulator from the low-pressure setting until the desired flow rate is obtained. The contents of both cylinders should be fully emptied into a disposable container and thoroughly mixed until the colour of the adhesive is completely uniform.

TG-75 INSTRUCTION APPENDIX 2

Dispensing Procedure B – Manual Gun (available from Thordon Bearings)

1. Fully depress the thumb release lever and then retract the piston carriage assembly. See Figure 3.

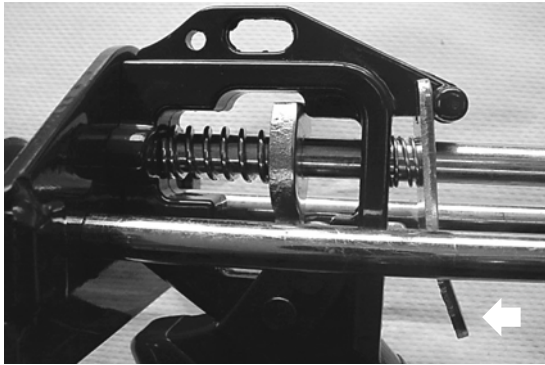


Figure 3: Thumb release lever (see arrow)

2. Insert the cartridge assembly: remove the “D” shaped plugs from the cartridge, keep in a safe place for re-storage. Place the open end of the cartridge assembly over the piston pads. Be careful to align the pads in the centre of the cartridge plungers. See Figure 4.

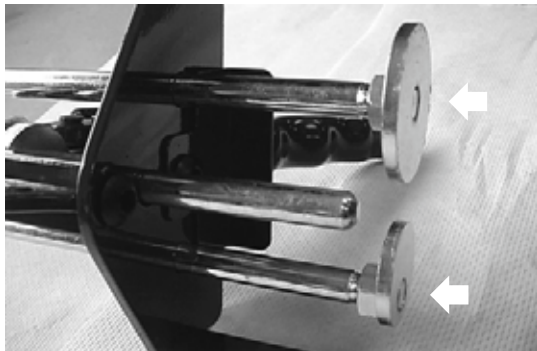


Figure 4: Plungers in manual gun (see arrows)

- If the pistons are not centred, the plungers may flip or be pushed unevenly resulting in improper mixing and leaking. Snap the front end of the cartridge assembly into position at the front of the gun. Manually push the piston forward until they bottom out against the inside of the cartridge plungers.
3. Place the cartridge tips over a disposable surface and squeeze the trigger handle slowly until compound extrudes from both cartridge tips. Release the trigger handle and depress the thumb release lever.
 4. Maintain consistent pressure on the trigger handle and dispense all the contents of the cylinders into a disposable container. Thoroughly mix until the colour of the adhesive is completely uniform.

Adhesive Curing

Provided the material was mixed correctly, the cure time for TG-75 is dependent upon the temperature during the curing period. The recommended curing temperatures for TG-75 are:

- Typical: 20°C to 40°C (68°F to 104°F)
- Minimum: 10°C (50°F)

If TG-75 is applied at temperatures outside the range shown above, please Contact Thordon Bearings for cure times.

Curing Times and Temperature

Over 60% of the bond strength is attained in 8 hours at 23°C (73°F). Approximately 80% of the bond strength is achieved in 4 hours at 40°C (104°F). Full cure is reached in 5 days at 23°C (73°F).

Insufficient curing time, particularly at low temperatures, prior to water immersion will result in reduced bond strength values. Water will stop further curing of the adhesive.

After application of adhesive, keep bearing and carrier assembly at a constant temperature while the adhesive cures.

NOTE: For bearings with large outside diameter (OD) of 250 mm (9.8 in.) and greater, it is important to machine the bearing AND perform the bonding installation at approximately the SAME temperature. Machining the bearing at one temperature and installing it at a different temperature may have significant effects on the optimal adhesive thickness – see the following example.

