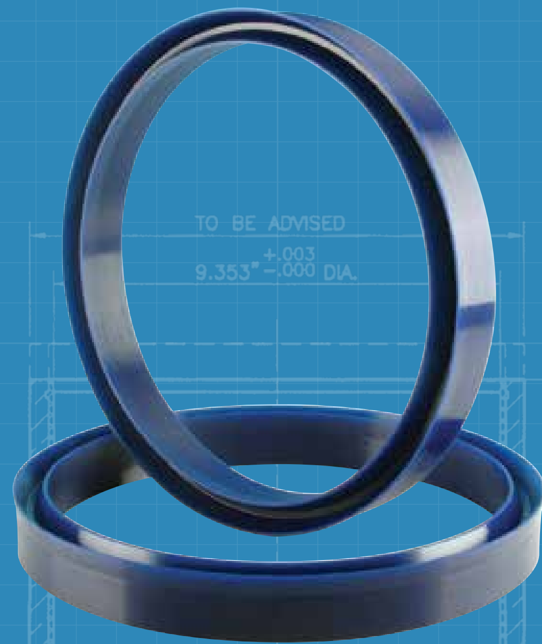
Thorseal

ENGINEERING MANUAL

Version: 2024.1

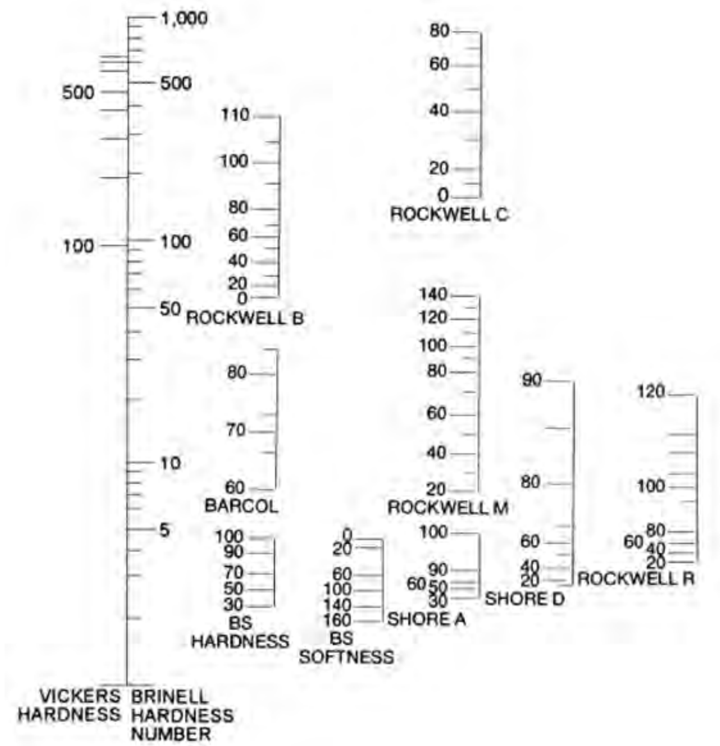


THORDON

SYMBOLS AND UNITS

			Units	
			Metric	Imperial
C_t	=	Thermal Expansion Allowance	mm	inches
C_s	=	Absorption Allowance	mm	inches
d	=	Shaft Diameter	mm	inches
E_o	=	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
T_a	=	Machine Shop Ambient Temperature (Nominally 21°C (70°F))	°C	°F
T_o	=	Operating Temperature	°C	°F
W.T.	=	Wall Thickness of Bearing	mm	inches
α	=	Coefficient of Thermal Expansion	$°C^{-1}$	$°F^{-1}$
μ	=	Coefficient of Friction	-	-
V	=	Velocity	m/sec.	ft./min.
γ	=	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.)
- Mass
  - 1 Kilogram (kg) = 2.205 lbs.
- Force
  - 1 Newton (N) = 0.2248 lbs.
- Pressure
  - * 1 kg/cm^2 = 14.223 psi ($lbs./in.^2$)
  - ** 1 Mega Pascal (MPa) = 145 psi ($lbs./in.^2$)
  - 1 N/mm^2 = 145 psi ($lbs./in.^2$) = 1 MPa
  - 1 MPa = 10.197 kgf/cm^2
  - 1 Bar = 1.0197 kgf/cm^2
  - 1 Mega Pascal (MPa) = 10 Bar

* *Kilo* = *1,000*
** *Mega* = *1,000,000*

OTHER THORDON TECHNICAL INFORMATION AVAILABLE

a. Thordon Marine Bearing Installation Manual

b. ThorPlas® Bearings Engineering Manual

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

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HYDRAULIC & PNEUMATIC SEALING TECHNOLOGY

1.0 INTRODUCTION TO HYDRAULIC & PNEUMATIC SEALING

1.1 Introduction

To better understand hydraulic and pneumatic sealing it it useful to review the complete range of both static and dynamic sealing technology. The diagram below illustrates the complete range of seal technology and the typical components used in various hydraulic and pneumatic applications. (Figure 1)

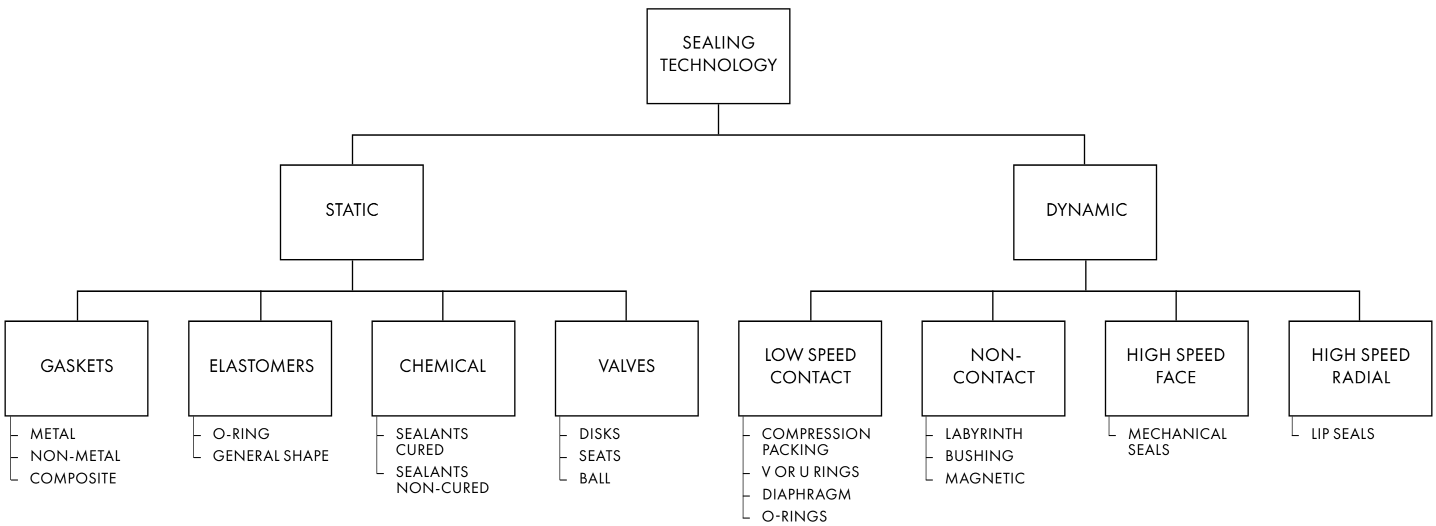


Figure 1

In most applications, hydraulic and pneumatic systems use a combination of both static and dynamic seals.
With the advanced polymers currently available, the static and dynamic sealing can both be performed by the same seal.

1.2 Hydraulic and Pneumatic Sealing

The successful operation of hydraulic or pneumatic equipment is dependent on the effectiveness of the seals. The varied operating conditions in which both hydraulic and pneumatic cylinders have function necessitates careful selection of seals and wipers to suit the application. The seal design and material composition must both be optimized to the specific requirements of the application.

The most common seals in hydraulic or pneumatic applications are O-rings. O-rings are primarily used for static and low speed dynamic sealing. In slow speed applications O-rings operate best when external lubricants are present. O-rings are also used as a resilient component to energize the seal lips in some V or U seal designs where the actual seal material is not resilient enough. O-rings are usually made from nitrile or Buna rubber, exhibit low lubricity and high static and dynamic dry co-efficients of friction.

This results in additional drag force in the cylinder requiring additional power to overcome the higher friction. Although elastomeric O-rings typically provide good resistance to wear, care must be taken when they are specified in dynamic applications because the higher friction usually translates into higher wear rates.

Special elastomers, such as Thorseal, offer a highly resilient, tough, long wearing, polymer alloy enhanced with a special low friction additive. Thorseals provide excellent wear life in both static and dynamic applications. Standard size Thorseals are all molded to size. Special sizes are molded or precision machined depending on the quantities. Thorseal sizes range from less than 3/4" (2cm) diameter to large 100" (254cm) diameter seals which can be machined from a molded tube.

1.3 Typical Hydraulic System

A typical hydraulic system consists of a tank to hold the hydraulic fluid, a strainer and filter, a motor and pump, a non-return valve and pressure regulator, a directional valve, and hydraulic cylinders. These are assembled as shown in Figure 2.

The volume of oil in the hydraulic tank is designed to ensure that the oil does not overheat during operation.

In some cases a cooler may be needed. The strainer and the filter are designed to keep contaminates out of the system. The motor and pump feed the system with oil at a designed flow rate, the non return valve controls the flow direction, and the pressure regulator limits the operating pressure in the system. The directional valves are used to direct the flow of oil to either side of the double acting cylinder. The oil from the opposite side of the cylinder flows back to the tank. The total system must be pressure tight and free from air in order to perform as designed.

1.4 Typical Pneumatic System

A typical pneumatic system is similar to a typical hydraulic system except the pump, motor and tank are replaced by a compressed air system. All other components are required except that they are designed to operate with air and not hydraulic oil. Figure 3 shows a typical pneumatic system.

1.5 Cylinder Designs

The type of seal used in a hydraulic or pneumatic cylinder varies depending on its location, the operating conditions and the external environmental conditions. The following descriptions and detailed drawings show Thorseal sealing options for both a typical single or double acting cylinder and the use of wipers to keep contamination out of the cylinder.

Figure 4 shows a cross section of a typical hydraulic and pneumatic cylinder with all static and dynamic seal locations. In the double acting cylinder, two seals are used on the piston and face in opposite directions. One seal resists the pressure as the piston moves in one direction and the other seal resists the pressure on the return stroke. In a single acting cylinder there is one seal on the piston, which resists the pressure from one direction. A spring, or gravity, returns the rod back to its original location when the pressure is released. The static O-ring seal between the rod and the piston is to prevent leakage from one side of the piston to the other. The gland also has a static O-ring seal that contacts the cylinder shell and prevents oil leakage from the cylinder. The seal around the shaft prevents leakage, and a wiper or scraper, or both, prevent the ingress of external contaminates. The size of the seal is determined by the diameters of the piston and rams as well as the specific requirements of the application. The height of the seal is generally greater than the cross section.

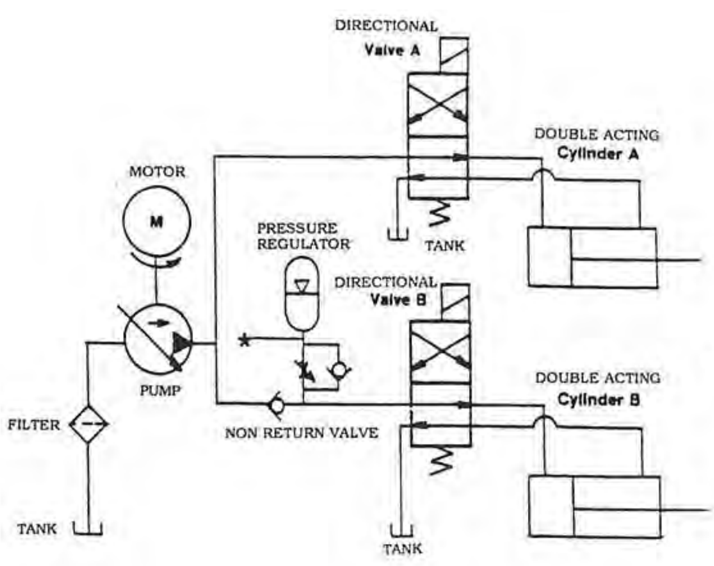


Figure 2

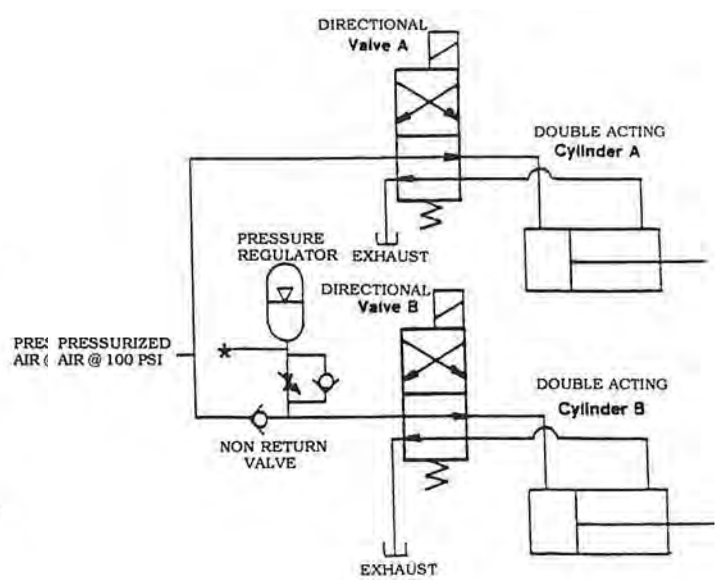


Figure 3

CROSS SECTION OF A TYPICAL HYDRAULIC AND PNEUMATIC CYLINDER

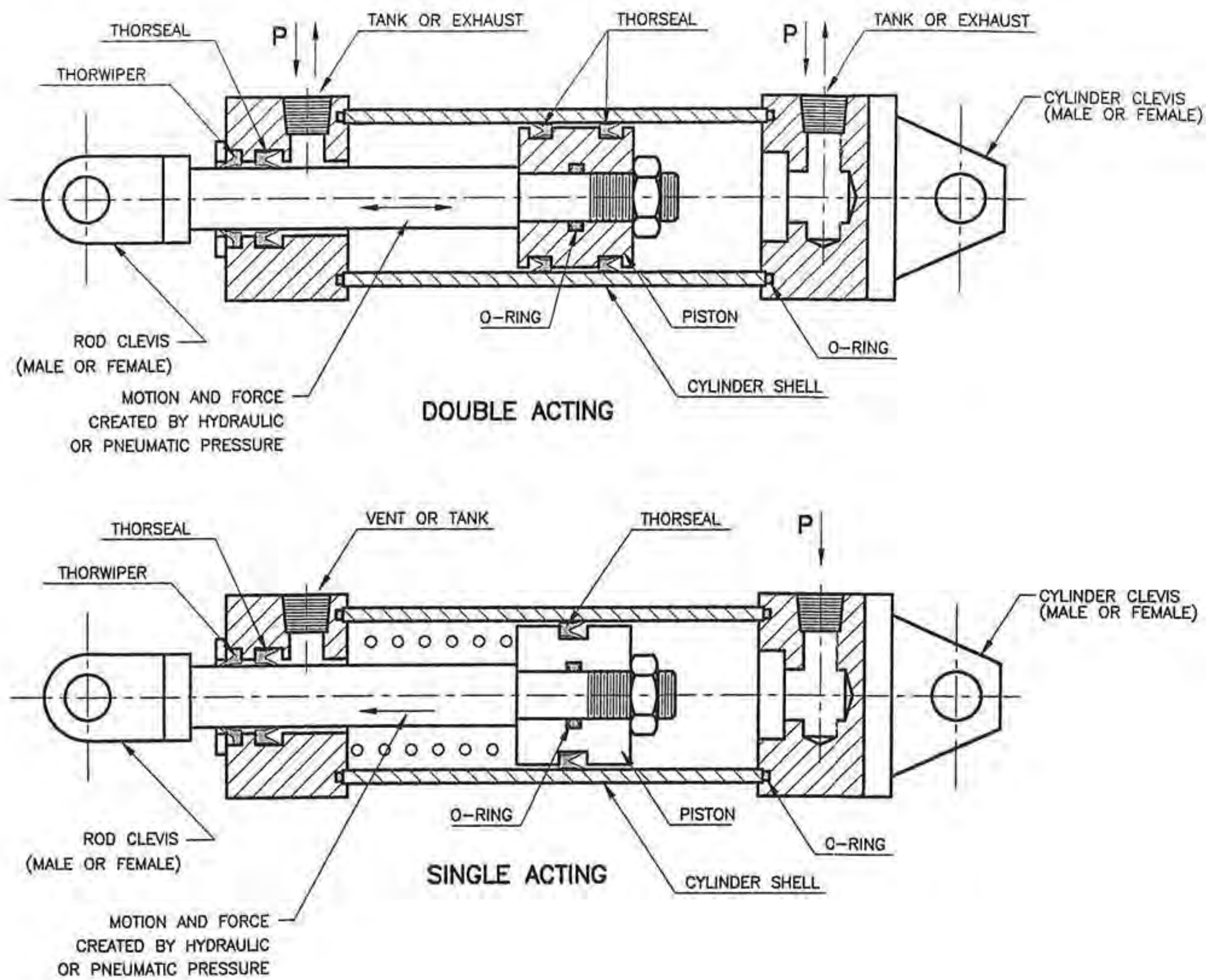


Figure 4

2.0 THORSEAL PRODUCT RANGE

2.1 Introduction

Thorseal is a molded, polymer U-packing uniquely designed for hydraulic and pneumatic applications.

Thorseals are designed to suit either piston or gland mounted applications. Positive sealing over a wide range of operating pressures and simplicity of design are two of the key elements of the Thorseal design.

Thorseals rely on their resilience or elastomeric ability to maintain an effective sealing force between the two sealing surfaces under low system pressure. Thorseal products feature a unique flared lip design allowing them to operate with greater interference than many competitive products. As the system pressure increases during cylinder operation, the sealing force on the seal lip also increases to prevent leakage.

Thorseals' superior wearlife is a result of the high tensile strength, toughness and flexibility properties of the unique polymer unused to formulate Thorseal. All Thorseal products are produced under quality procedures certified to the ISO 9001:2000 Quality System. Thorseals can be supplied in diameters up to 100" (254cm).

2.2 Thorseal Single Rings

Thorseal single ring seals perform both a static and dynamic sealing function. The static seal is positioned against surfaces where there is no motion and the dynamic sealing is performed against the sliding surface. Thorseals are designed to suit each of these conditions and are specified for reciprocating rods, rams or pistons and fixed glands or stuffing boxes. Often used to replace nested V-ring packing sets, Thorseal rings require no axial compression or periodic adjustment and do not require spacer rings.

A typical Thorseal single ring is shown in Figure 5.

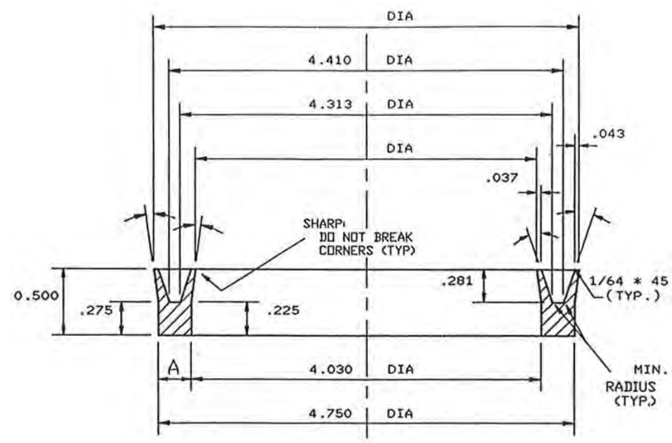


Figure 5

2.3 Thorwiper

Thorwiper is a wiper designed to keep the rod clean and prevent dirt and abrasives from entering and contaminating the hydraulic or pneumatic system, or damaging the Thorseal. The Thorwiper has a molded lip that is rigid enough to wipe contaminates from the rod but flexible enough to conform to rods that wander. A typical Thorwiper is shown in Figure 6.

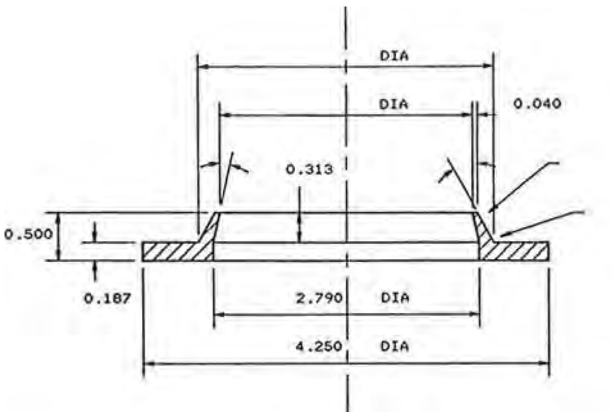


Figure 6

2.4 Thorcup Piston Cups

Thorcup seals are designed for reciprocating pistons using a metallic disc centre plate molded into the base to ensure accurate centering and prevent failures caused by distortion and heel wear. The centre hole can be modified to suit any ram size. A typical single acting Thorcup is shown in Figure 7.

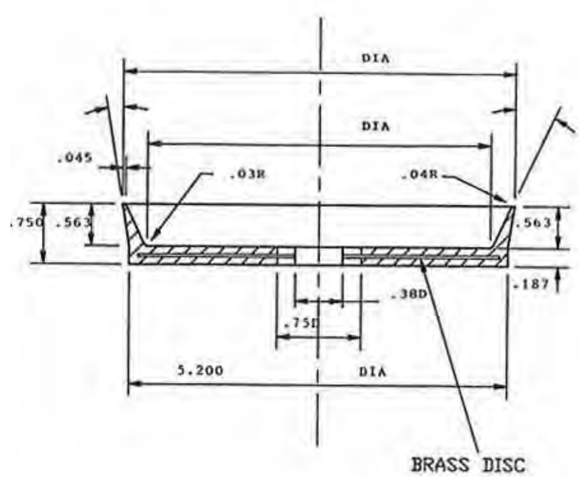


Figure 7

2.5 Thorpak Multiple Ring V-sets

Thorpak is a set of molded, nested V-rings with a top and bottom adapter for use in a stuffing box assembly. Unlike conventional V-set packings, Thorpak contains more sealing rings per inch(mm) of depth resulting in superior sealing ability to minimize leakage. Thorpak seals can be supplied in a split configuration in order to simplify the assembly. Solid rings are also available. A typical Thorpak set is shown in Figures 8, 9, and 10; An assembled set is shown in Figure 10B. Thorpak seals can also be precision machined from stock Thorseal tubes to suit special sizes or low volume specialized seal requirements. Machined Thorpak seal sets offer all the performance advantages of molded v-ring sets while allowing more flexibility in sizing when molds are not practical due to cost or lead time.

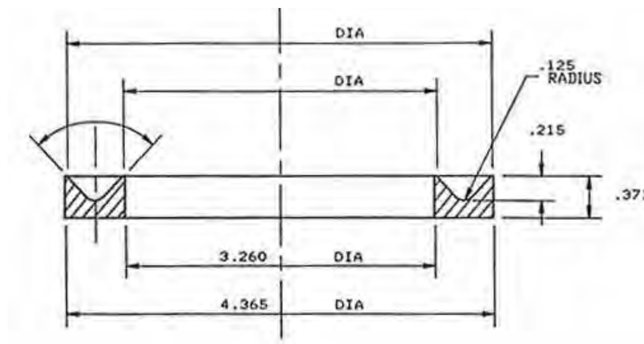


Figure 8 - Adapter

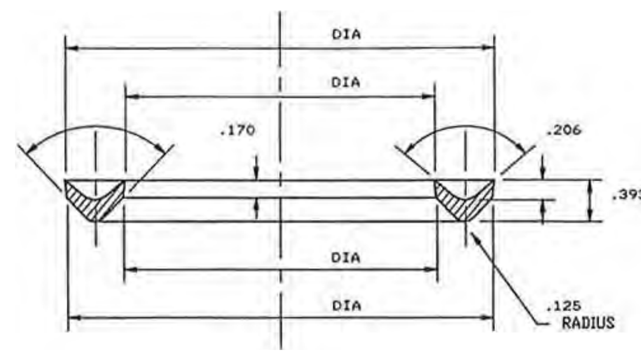


Figure 9 - Sealing Ring

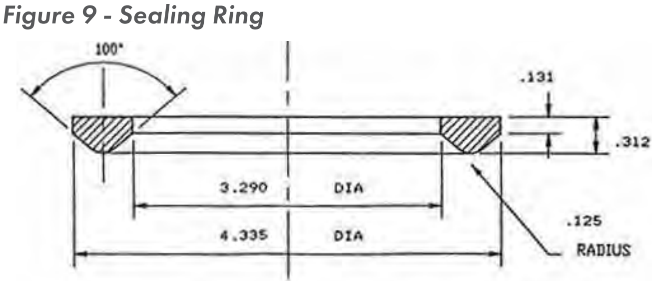


Figure 10 - Bottom Adapter

THORSEAL PRODUCT RANGE

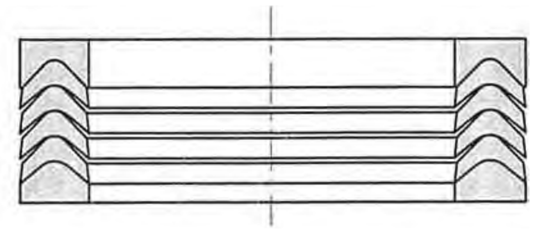


Figure 10B - Assembled Thorpak

2.6 Flexlip Family of Seals

Flexlip seals include all the various "Thorseal" family of products that are not molded, but are machined to size. The design and sizes are identical to the molded products but they are machined because of the small quantities, or the small or large sizes required. The same Thorseal polymer is used, but produced in tube or rod form to facilitate precision machining. Flexlip offers all the performance advantages of our standard family of molded seals in sizes up to 100" (254cm) in diameter. A typical Flexlip seal is shown in Figure 11.