Example: Effect of Temperature on Adhesive Thickness

A Thordon SXL bearing is machined in the afternoon at 30°C (86°F) to suit a housing ID of 250 mm (9.843 in.).

Based on optimal adhesive thickness, the bearing OD is machined to:

$$250 \text{ mm} - 2 \times 0.25 \text{ mm} = 249.50 \text{ mm} \\ (9.843 \text{ in.} - 2 \times 0.010 \text{ in.} = 9.823 \text{ in.})$$

The bearing is to be installed the next day. However, the shop temperature has increased to 35°C (95°F) on the next day. Using the thermal coefficient of expansion for SXL [21.1×10^{-5} cm/cm/°C (11.7×10^{-5} in./in./°F)] and the temperature difference 5°C (9°F), the bearing OD at 35°C (95°F) has increased to 249.76 mm (9.833 in.).

The adhesive thickness is reduced to 0.12 mm (0.005 in.) with the temperature difference. Such thermal effects are even greater with larger bearings.

APPENDIX 2 TG-75 INSTRUCTION

Adhesive Application

As mentioned previously, for best results it is recommended to conduct the bonding installation at the SAME temperature at which the bearing was machined. In cold weather environments, it is important to maintain the temperature above 10°C (50°F) for proper curing of the adhesive.

Split Bearings or Flat Surfaces

1. Apply masking or painters tape to metal edges and ends where adhesive will not be required. Apply the adhesive to the prepared surface of the metal and bearing O.D. spreading evenly with a spatula or a small notched trowel. See Figures 5 and 6.



Figure 5: Adhesive applied to split metal housing.

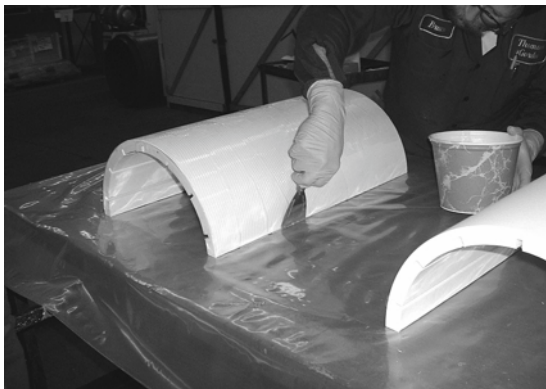


Figure 6: TG-75 applied to OD of split SXL bearing.

2. Position the Thordon component and clamp so that a small amount of the adhesive is extruded out from the edges of the Thordon part. See Figure 7. Do not machine or handle the bonded piece for a minimum of 8 hours at 23°C (73°F). Avoid smearing the adhesive during assembly. Wipe off any excess adhesive from the tape for easy tape removal once the adhesive has cured.



Figure 7: Clamping SXL, with slight force, to metal housing.

Cylindrical Bearings

1. The bearing should be sized to allow for a 0.25 mm to 0.38 mm (0.010 in. to 0.015 in.) adhesive thickness. This is an allowance of 0.50 mm to 0.76 mm (0.020 in. to 0.030 in.) on the outside diameter. TG-75 will fill gaps up to a thickness of 3.0 mm (0.125 in.) but the shear strength of the adhesive decreases at thickness over 0.6 mm (0.025 in.).
2. Apply the adhesive to both the metal and Thordon. Spread evenly with a spatula or small notched trowel.
3. Slide the bearing into the housing. Slight rotation of the bearing can help homogenize the adhesive layer, but do not use excessive back-and-forth movements as this could induce the creation of air bubbles within the layer.
4. Spacers can be used in situations where the bearing cannot be held concentrically with the housing and uneven adhesive thickness is an issue. Glass beads and metal shims and wire can be used to ensure an even thickness throughout the circumference – see Figure 8 for suggested set up.