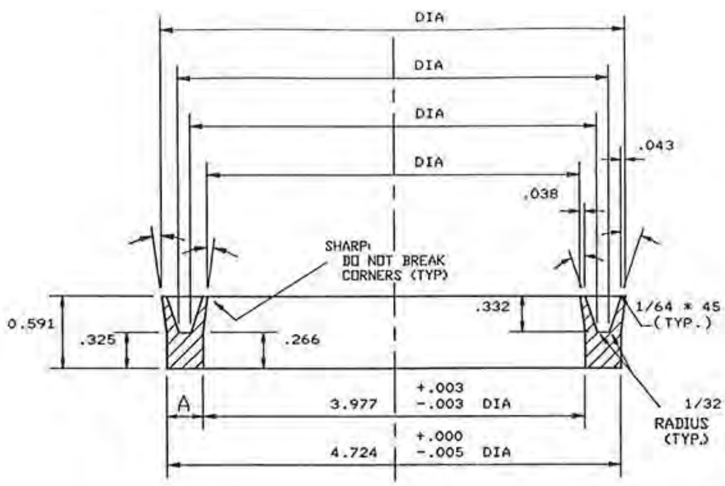


Figure 11

3.0 PHYSICAL PROPERTIES

PHYSICAL PROPERTIES OF THORSEAL MATERIALS

Thorseal Polymer Physical Properties	Standard Thorseal	
Operating Pressure	0 to 15,000 psi	0 to 103 MPa
Operating Temperature	-60°F to 195°F	-50°C to 85°C
Tensile Strength	7,100 psi	49.0 MPa
Hardness - Shore A	95	95
Tensile Modulus at 100% Extension	2,300 psi	15.9 MPa
Tensile Modulus at 300% Extension	5,800 psi	40.0 MPa
Elongation at Break	400%	400%
Tear Strength - Die C	700 lb/in	122.5 KN/m
Compression Set - Method B, 22 hours at 158°F (70°C)	40%	40%
Abrasion Resistance NBS Index	300	300
Abrasion Resistance 5,000 Cycles @ GRM/1,000	18 GRM	18 GRM
Torsional Stiffness - Clash-Berg Method at 75°F (24°C)	2,400 psi	16.8 MPa

Chart 1

3.1 Ideal Properties of a Seal Material

To optimize the sealing qualities of a hydraulic or pneumatic V or U-ring seal, the seal should have the following properties:

- Easily conforms with the sealing surfaces in order to prevent leakage.
- Possesses the memory and flexibility to retain an effective sealing force between the sealing surfaces over a long period of time.
- Demonstrates excellent sliding wear resistance at the required pressures and stroke, over a long period of time.
- Demonstrates excellent fluid and chemical compatibility over the required temperature and pressure range.
- Has a low static and dynamic coefficient of friction over the required pressure range and stroke movement.
- Installs easily without being damaged.
- Provides extended service life reducing life cycle costs.
- Offers good resistance to abrasion where necessary.
- Performs well at high pressures.

3.2 Physical Properties of Thorseal

The unique Thorseal polymer alloys have been specifically developed to suit the sealing requirements of hydraulic and pneumatic applications. The following section deals with both the tribology and physical properties of the Thorseal polymer. As shown in Chart 1, the physical properties of Thorseal materials contribute to their excellent sealing qualities.

3.2.1 Tensile Strength

The tensile strength of Thorseal at 7,100 psi (49 MPa) is much higher than other elastomeric materials commonly used for seals as shown in Chart 2. High tensile stress results in better dimensional stability under high pressure and prevents extrusion.

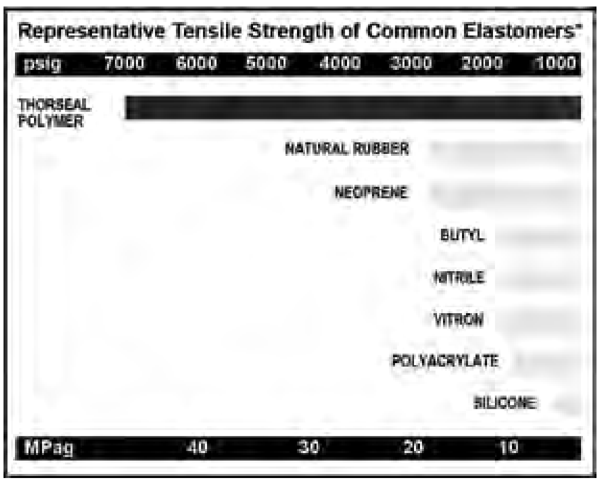


Chart 2

3.2.2 Elongation

Maximum elongation is over 400% giving the Thorseal polymers very high resilience. Fast recovery after removal of the load is essential for a seal to prevent leakage in harsh environments. Thorseal's high tensile strength combined with high ultimate elongation results in very high toughness compared to other elastomers.

3.2.3 Tensile Modulus

A high tensile modulus confirms the toughness of the material throughout the stress-strain curve ensuring excellent sealing at lower pressures where initial lip deflection must prevent oil or air leakage.

3.2.4 Abrasion Resistance

The Thorseal polymer's high toughness contributes to its excellent resistance to abrasion allowing it to perform well in severe abrasive conditions where other materials tend to wear or cut very quickly. This results in increased service life under these operating conditions.

3.2.5 Compression Set and Creep

The low compression set of the Thorseal polymers allow the seal to maintain its effective sealing ability in actual operation. Low creep ensures the Thorseal's effectiveness over time and throughout the operating temperature range of the system.

3.2.6 Hardness

Hardness measures the stress/strain relationship of an elastomer at small deflections. The Thorseal polymers offer a unique balance of wear life and strength with a Shore Hardness of 95A. Other elastomers commonly used for seals are significantly softer falling in a range from 30A to 90A.

3.2.7 Shock Resistance

The Thorseal polymers exhibit good shock resistance due to the combination of high tensile strength and ultimate elongation, allowing them to absorb shock loads without damage.

3.2.8 Coefficient of Friction

In actual field operation, the coefficient of friction depends largely on the operating conditions and environment.

In laboratory tests the Thorseal coefficient of friction ranges from 0.15 to 0.25. In an actual installation where there is oil present the value is much lower. Thorseals are self-lubricating due to the built-in lubricant which is part of the homogenous structure of the polymer.

3.2.9 Torsional Stiffness

Thorseal's high torsional stiffness prevents it from being twisted in operation resulting in a more effective seal. Thorseal's cross sectional design is also proportioned to prevent twisting.

3.2.10 Dynamic Fatigue

Repeated high frequency flexing of an elastomer can produce an energy or thermal build up in the material which can cause a dynamic fatigue failure called hysteresis. Thorseals are computer designed to proportion the seal to minimize the risk of this type of failure occurring.

3.2.11 Temperature Ranges

The standard Thorseal polymer can be specified for temperatures ranging from -60°F (-50°C) to 195°F (85°C). Most hydraulic and pneumatic applications fall within this temperature range.

3.2.12 Easy Installation

High tensile strength, resilience and toughness make Thorseals less susceptible to damage during installation compared to rubber, leather or other types of seals.

3.3 Chemical Compatibility

Thorseals are non-corrosive and resistant to oil, water and a wide variety of most hydraulic fluids as noted in Table 1 of the Appendices. The polymers are compatible with most lubricants and do not swell in oil.

3.4 Competitive Material Comparison

Although recent trends indicate the increased usage of special polymers like Thorseal, a significant number of other materials are still being used for seals. These materials usually cost less to purchase, but the higher maintenance costs associated with their reduced life is often overlooked.

The following is a general overview of other commonly used seal materials.

Leather Seals:

Leather or rawhide U-cup seals were introduced in the 1920's and offered a tremendous advantage over the existing materials at that time. However, leather seals have poor memory, absorb fluids and do not seal effectively without being spring loaded. In pneumatic applications, the leather often drys and cracks resulting in seal failure.

Fabric Reinforced Rubber Seals:

U-cup seals made from reinforced rubber tend to swell inconsistently resulting in high friction and subsequent wear on the mating surface. Eventually the seal will bind and subsequently leak, reducing the operating life.

Rubber Seals:

Rubber U-cups have very good abrasion resistance but low tensile strength. As a result, they tend to tear or cut easily and extrude more easily under higher pressures. Their lower tensile strength reduces sealing effectiveness at lower pressures and a lack of internal self-lubrication results in higher friction and occasional erratic cylinder operation at slower speeds due to a phenomenon called stick-slip.

Fluorocarbon Seals:

Fluorocarbon or filled fluorocarbon seals offer low friction, high temperature capabilities and excellent chemical resistance. Fluorocarbons are, however, poor in abrasive environments, lack resilience, and exhibit poor mechanical properties.

Plastic Seals:

A variety of seals manufactured from thermoplastic materials are specified for various reasons. Most of these plastics have high tensile modulus, but at low elongation resulting in poor compliance, low resilience, decreased wear resistance and reduced operating pressure limits in seal applications.

4.0 DESIGN GUIDE

4.1 Introduction

The Thorseal range of elastomeric sealing products depend on an initial deflection of the seal lip during installation to seal. They rely on the resilience and elastomeric properties of the polymer alloy to retain an effective sealing force between the two sealing surfaces under low system pressure. During the operation of a cylinder as the hydraulic or pneumatic system pressure increases, the sealing force on the lip seal also increases to prevent leakage.

The dimensional parameters and design considerations for the basic Thorseal products are outlined in the following sections.

4.1.1 Thorseal Single Rings

Thorseal single ring seals are designed to perform both a static and dynamic sealing function. A static seal is effected against surfaces where there is no motion and a dynamic seal is effected against sliding surfaces where motion is involved.

On the static side, the seal heel is dimensioned to match the mating part with a size on size fit, while on the dynamic side there is a radial clearance that varies from 0.010" (0.25mm) to 0.035" (0.88mm) depending on the diameter of the seal. The seal lips are designed to deflect from 0.030" (0.762mm) to 0.090" (2.286mm) depending on the pressure and the seal diameter. The flexible seal lips are designed to contour the sealing surface facilitating an effective seal with little or no system pressure. In addition, the strength of the Thorseal polymer alloy, combined with the seal design also enables it to seal from very low to very high system pressures.

The design of a piston mounted Thorseal is shown in Figure 12 and a gland-mounted Thorseal is shown in Figure 13. The only difference between the two designs is that the dynamic surface for a gland mounted seal is on the inside, and on the outside for a piston mounted seal. The static surfaces are also reversed.

TYPICAL THORSEAL PISTON MOUNT

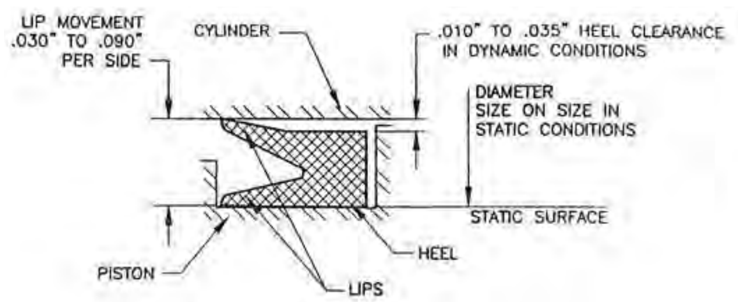


Figure 12

TYPICAL THORSEAL GLAND MOUNT

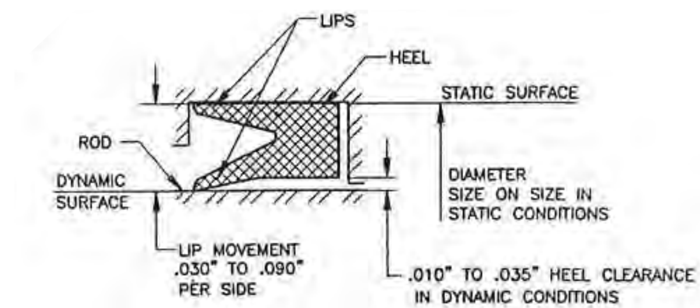


Figure 13

Figure 14 illustrates a gland mounted Thorseal designed to suit a 4.00" (101.6mm) diameter rod and a 4.75" (120.7mm) inside diameter gland. As the rod is the dynamic surface, the seal heel has a nominal diametrical clearance of 0.030" (0.76mm), while the static side is designed size on size with the gland.

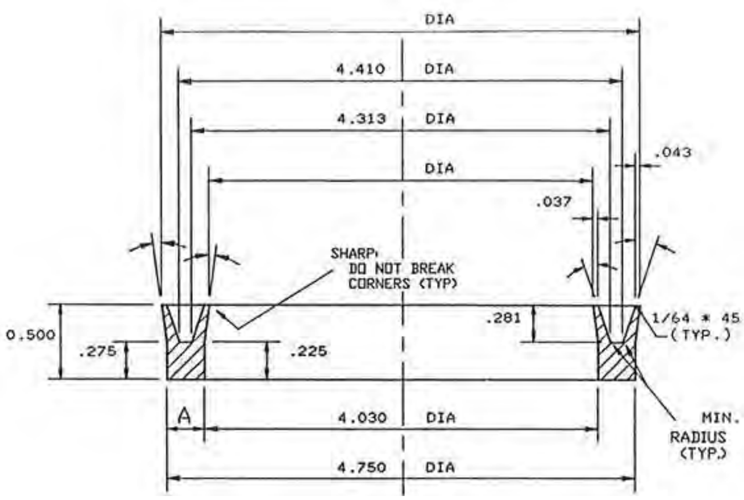


Figure 14

4.1.2 Thorwiper

Thorwiper is a wiper designed to keep the rod clean and prevent dirt and abrasives from entering and contaminating the hydraulic or pneumatic system, or damaging the Thorseal. The Thorwiper has a molded lip that is rigid enough to wipe contaminates from the rod but flexible enough to conform to rods that wander. The lip movement varies from 0.030" (0.76mm) to 0.090" (2.29mm) depending on the size of the Thorwiper. The heel is designed with a 0.010" (0.25mm) to 0.030" (0.76mm) clearance in order to give sufficient support to the lip as shown in Figure 15. The minimum clearance provided in the heel design supports the lip.

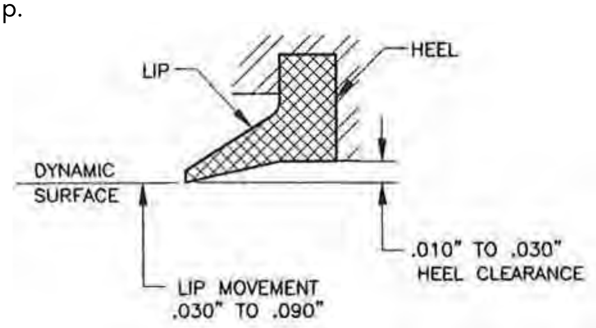


Figure 15

Figure 16 shows a typical Thorwiper design with a radial heel clearance of 0.020" (0.50mm) over the rod size of 2.75" (69.9mm).

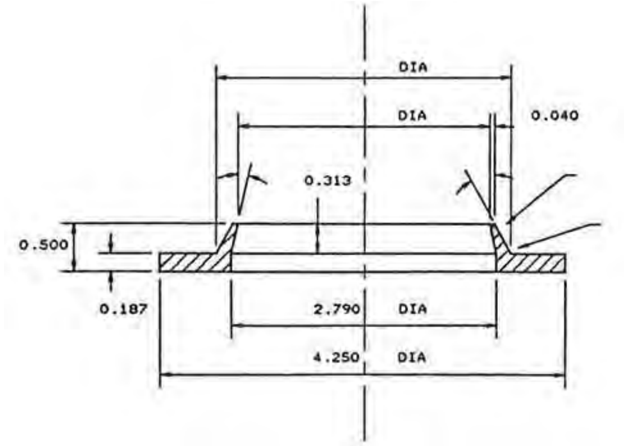


Figure 16

4.1.3 Thorpak

Thorpak is a set of molded, nested V-rings with a top and bottom adapter for use in a stuffing box assembly.

Unlike conventional V-set packings, Thorpak contains more sealing rings per inch(mm) of depth resulting in superior sealing ability to minimize leakage. The total assembly height can be adjusted to suit the actual length of the stuffing box by adding or subtracting centre sealing rings as required (see Table 2 in the Appendices).

DESIGN GUIDE

4.2 Operating Pressure

In plants where many hydraulic/pneumatic units are used, the system pressure will vary depending on plant usage and as loads come on, and go off, line. In a well designed system pressure regulators control the volume of hydraulic fluid or air to the cylinder, thereby controlling the rate of movement of the cylinder ram. The system will operate at the pressure and speed proportional to the resistance force in the application. Pressure in the system will only increase to the maximum level when the cylinder movement is opposed by the maximum load required.

Thorseals can be specified for use on hydraulic and pneumatic cylinders operating through a pressure range from 0 to 15,000 psi (0 to 100 MPa). Thorseals are designed to seal at very low pressures due to the initial deflection of the Thorseal lip. As the pressure is increased, the unique Thorseal lip geometry creates an increased radial force to prevent leakage yet still allow smooth movement in the cylinder. A properly designed and installed Thorseal will not leak throughout the operating pressure range.

APPLIED PRESSURE

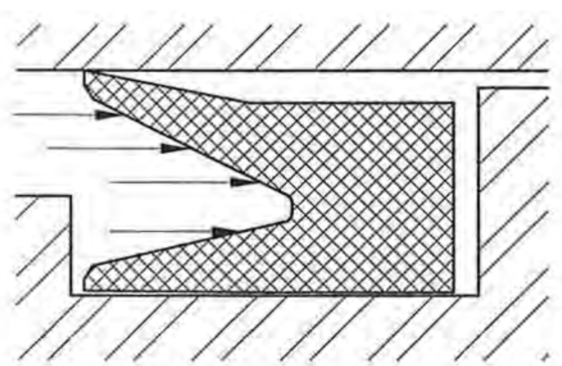


Figure 17

During normal operation of a double acting cylinder, the applied hydraulic or pneumatic pressure on the piston forces it to move along the cylinder at a rate proportional to the volume of the cylinder, the load and the flow rate of the fluid. The seal on the pressurized side of the piston is forced against the back of the piston so that the heel of the seal is in full contact and creates a static seal. The outer lip of the U-ring seal is forced outwards against the cylinder wall by the applied pressure creating an effective dynamic seal. The higher the operating pressure, the greater the force applied to the seal to prevent leakage.

On the other side of the piston, the oil or air is being forced out of the cylinder at a pressure related to the piston speed and the size of the outlet. The faster the piston travels, or the smaller the outlet hose, the greater the resistance or back pressure. This back pressure pressurizes the seal on this end of the piston in a similar way to the one on the other side, and a good static and dynamic seal is created here as well.

4.3 Operating Temperature

The standard Thorseal polymer can be specified through a temperature range from -60°F to 195°F (-50°C to 85°C).

4.4 Maximum Velocity

The guideline for the maximum recommended linear reciprocating velocity for a Thorseal application is 185 ft./minute (0.95metres/second). The guideline for the maximum recommended rotational velocity is 100 ft./minute (0.50metres/second). There are, however, many Thorseal applications performing well at velocities higher than these recommended maximums. Please contact Thomson-Gordon Limited for further information.

4.5 Surface Finish

In hydraulic/pneumatic applications, effective sealing performance requires that the seal maintain continuous contact with the sealing surfaces. The resilience of an elastomer generates the energy to maintain the contact, but the roughness of the sealing surface has a significant effect on both absolute sealability and seal wear life.

The recommended surface finish for dynamic surfaces is 15 to 25 micro inches (0.38 to 0.63 micrometres) RMS, although surface finishes up to 38 micro-inches (0.96 micrometres) will perform satisfactorily).

The recommended surface finish for static surfaces is 30 to 45 micro-inches (0.75 to 1.13 micrometers) RMS.

4.6 Chemical Compatibility

The Thorseal polymers are non-corrosive; are resistant to oil, water and most chemicals; and are compatible with most hydraulic fluids excluding phosphate esters and glycols. A chemical compatibility chart is included in the Appendix as Table 1, however, it should be used only as a guide since results can vary depending on concentrations, temperature, aeration, flow velocity, duration of exposure, fluid stability, pressure, temperature and many other factors.

For critical applications an immersion test is recommended. If significant softening or dimensional changes are observed after twenty four hours of immersion at application temperatures then Thorseal is not suitable for the application.

4.7 Piston and Gland Sizing for Thorseals

Whenever possible, the cylinder bore I.D. and piston O.D. or cylinder gland I.D. and rod O.D. should be maintained as standard nominal sizes to avoid expensive machining and waste of material. However, if a component has been damaged, it is often possible to salvage the damaged component by re-machining and then ordering a machined to size Flexlip Thorseal.

Typically the fits and tolerances on the cylinder, piston, gland and rod vary depending on the operating pressure of the application and the diameter of the seal. Recommended dimensioning and tolerancing for various Thorseal application locations at varying operating pressures follow in Charts 3 and 4.

NOTES:

1. *The fits and tolerances given in the following sections pertain to Thomson-Gordon's sealing products and are the recommended values to ensure the optimum combination of effective sealing and maximum seal life.*
2. *Consult the Original Equipment Manufacturer's specifications when modifying existing hydraulic/ pneumatic equipment.*