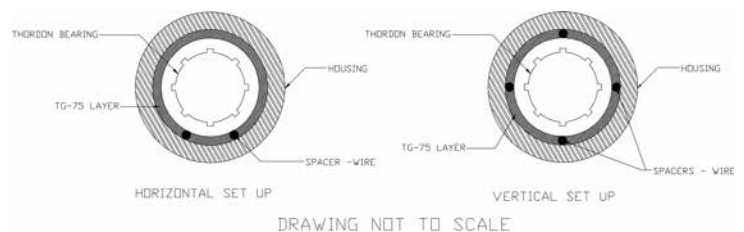


Figure 8: Wire used to keep bearing concentric in housing.

Note: drawing not to scale.

Troubleshooting

1. If compound bypasses the plungers and leaks from the backside of the cartridges, check that the plungers are seated squarely against the cartridge plungers.
2. If the compound leaks around the retaining nut, ensure that the nut is not cross-threaded and tighten it further.
3. The dispensed compound must be consistent in colour.

Clean Up

Scrape off excess adhesive with a trowel, then clean surface with a dry cloth to carefully remove the remainder of the adhesive from the bonded assembly edges.

Storage of TG-75 & Shelf Life

TG-75 cartridges can be stored at room temperature, approx. 20°C (68°F), with a shelf life of 15 months from time of delivery. To increase the shelf life of the material, the cartridges can be placed in a fridge or freezer. The lower temperature increases the shelf life of the unmixed components to 30 months from time of delivery.

Storage at lower temperatures, -10°C to -20°C (14°F to -4°F) may cause the adhesive to crystallize or solidify, giving the product the appearance of a hazy liquid or waxy semi-solid. Crystallization is not an indication of material problems and does not affect the performance of the material. However, crystallization **MUST** be reversed before usage, otherwise Parts A and B should not be mixed.

This crystallization phenomenon is reversible by bringing the materials back to room temperature. If time permits, allow the material to warm up naturally overnight. Gentle warming (no direct heat or flame) of the cartridge and its contents is acceptable. Bring the cartridge to 50°C (120°F) for approximately 30 minutes. Allow to cool back to room temperature prior to use.

NOTES:

- *TG-75 does not contain volatile photochemical reactive solvents.*
- *Produced CFC free.*
- *MSDS available upon request*

LIMITED WARRANTY AND LIMITATION OF LIABILITY FOR THORDON BEARINGS INC. ('TBI')