4.7.1 Cylinder Bore I.D./Piston O.D. Fits and Tolerances

Cylinder Dia. Range	Cylinder Bore I.D Pressure Range - psi (MPa)			Piston O.D. Pressure Range - psi (MPa)		
inches	0 - 3000	3000 - 7000	7000 - 15000	0 - 3000	3000 - 7000	7000 - 15000
(mm)	(0 - 20)	(20 - 50)	(50 - 100)	(0 - 20)	(20 - 50)	(50 - 100)
.250 to .375	+.001/.000	+.001/.000	+.001/.000	-.0005/-.004	-.0005/-.002	-.0005/-.001
(6 to 10)	(+.036/.000)	(+.036/.000)	(+.036/.000)	(-.013/-.103)	(-.013/-.049)	(-.013/-.035)
.375 to .750	+.002/.000	+.022/.000	+.002/.000	-.0006/-.005	-.0006/-.002	-.0006/-.002
(10 to 18)	(+.043/.000)	(+.043/.000)	(+.043/.000)	(-.016/-.126)	(-.016/-.059)	(-.016/-.043)
.750 to 1.25	+.002/.000	+.002/.000	+.002/.000	-.0008/-.006	-.0008/-.003	-.0008/-.002
(18 to 30)	(+.052/.000)	(+.052/.000)	(+.052/.000)	(-.020/-.150)	(-.020/-072)	(-.020/-.053)
1.25 to 2.00	+.002/.000	+.002/.000	+.002/.000	-.0009/-.007	-.0009/-.003	-.0009/-.002
(30 to 50)	(+.062/.000)	(+.062/.000)	(+.062/.000)	(-.025/-.185)	(-.025/-.087)	(-.025/-.064)
2.00 to 3.25	+.003/.000	+.003/.000	+.003/.000	-.001/-.009	-.001/-.004	-.001/-.003
(50 to 80)	(+.074/.000)	(+.074/.000)	(+.074/.000)	(-.030/-.220)	(-.030/-104)	(-.030/-.076)
3.25 to 4.75	+.003/.000	+.003/.000	+.003/.000	-.001/-.010	-.001/-.005	-.001/-.003
(80 to 120)	(+.087/.000)	(+.087/.000)	(+.087/.000)	(-.036/-.256)	(-.036/-.123)	(-.036/-.090)
4.75 to 7.00	+.004/.000	+.004/.000	+.004/.000	-.002/-.011	-.002/-.006	-.002/-.004
(120 to 180)	(+.100/.000)	(+.100/.000)	(+.100/.000)	(-.043/-.293)	(-.043/-143)	(-.043/-.106)
7.00 to 10.0	+.004/.000	+.004/.000	+.004/.000	-.002/-.013	-.002/-.006	-.002/-.005
(180 to 250)	(+.115/.000)	(+.115/.000)	(+.115/.000)	(-.050/-.340)	(-.050/-.165)	(-.050/-.122)
10.0 to 12.5	+.005/.000	+.005/.000	+.005/.000	-.002/-.015	-.002/-.007	-.002/-.005
(250 to 315)	(+.130/.000)	(+.130/.000)	(+.130/.000)	(-.056/-.376)	(-.056/-186)	(-.056/-.137)
12.5 to 16.0	+.005/.000	+.005/.000	+.005/.000	-.002/-.017	-.002/-.008	-.002/-.006
(315 to 400)	(+.140/.000)	(+.140/.000)	(+.140/.000)	(-.062/-.422)	(-.062/-.212)	(-.062/-.151)
16.0 to 20.0	+.006/.000	+.006/.000	+.006/.000	-.003/-.018	-.003/-.009	-.003/-.006
(400 to 500)	(+.155/.000)	(+.155/.000)	(+.155/.000)	(-.068/-.468)	(-.068/-.223)	(-.068/-.165)
20.0 to 25.0	+.007/.000	+.007/.000	+.007/.000	-.003/-.020	-.003/-.010	-.003/-.007
(500 to 630)	(+.175/.000)	(+.175/.000)	(+.175/.000)	(-.076/-.520)	(-.076/-.251)	(-.076/-.186)
25.0 to 32.0	+.008/.000	+.008/.000	+.008/.000	-.003/-.022	-.003/-.011	-.003/-.008
(630 to 800)	(+.200/.000)	(+.200/.000)	(+.200/.000)	(-.080/-.560)	(-.080/-280)	(-.080/-.205)
32.0 to 42.0	+.009/.000	+.009/.000	+.009/.000	-.003/-.024	-.003/-.012	-.003/-.009
(800 to 1100)	(+.230/.000)	(+.230/.000)	(+.230/.000)	(-.086/-.610)	(-.086/-.316)	(-.086/-.226)

Chart 3

4.7.2 Gland Bore I.D./Rod O.D. Fits and Tolerances

Gland Dia. Range	Gland Bore I.D Pressure Range - psi (MPa)			Rod O.D. Pressure Range - psi (MPa)		
inches	0 - 3000	3000 - 7000	7000 - 15000	0 - 3000	3000 - 7000	7000 - 15000
(mm)	(0 - 20)	(20 - 50)	(50 - 100)	(0 - 20)	(20 - 50)	(50 - 100)
.250 to .375	+.004/.0005	+.002/.0005	+.001/.0005	.000/-.001	.000/-.001	.000/-.001
(6 to 10)	(+.103/.013)	(+.049/.013)	(+.035/.013)	(.000/-.036)	(.000/-036)	(.000/-.036)
.375 to .750	+.005/.0006	+.002/.0006	+.002/.0006	.000/-.002	.000/-.002	.000/-.002
(10 to 18)	(+.126/.016)	(+.059/.016)	(+.043/.016)	(.000/-.043)	(.000/-.043)	(.000/-.043)
.750 to 1.25	+.006/.0008	+.003/.0008	+.002/.0008	.000/-.002	.000/-.002	.000/-.002
(18 to 30)	(+.150/.020)	(+.072/.020)	(+.053/.020)	(.000/-.052)	(.000/-052)	(.000/-.052)
1.25 to 2.00	+.007/.0009	+.003/.0009	+.002/.0009	.000/-.002	.000/-.002	.000/-.002
(30 to 50)	(+.185/.025)	(+.087/.025)	(+.064/.025)	(.000/-.062)	(.000/-.062)	(.000/-.062)
2.00 to 3.25	+.009/.001	+.004/.001	+.003/.001	.000/-.003	.000/-.003	.000/-.003
(50 to 80)	(+.220/.030)	(+.104/.030)	(+.076/.030)	(.000/-.074)	(.000/-074)	(.000/-.074)
3.25 to 4.75	+.010/.001	+.005/.001	+.003/.001	.000/-.003	.000/-.003	.000/-.003
(80 to 120)	(+.256/.036)	(+.123/.036)	(+.090/.036)	(.000/-.087)	(.000/-.087)	(.000/-.087)
4.75 to 7.00	+.011/.002	+.006/.002	+.004/.002	.000/-.004	.000/-.004	.000/-.004
(120 to 180)	(+.293/.043)	(+.143/.043)	(+.106/.043)	(.000/-.100)	(.000/-100)	(.000/-.100)
7.00 to 10.0	+.013/.002	+.006/.002	+.005/.002	.000/-.004	.000/-.004	.000/-.004
(180 to 250)	(+.340/.050)	(+.165/.050)	(+.122/.050)	(.000/-.115)	(.000/-.115)	(.000/-.115)
10.0 to 12.5	+.015/.001	+.007/.002	+.005/.002	.000/-.005	.000/-.005	.000/-.005
(250 to 315)	(.376/.056)	(.186/.056)	(.137/.056)	(.000/-.130)	(.000/-.130)	(.000/-.130)
12.5 to 16.0	+.017/.002	+.008/.002	+.006/.002	.000/-.005	.000/-.005	.000/-.005
(315 to 400)	(+.422/.062)	(+.212/.062)	(+.151/.062)	(.000/-.140)	(.000/-.140)	(.000/-.140)
16.0 to 20.0	+.018/.003	+.009/.003	+.006/.003	.000/-.006	.000/-.006	.000/-.006
(400 to 500)	(+.468/.068)	(+.223/.068)	(+.165/.068)	(.000/-.155)	(.000/-.155)	(.000/-.155)
20.0 to 25.0	+.020/.003	+.010/.003	+.007/.003	.000/-.007	.000/-.007	.000/-.007
(500 to 630)	(+.520/.076)	(+.251/.076)	(+.186/.076)	(.000/-.175)	(.000/-.175)	(.000/-.175)
25.0 to 32.0	+.022/.003	+.011/.003	+.008/.003	.000/-.008	.000/-.008	.000/-.008
(630 to 800)	(+.560/.080)	(+.280/.080)	(+.205/.080)	(.000/-.200)	(.000/-200)	(.000/-.200)
32.0 to 42.0	+.024/.003	+.012/.003	+.009/.003	.000/-.009	.000/-.009	.000/-.009
(800 to 1100)	(+.610/.086)	(+.316/.086)	(+.226/.086)	(.000/-.230)	(.000/-.230)	(.000/-.230)

Chart 4

4.7.3 Piston or Gland Seal Groove Diameter

The appropriate piston seal groove or gland seal groove inside diameter is determined by subtracting twice the radial cross section of the seal from the nominal cylinder diameter. Twice the radial cross section can be calculated by subtracting the O.D. of the seal from the I.D.

The recommended tolerance on the groove diameter should be the same as that given for the piston itself on the fits and tolerances in Chart 3, in section 4.7.1. or for the gland in the fits and tolerances in Chart 4 in section 4.7.2.

4.7.4 Piston or Gland Seal Groove Width

The recommended width of the piston or gland groove is 10% wider than the height of the seal. The minimum recommended groove width is 0.063″ (1.6mm) larger than the height of the seal.

The recommended tolerance on the width of the piston or gland seal groove is:

Nominal +0.012″/-0.000″ (0.305mm/-0.000mm)

4.7.5 Back-Up Rings

If the diametrical clearance between the piston and cylinder or the gland and rod exceeds the value given in Chart 5 below for the maximum application pressure given, a back-up ring is required. The back-up ring should be made from a material with a higher stiffness modulus than the Thorseal polymer and should contain a friction reducing additive. The back-up ring should be at least 50% as wide as the axial cross section of the seal. The outside diameter of the back-up ring should meet the recommended size and tolerances for either the piston or the gland as outlined previously. A Thorpak seal arrangement can tolerate approximately 20% greater diametrical clearance between the piston and the cylinder before a back-up ring is required. Thomson-Gordon can supply the appropriate back-up ring when required with a Thorseal solution.

BACK-UP RING REQUIREMENT CHART

Pressure		Max. Diametrical Clearance Without Back-Up Ring	
PSI	MPa	Inches	mm
0 - 3000	0 - 20.5	0.030	0.75
3,000 - 4,000	20.5 - 27.5	0.025	0.65
4,000 - 5,000	27.5 - 34.5	0.020	0.50
5,000 - 6,000	34.5 - 41.5	0.015	0.40
6,000 - 10,000	41.5 - 69.0	0.010	0.25
10,000 - 15,000	69.0 - 103.0	0.005	0.13

Chart 5

4.8 Seal Sizes for Existing Applications

The following is an example of calculating the seal cross sections required to order a custom seal to fit an existing application:

Piston Seal

Existing cylinder inside diameter (seal outside diameter):
6.315″ (160.41mm)

Existing piston groove inside diameter (seal inside diameter):
5.200″ (132.08mm)

Existing groove length: 0.875″ (22.23mm)

Radial cross-section:
(6.315 - 5.200)/2 = 0.557″ (14.15mm)

Seal height (10% less than piston groove length)
0.875/1.1 = 0.795″ (20.13mm)

Gland Seal

Existing rod diameter (seal inside diameter):
2.995″ (76.07mm)

Existing gland groove inside diameter (seal outside diameter):
3.760″ (95.50mm)

Existing groove length: 0.612″ (15.55mm)

Radial cross-section:
3.760 - 2.995/2 = 0.383″ (9.73mm)

Seal height (10% less than gland groove length)
0.612″/1.1 = 0.556″ (14.12mm)

NOTES:

1. *The seal dimensions that are calculated should always be checked against the Thorseal mold list to determine if a standard molded seal size is available.*
2. *The seal height should always be at least 0.125″ (3.18mm) greater than the radial cross section and the groove length should always be 10% greater than the seal height [minimum 0.063″ (1.6mm)]. In some cases it may be necessary to machine the groove length to meet these requirements. For extra long grooves, a back-up ring can be used in order to use a standard cross section.*

5.0 THORSEAL CONVERSIONS

5.1 Introduction

Most of the applications where Thorseals are specified involve conversions from a "standard" duty seal to the high performance benefits of Thorseal. The benefits of longer life and reduced maintenance down times associated with a Thorseal conversion result in dramatically reduced life cycle costs. The following information illustrates how various sealing arrangements can be converted to a Thorseal design.

5.2 Piston Conversion from O-rings to Thorseals

Figure 18 shows a typical conversion on a piston from an O-ring to a Thorseal design. The piston Oring grooves will usually require machining in order to suit the increased Thorseal cross section. If a Thorseal is used to replace an O-ring used as dynamic seal with no back-up ring, then the Thorseal will not require a back-up ring either unless the O-ring has failed prematurely due to extrusion. If the O-rings have back-up rings then the clearance between the piston and the cylinder inside diameter should be checked per the instructions in design section 4.7.9 to determine if the Thorseal will require a back-up ring.

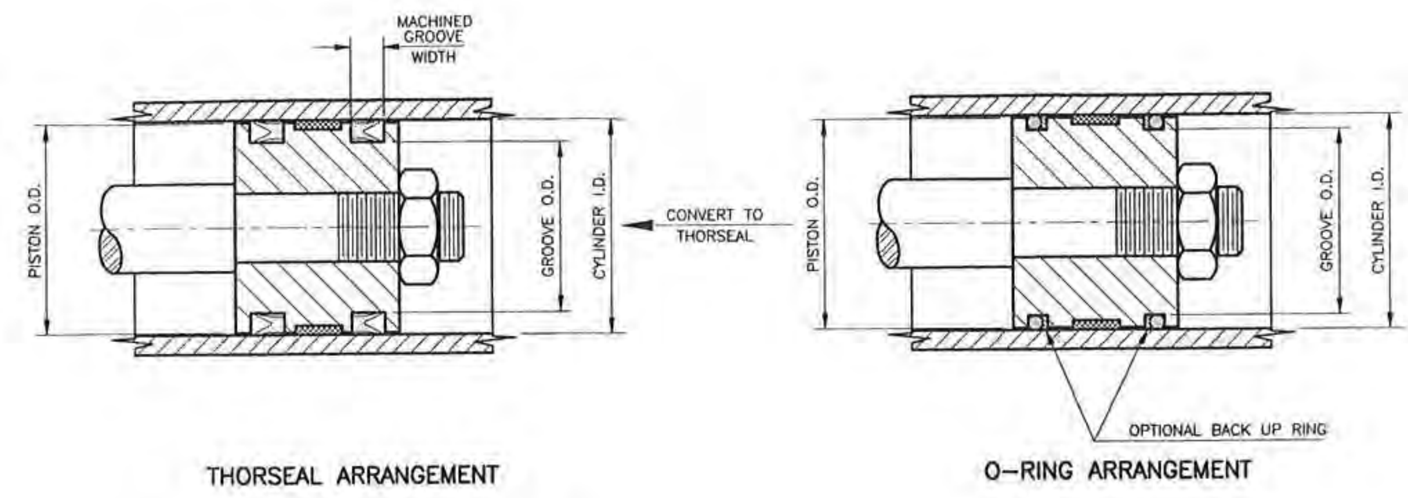


Figure 18

THORSEAL CONVERSIONS

5.3 Piston Conversion from Packing to Thorpak or Thorseals

Figure 19 shows a conversion from a compression packing on a piston to a Thorseal or Thorpak arrangement. Thorpak can be selected to directly replace the compression packing in both a single and double acting cylinder. If a conversion to a single ring Thorseal is preferred, a spacer to reduce the length of the groove and prevent excessive movement of the Thorseal on the piston is recommended. The spacer should be designed to eliminate the excess clearance and also function as a back-up ring.

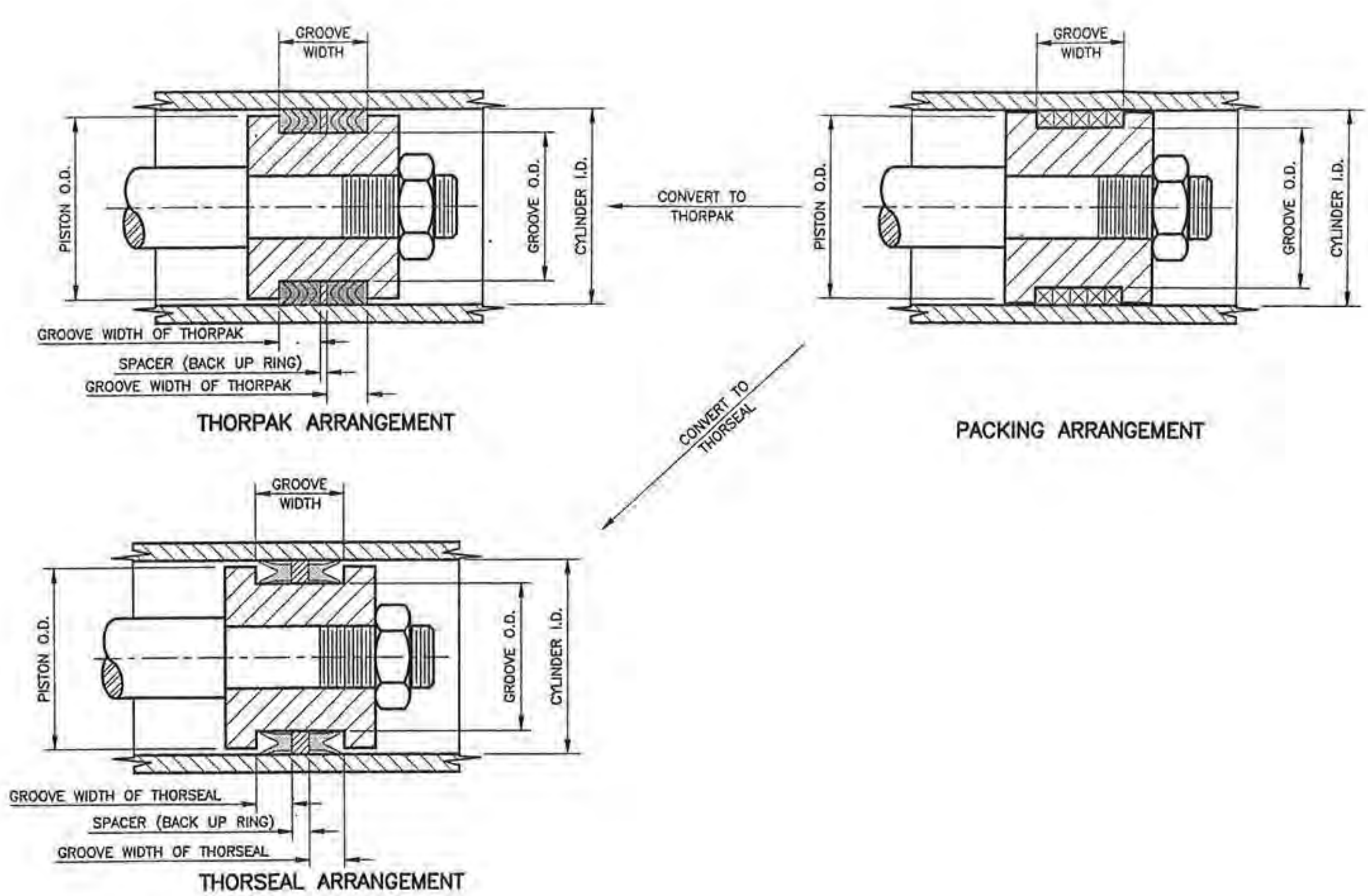


Figure 19

5.4 Gland Conversion from Packing to Thorpak or Thorseals

Figure 20 shows a conversion from a compression packing to a Thorseal or Thorpak arrangement in a gland plate or stuffing box. Thorpak can be selected as a direct replacement or may require a spacer in order to use standard Thorpak sizes. The Thorseal single ring seal requires a spacer to properly locate the seal and the gland may require machining to suit the recommended cross section if a Thorwiper is used. The spacer should also be designed to act as a back up ring for the seal.

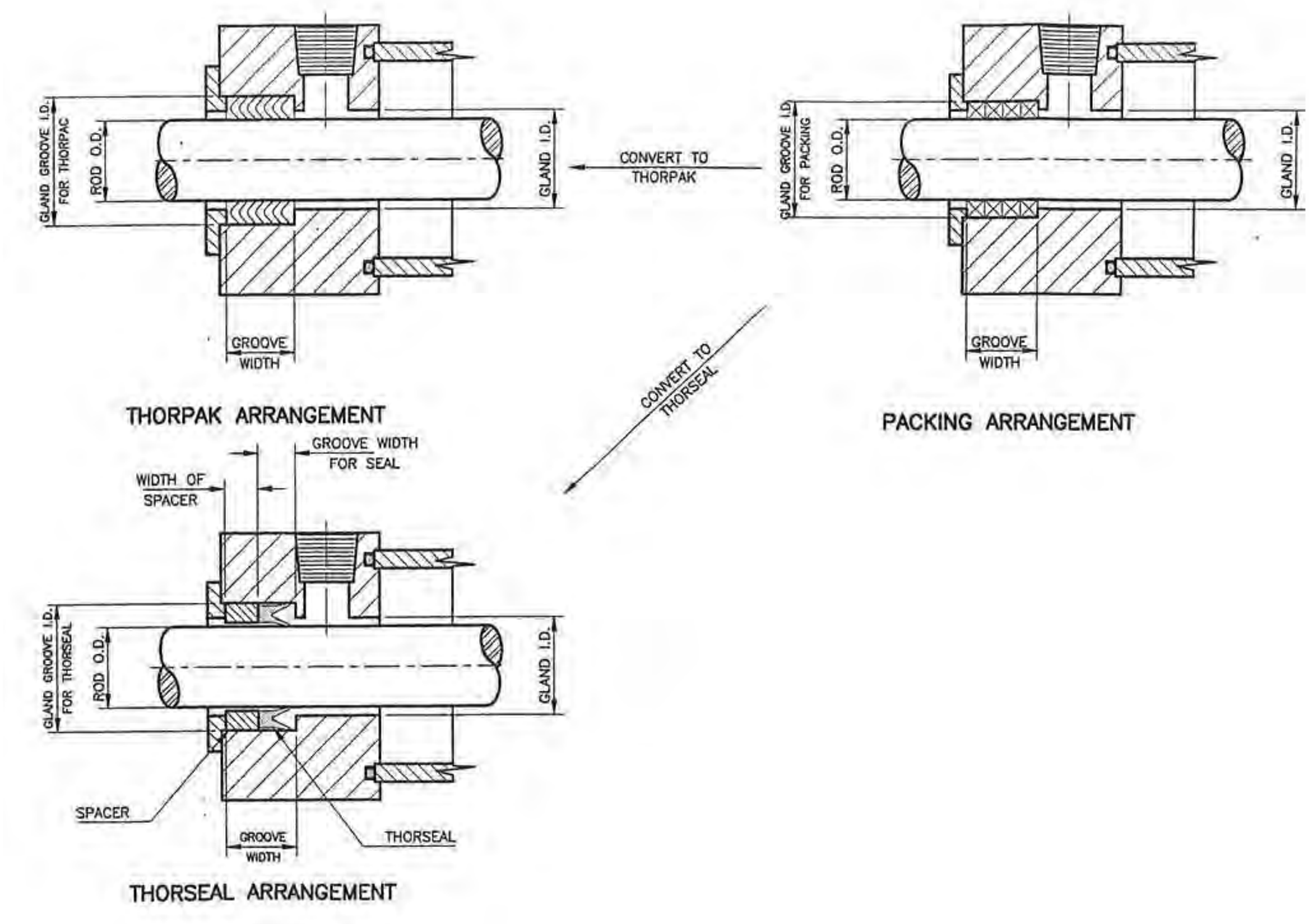


Figure 20

6.0 THORSEAL SELECTION & ORDERING

6.1 Sizing

The appropriate sizing of the Thorseal specified is determined by the diameters of the piston, ram and cylinder as well as the specific requirements of the application. Figures 21 and 22 show enlarged crosssections of a typical piston for a double acting cylinder and gland plate or stuffing box with all the dimensions required to correctly size the appropriate Thorseal product shown. When placing an order it is important to accurately measure the components where indicated, carefully record the dimensions and specify whether the seal is gland mounted or piston mounted.

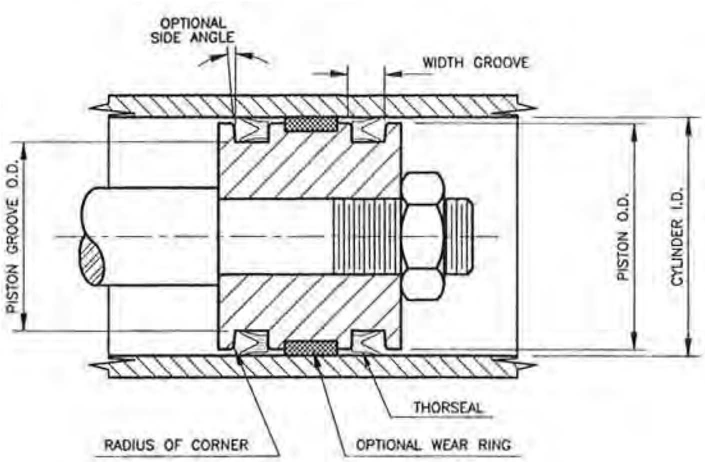


Figure 21

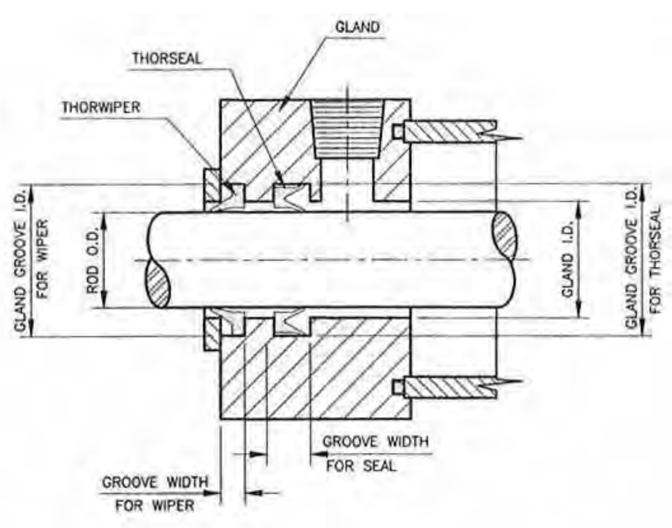


Figure 22

6.2 Thorseals

To order either a gland (or piston) mounted Thorseal the following steps must be followed:

1. Determine the outside diameter of the cylinder rod (or inside diameter of the piston seal groove).
   This determines the inside diameter of the seal required.
2. Determine the outside diameter of the gland seal groove (or inside diameter of the cylinder bore).
   This determines the outside diameter of the seal required.
3. Refer to the mold list and search for seals with the required I.D. and mounting orientation. Piston mounted seals are designated as P.M.
4. Then find the seal with the correct O.D.
5. Check that the height of the seal will fit into the existing groove. The groove must be at least 0.063" (1.6mm) larger than the height of the seal.
6. When you have found the correct seal the order number is listed under Mold #.