- a. **Basic Terms.** TBI provides a limited warranty on the Goods of its own manufacture sold by it to the Buyer thereof, against defects of material and workmanship (the "Limited Warranty").
- b. **Coverage.** This Limited Warranty covers the repair or replacement or the refund of the purchase price, as TBI may elect, of any defective products regarding which, upon discovery of the defect, the Buyer has given immediate written notice. TBI does NOT warrant the merchantability of its product and does NOT make any warranty express or implied other than the warranty contained herein.
- c. **Third Party Products.** Accessories, equipment and parts not manufactured by TBI are warranted or otherwise guaranteed only to the extent and in the manner warranted or guaranteed to TBI by the actual manufacturer, and then only to the extent TBI is able to enforce such warranty or guarantee.
- d. **Limited Liability.** TBI's liability for any and all claims, damages, losses and injuries arising out of or relating to its performance or breach of any contract of sale of goods and the manufacture, sale delivery, re-sale, repair, or use of any goods, shall NOT exceed the agreed price of such Goods. The Buyer's remedy shall be at TBI's option, the replacement or repair of the Goods. This shall be the Buyer's sole, exclusive and only remedy against TBI.
- IN NO EVENT SHALL TBI BE LIABLE FOR INCIDENTAL, SPECIAL OR CONSEQUENTIAL DAMAGES, INCLUDING BUT NOT LIMITED TO LOSS OF PROFITS, BUSINESS, GOODWILL, INCURRING OF MACHINERY DOWNTIME, DESTRUCTION OR LOSS OF ANY CAPITAL GOODS, LIABILITY FOR PERSONAL INJURY, DEATH, PROPERTY DAMAGE AND ANY OTHER TYPE OF DAMAGES WHETHER SIMILAR TO OR DIFFERENT FROM THIS LISTING.
- e. **Latent Defects.** In cases of defects in materials or workmanship or defects arising from the selection of material or processes of manufacturer, such defects must be apparent in the Goods within three (3) months, after delivery and acceptance of the Goods to the Buyer.
- f. **Exclusions.** TBI shall, as to each aforesaid defect, be relieved of all obligations and liability under this Limited Warranty if:
1. The Goods are operated with any accessory, equipment or part not specifically approved by TBI and not manufactured by TBI or to TBI's design and specifications, unless the Buyer furnishes reasonable evidence that such installation was not a cause of the defect; provided, that this provision shall not apply to any accessory, equipment or part, the use of which does not affect the safety of the Goods;
 2. The Goods shall not be operated or maintained in accordance with TBI's written instructions as delivered to the Buyer, at any time or from time to time, unless the Buyer furnishes reasonable evidence that such operation or maintenance was not a cause of the defect;
 3. The Goods shall not be operated or maintained under normal industry use, unless the Buyer furnishes reasonable evidence that such operation was not a cause of the defect;
 4. The Goods shall have been repaired, altered or modified without TBI's written approval or, if the Goods shall have been operated subsequent to its involvement in an accident or breakdown, unless the Buyer furnishes reasonable evidence that such repair, alteration, modification, operation, accident or breakdown was not a cause of the defect; provided, however, that this limitation insofar as it relates to repairs, accidents and breakdowns, shall NOT be applicable to routine repairs or replacements or minor accidents or minor breakdowns which normally occur in the operation of a machine, if such repairs or replacements are made with suitable materials and according to standard practice and engineering;
 5. The Buyer does not submit reasonable proof to TBI that the defect is due to a material embraced within TBI's Limited Warranty hereunder.
- g. **Warranty Term.** This Limited Warranty made by TBI contained in these Terms and Conditions, or contained in any document given in order to carry out the transactions contemplated hereby, shall continue in full force and effect for the benefit of the Buyer, save and except, no warranty claim may be made or brought by the Buyer after the date which is twelve (12) months following delivery and acceptance of the Goods pursuant to this Contract.
- h. **Expiration and Release.** After the expiration of this Limited Warranty's period of time, as aforesaid, TBI shall be released from all obligations and liabilities in respect of such warranty made by TBI and contained in this Contract or in any document given in order to carry out the transactions contemplated hereby.

CUSTOMER FOCUSED TO SUPPORT YOUR IMMEDIATE AND FUTURE NEEDS

Supply and Service

Geared to provide quick response to customer needs, Thordon Bearings understands the importance of fast delivery and reduced down time. Thordon marine and industrial bearings can be designed, produced to the exact requirements of the customer and shipped quickly.

Distribution

With Thordon bearings and seals specified all around the world, an extensive distribution network has been established in over 100 countries. Inventories of common bearing sizes are stocked by local Thordon Distributors and are backed up by large regional and head office Thordon stocks.

Application Engineering

Thordon Bearing's engineers work closely with customers to provide innovative bearing system designs that meet or exceed the technical requirements of the application.

Manufacturing

Thordon's modern polymer processing facility is staffed with experienced and dedicated employees. Bearings up to 2.2 m (86") in diameter have been supplied and bearings up to 1.5 m (60") O.D. can be machined in-house.

Quality

Thordon Bearings Inc. is a Canadian company manufacturing to ISO 9001 Quality System requirements.

With over 40 years experience in polymer bearing design, application engineering and manufacturing, Thordon marine and industrial bearings are recognized worldwide for both quality and performance.

Research and Development

Thordon bearings are being continuously tested by our Bearing Test Facility. The Facility evaluates new designs and applications before they are put into service. Ongoing testing not only allows for design refinements, but ensures quality and performance after installation. Our polymer laboratory evaluates new and modified polymers in a continuing quest to improve Thordon bearing performance and searches for new polymer bearing solutions.

Your Authorized Thordon Distributor

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