Notes:

1. *If the correct size cannot be found please contact our office for assistance. A new mold can be manufactured or a machined Flexlip seal may be the best option depending on your requirements.*
2. *Some seals are designated as specials. Do not order these seals without contacting Thomson-Gordon for further information.*

6.3 Thorpak

To order a Thorpak set the following steps must be followed:

1. Determine the number of sealing rings required from Chart 6 below.

Pressure Psi (MPa)	Number of Sealing Rings
0 - 1000 psi (0 - 7.0 MPa)	3
1000 - 1500 psi (7.0 - 10.0 MPa)	4
1500 - 2000 psi (10.0 - 14.0 MPa)	5
2000 - 2500 psi (14.0 - 17.0 MPa)	6
2500 - 3000 psi (17.0 - 20.5 MPa)	7
3000 - 3500 psi (20.5 - 24.0 MPA)	8
3500 - 4000 psi (24.0 - 27.5 MPa)	8
4000 - 5000 psi (27.5 - 34.5 MPa)	9
5000 - 6000 psi (34.5 - 41.5 MPa)	10

Note: For pressures above 6,000 psi (41.5MPa) please contact Thomson-Gordon for further information.

Chart 6

2. Determine the Radial Cross Section required by subtracting the rod diameter from the outside diameter of the gland groove and dividing by 2.
3. Check that the stack height of the number of rings required per Chart 6 above can be accommodated either in the existing gland groove or by re-machining it.
4. Measure the rod diameter to determine the I.D of the seal.
5. Measure the O.D. of the gland groove to determine the O.D. of the seal.
6. Refer to the mold list to find the correct I. D. and then the correct O.D. for the application.
7. When you have found the correct seal the order number is listed under Mold #.

Notes:

1. *If the correct size cannot be found it is possible to reduce the diameter of the next largest size by up to 20% depending on the diameter and cross section of the Thorpak ring selected. Please contact Thomson-Gordon for additional information.*
2. *If the correct size cannot be found please contact our office for assistance. A new mold can be manufactured or it is also possible to machine a Thorpak solution depending on your requirements.*

6.4 Thorcups

To order a Thorcup the following steps must be followed:

1. Determine if the application is single acting or double acting.
2. Determine the diameter of the cylinder bore.
3. Determine the centre hole diameter.
4. Refer to the mold list to find the appropriate diameter and then the appropriate centre hole diameter making sure that if a double acting seal is required that the seal is designated as such.
5. When you have found the correct seal the order number is listed under Mold #.

Notes:

1. *If a non-standard centre hole is required please state this fact on the order.*
2. *If the correct size cannot be found please contact our office for assistance. A new mold can be manufactured if required.*

6.5 Thorwipers

To order a Thorwiper the following steps must be followed:

1. Determine the rod diameter to determine the I.D of the Thorwiper.
2. Determine the outer diameter of the seal groove in the gland to determine the O.D. of the Thorwiper.
3. Determine the housing lip clearance diameter.
4. Determine the gland groove width.
5. Refer to the mold list to find the appropriate I.D. and then look for the appropriate O.D. Then check to make sure that the housing lip clearance is adequate to clear the lip of the seal (dimension LR) and that the base height of the seal (WB) can be accommodated by the width of the gland groove.

Note:

1. *If the correct size cannot be found please contact our office for assistance. A new mold can be manufactured if required.*

7.0 SEAL INSTALLATION

7.1 Introduction

The single biggest cause of premature seal failure is damage caused at installation. The main areas for concern during seal replacement are overall cleanliness, damage of the seal lip during assembly, incorrect sizing and use of improper lubricants. Good maintenance practices and common sense can solve most installation problems.

7.2 General Inspection & Installation Tips

The proper installation of a seal in a hydraulic or pneumatic application is essential to achieve optimum performance and long life. In addition to the more specific instructions reviewed previously the following general assembly points should be followed:

1. Ensure that all sharp corners are removed from any metal parts that could come in contact with the seals. Chamfers should be added to cylinders and rods as recommended to facilitate easy assembly and prevent the sealing components from being cut or damaged during assembly.
2. Ensure that all components are clean and free from foreign materials, especially machining cuttings, before assembly. Assemble all components in a clean environment, and ensure that all tools and lubricants are clean and free from contaminants.
3. Ensure that the seal is fully inspected prior to installation, paying special attention to the seal lip. Also make sure that the correct type and size of seal has been selected for the application and that the seal dimensions are correct for the space provided.
4. Install the seals with the lips facing the pressure side of the application. If using a back-up ring or spacer bushing the seal heel should rest against the ring. Ensure that there are no twists or kinks in the seal. Thorseals are a snap fit so it is important to ensure that the correct tools are used in the installation of the seals and where necessary use special tools with no sharp edges to make sure the seal is not damaged as it is being installed. The seals may have to be stretched substantially upon installation, however they will quickly return to their original shape and size.
5. Ensure that any axial compressed packings in the component are not over tightened preventing excessive friction and wear.
6. Lubrication will facilitate easier installation of the seal, however, ensure that the lubricant used is compatible with the Thorseal polymer.

Notes:

1. *Thorseal and Flexlip single rings will seat in the correct position under pressure. They will not float axially if the groove is longer than necessary and do not require spacers. A minimum clearance of 0.62" (1.5mm) is required beyond the sealing lips to allow the lips to flex freely and seal properly.*
2. *Thorseal and Flexlip single rings are not designed to be split. Please contact Thomson-Gordon Limited for recommendations on single split seal applications.*

There should also be a chamfer on the inside diameter of the cylinder barrel to allow the Thorseal lips to deflect into their pre-loaded condition as the piston is being re-assembled into the cylinder. If there is no chamfer on the cylinder, a compression tool must be used to compress the lips and prevent them from being cut or nicked during re-assembly.

7.3 Piston and Gland Mounted Seals

(Refer to Section 7.2 for General Inspection & Installation Tips)

To facilitate easy, damage free installation of piston or gland mounted seals the diameter closest to the lip should be reduced in diameter and chamfered as shown in Figure 23. This allows the Thorseal to be easily stretched and positioned in the piston (gland) groove without damage. If the piston (gland) is not stepped and chamfered, it is possible to machine a separate chamfered cone (Figure 24) that can be used to ease assembly.

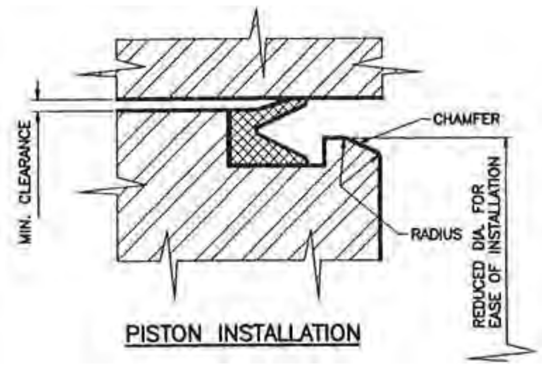


Figure 23

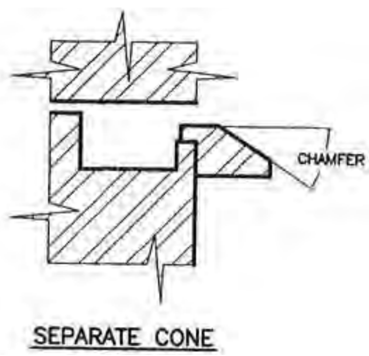


Figure 24

The Thorseal ring is best assembled into the piston groove using a method similar to installing tires on a wheel. The seal should be started in the groove and using a center pivot and a smooth bar smoothly stretched into the groove as shown in Figure 25. The same assembly techniques should be used to install non-split Thorpak rings.

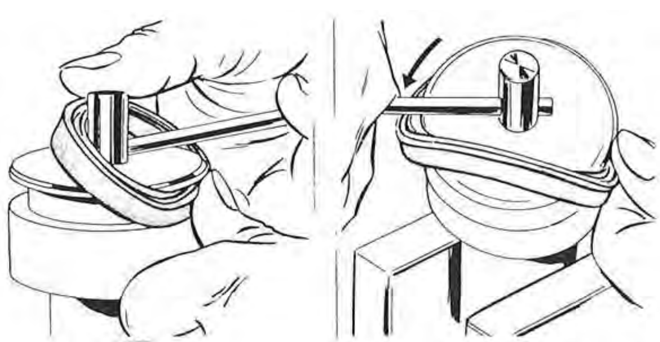


Figure 25

7.4 Rod Seals and Wipers

(Refer to Section 7.2 for General Inspection & Installation Tips)

Rod seals & wipers should be installed using a standard hydraulics tool that kinks the Thorseal or Thorwiper and allows it be inserted into the housing groove and released into position in the groove.

The housing diameter closest to the lip, as shown in Figure 26, should be increased in size and the corner should be radiused to allow easy, damage free installation.

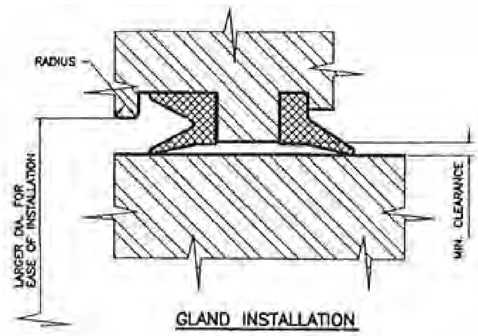


Figure 26

7.5 Thorpak and Flexlip V-Sets

(Refer to Section 7.2 for General Inspection & Installation Tips)

Thorpak sets should be installed using the same techniques as Thorseals. If split Thorpak (Flexlip) rings are being installed the splits on succeeding sealing rings should be offset from each other by at least 90°. Depending on the working stuffing box depth and number of sealing rings required to seal the application as determined in Chart 5 in section 4.7.5, it may be necessary to add internal or external shims to obtain the correct compressed height of the Thorpak (Flexlip) set.

To determine the size of the shim required the following steps must be followed:

1. If you have access to the Thorpak (Flexlip) set, measure the actual free stack height as supplied.
2. If the Thorpak (Flexlip) set is not available, refer to the stack height chart in the mold list.
3. Subtract the O.D. from the I.D. of the seals and divide by 2 to calculate the radial cross section.For this radial cross section use the chart "Thorpak Approximate Stack Heights" in Appendix 2 to read the height of the number of sealing rings being specified and add to that dimension the height of the top and bottom adapters to obtain the estimated free height.
4. Determine the actual working stuffing box depth by subtracting the gland nose length from the overall stuffing box depth.
5. Determine the Thorpak set compressed stack height by multiplying the actual free height measured in step 1 or the height calculated in step 3 by 0.98 to obtain the stack height when compressed by the recommended 2%. For Flexlip V-Sets multiply the actual free height or calcuated height by 0.95 to obtain the stack height when compressed by the recommended 5%. The actual free height from is preferred to an estimate from the charts.
6. Determine the thickness and type of shim required by subtracting the compressed stack height from the working stuffing box depth. If the number obtained is positive, an internal shim of that thickness is required. If negative, an external shim of that thickness is required. If preferred, the gland could be machined back instead of using an external shim but this should only be done after measuring the actual free stack height.
7. Install the bottom ring first, followed by each center sealing ring staggering the splits in the rings (if applicable) at 90° or more from the ring below.

8.0 TROUBLE SHOOTING

8.1 General Seal Failure Analysis

Any discussion of sealing technology would not be complete without a brief review of “service problems”. All the possible environmental and operating considerations are seldom known when the initial selection of a seal is made. In addition, since the initial cost of the seal, rather than its high performance characteristics, is often one of the main selection criteria for a cylinder manufacturer, it is sometimes valuable to re-evaluate the seal selection in light of actual field performance.

When seal problems do occur, a visual examination of the worn or damaged seal is generally sufficient to determine the cause of failure and take the necessary corrective action. The following factors are some of the more common types of problems which may occur in the operation of a hydraulic or pneumatic component:

8.1.1 Installation Damage

The single biggest cause of premature seal failure is damage caused during installation. The main areas for concern during seal installation are damage of the seal lip during assembly, overall cleanliness, incorrect sizing and use of improper lubricants. Careful design, good maintenance practices and common sense will eliminate most installation problems.

8.1.2 Seal Lip Cracking

During dynamic operation the seal lip can become brittle and exhibit cracks or breaks due to a combination of excessive frictional heat and other environmental conditions. Excessive seal force, lack of lubrication or incorrect material selection could be the cause.

8.1.3 Rapid Wear

Rapid seal wear can be the result of heat build up, but may also be the result of internal or external abrasive particle contaminants. Internal contamination is often the result of poor cleaning of the hydraulic or pneumatic system during assembly and the lack of an effective filtering system. Flushing the system and installing a good quality filter will solve this problem. External contamination requires the installation of a rod wiper, and possibly a scraper, if the operating conditions are extremely dirty.

8.1.4 Scoring

Scoring of the cylinder and the rod is a result of internal contamination in the system. Rod scoring only is a result of external contaminants.

8.1.5 Extrusion

Extrusion failure of an O-ring takes place when the clearance between the sealing surfaces is too large for the operating pressure and the strength of the O-ring. The O-ring is forced out of the O-ring groove and extruded between the static sealing surface and the sliding surface resulting in the O-ring being cut. Reduction of the clearance by using a back-up ring or replacement with a correctly sized Thorseal will solve this problem.

8.1.6 Spiral Failure

Spiral failure of an O-ring or seal is generally the result of seal geometry, hardness, and length of stroke causing the seal to be twisted in the groove during the sliding action. This problem can also be corrected by specifying a Thorseal because the cross section of the seal has a length that is greater than the thickness. This gives the seal more stability, particularly in applications where side loading is a concern.

8.1.7 “Stick Slip”

The dynamic operation of a hydraulic or pneumatic cylinder often involves a vibration or jerking action in the system which occurs mainly during start up or change of direction. This phenomenon is called “stick slip” and occurs when the dynamic friction is higher than the static friction. This condition improves as the system oil is transferred to the sliding surface. However, to completely solve the problem, the standard seal must often be replaced with seals such as Thorseals that have a high built-in lubricity.

8.1.8 Chemical Breakdown or Reaction

Another common seal failure mode is failure resulting from chemical attack caused by using incompatible seal material and hydraulic fluid. Chemical breakdown causes the seal material to lose its resilience, elasticity and hardness resulting in leakage and high wear. Excessive swelling can also occur and cause complete seizure of the cylinder. It is important to check the Chemical Compatibility Chart (Appendix Table #1) for the seal material to ensure that it is compatible with the system fluid. Care should also be taken to identify any additives such as corrosions and oxidation inhibitors, friction modifiers, viscosity improvers, antiwear agents or others which could be included in the fluid to ensure their compatibility with the seal material.

8.2 SYSTEM PROBLEMS, PROBABLE CAUSES & POSSIBLE SOLUTIONS

Problem	Probable Cause	Possible Solution
A. Slow, Uniform Leakage	✓ Poor low pressure sealing ✓ Too little initial interference ✓ Loss of interference or squeeze due to wear or compression set ✓ Seal shrinkage after installation ✓ Possible omission or failure of static seals ✓ Microscopic debris lodged under seal lip ✓ Scored lip due to passage of sharp particle under seal ✓ Seal lip damaged during installation ✓ Overheating hardens compound ✓ Off-center alignment causes all clearance to one side, compression on the other ✓ Minor scoring on cylinder wall	• review operating pressures with seal supplier - seal dimensions or design may have to be modified • review operating pressures with seal supplier - seal dimensions or design may have to be modified • replace seal - to extend replacement cycle consider installing a higher performance seal • replace seal • install or replace static seals • disassemble and flush cyclinder to remove debris, check for seal damage and reassemble • replace damaged seal and flush cyclinder to remove debris • replace damaged seal using recommended installation procedures • if possible, modify hydraulic system to operate at lower temperatures or replace seal with an alternative that will withstand higher temperatures • re-configure installation to eliminate off-centre alignment • hone cyclinder wall and check seal for damage
B. Gradually Increasing Leakage	✓ Progressive wear ✓ Increasing compression set ✓ Progressive tear or erosion from damage during installation ✓ Fine score mark on dynamic surface abrades seal lip	• replace seal - review options to determine if a seal option with increased wear life is available • replace seal - review options to determine if an option with increased resistance to compression set is available • replace damaged seal using recommended installation procedures • re-machine problem surface and replace seal
C. Sudden, Severe Leakage	✓ Extruded seal ✓ Badly torn seal lip Twisted seal ✓ Dramatic seal failure due to excessive load or shock ✓ Massive infusion of contamination ✓ Slow rod seal leakage builds up behind wiper and then dumps fluid ✓ Reverse pressure blowout of piston seal due to pressure trap failure of opposed seal	• replace seal and determine if back-up ring is required • determine cause of seal damage, correct and replace seal • reinstall or replace seal - back-up ring may be required • replace seal with more shock resistant option or eliminate overload or shock loading • clean & flush system, install new filters and new seal • replace rod seal • replace seal
D. Erratic Leakage	✓ Cold start-up shrinks seal ✓ Intermittent eccentric loading ✓ Fibrous contamination moving past seal lips ✓ Unstable seal due to shock loading ✓ Slow rod seal leakage buildup causing the wiper to dump fluid ✓ Fluid viscosity changes as temperature cycles	• allow system to warm up at low loading, pre- heat hydraulic fluid or redesign seal to operate at lower temperatures • eliminate eccentric loading conditions clean and flush system, install new filters,install fresh hydraulic fluid and • replace seal if damaged • eliminate shock loading or specify seal with higher shock loading tolerance • replace rod seal after correcting any areas that were damaging the seal • specify higher quality more tolerant seal or improve system design to better control fluid temperature

Problem	Probable Cause	Possible Solution
E. Stick-Slip Operation	✓ Low friction surface treatment worn away ✓ Breakdown of fluid lubricity due to contamination or deterioration of fluid ✓ Viscosity change due to temperature ✓ Excessive burnishing of dynamic surface to finer finish destroys ability to maintain lubricant film	• replace seal • clean and flush system, install new filters, install fresh hydraulic fluid and replace seal if damaged • specify higher quality more tolerant seal or improve system design to better control fluid temperature • re-machine dynamic surface to recommended surace finish
F. Seizing	✓ Seal and bearing swell due to incompatible fluid and compound ✓ Thermal expansion of seal compound ✓ Pressure trap between dual squeeze seals ✓ Wedging of seal or backup device into extrusion gap ✓ In low pressure systems shock can cock, cant or disorient seals in the grooves ✓ Bent rod, cocked head, etc.	• analyze seal and fluid options and select compatible options • redesign seal with decreased dimensions, improve hydraulic fluid cooling or select a seal with increased temperature stability • redesign to remove pressure trap • redesign to eliminate extrusion of seal or back- up ring • eliminate shock loading or specify seal with higher shock loading tolerance • repair components as required
G. Scored Ram or Rod	✓ Internally generated contamination ✓ Contamination from external sources, ie: dirty rod, unclean assembly or reassembly ✓ Misoriented exclusion devices/ eccentric installation ✓ Misaligned loads cock ram into metal-to-metal contact with head ✓ Wiper in vertical ram forms catch-all pocket for contamination	• repair ram or rod as required, clean and flush system, install new filters, install fresh hydraulic fluid and replace seal if damaged • remove source of contamination, repair ram or rod as required and replace wiper seal if damaged • correct external problems and repair as required • eliminate misaligned loading and repair as required • eliminate external contamination as much as possible and clean contaminants from wiper area regularly
H. Drift	✓ Refer to sections A and B Hydraulic lock valve leaking ✓ Wrong cast iron rings in a hold cylinder ✓ Static internal seals may provide leakage path past piston ✓ Retract mode creep could be caused by rod or piston seal leakage	• repair as necessary • replace with correct components • replace defective seals • replace seals
I. Increasing Cylinder Drag	✓ Seal swell caused by incompatible installation lubricant ✓ Packing of contaminants into wiper groove of vertical ram ✓ Thermal expansion of bearings and/ or seals ✓ Undetected flow restriction in supply ✓ Bypass of pressure through improperly closing valve ✓ Cocked or twisted seal bypassing fluid and wedging into extrusion gap	• replace seals if necessary using compatible installation lubricant • remove source of contamination, repair ram or rod as required and replace wiper seal if damaged • increase fluid cooling capacity to lower operating temperature or redesign seals/ bearings to operate at higher temperatures • remove flow restriction or return line • repair valve • disassemble, evaluate reason for twisting and replace seal as required
J. Increasing Cylinder/Rod Temperature	✓ See I. (above) causes ✓ Internal leakage throttling past seals ✓ Decreased lubricity of fluid due to contamination or deterioration can boost friction and heating ✓ Diluted fluid can boost friction ✓ Condensation in reservoirs can emulsify or hit cylinders as slugs of fluid with near-zero lubricity ✓ Hot water resulting from condensation can swell the Thorseal polymers increasing friction	• determine reason for leakage and repair or replace as required • drain and flush system and refill with fresh fluid • drain and flush system and refill with fresh fluid • clean and flush system, install new filters, install fresh hydraulic fluid and replace seal if damaged • clean and flush system, install new filters, install fresh hydraulic fluid and replace seal if damaged

Chart 7

TROUBLE SHOOTING

8.3 SEAL PROBLEMS, PROBABLE CAUSES & POSSIBLE SOLUTIONS

Failure & Appearance	Probable Cause	Possible Solution
A. EXTRUSION i. Extrusion occurring on dynamic side of seal heel ii. Extrusion occurring on static side of seal	✓ Excessive pressure Excessive clearances between mating surfaces ✓ Worn bearings ✓ Back-up ring too small Seal support surface uneven	• use alternative seal use a back-up ring • replace bearings • replace with correct size machine support surface
B. DERIORATION i. Seal loses elasticity and cracks or crumbles	✓ High fluid temperature ✓ ✓ Seal exposed to ozone or sunlight	• lower fluid temperature or install higher temp. • seal • ensure seals are not stored near arc welding • or exposed to sunlight
C. SWELLING i. Seal mis-shaped and soft	✓ Incompatibility of seal and hydraulic fluid Water in system	• change either seal or fluid to remove incompatibility drain and re-fill system
D. WEAR i. Wear on one side of the dynamic lip ii. Glossy mirror-like finish on dynamic seal face iii. Egg-shaped wear on dynamic surface	✓ Worn wear ring or bearing Excessive lateral loads ✓ Insufficient lubrication ✓ Un-concentric rod or piston	• replace increase bearing area • increase oil viscosity or use alternate seal • hone to required concentricity or replace worn cylinder tube or rod
E. GROOVING i. Axial cuts on dynamic side of seal	✓ Metal shavings or foreign material in system Imploded air bubbles	• flush and refill system • bleed air from system
F. FRACTURING i. Long cracks in the U section of the seal ii. Pressure side of seal broken and burned iii. Entire side of dynamic lip breaks off iv. Chunks of seal torn from dynamic lip	✓ Low temperature start up High pressure spikes ✓ Residual air exploding or dieseling at high pressure ✓ Fluid or seal material deterioration ✓ Excess back pressure	• warm system before start up • eliminate source of pressure spikes or use alternate seal • check maximum system pressure and bleed air from system • flush system and use alternate seal or fluid • check system relief valves
G. SCARRING i. Scratches on dynamic side of seal lip ii. Groove or cut on the seal lip	✓ Damaged rod or cylinder wall cycles Improper installation Seal stored by hanging on peg or nail	• hone, polish and de-burr • replace damaged rod or cylinder • carefully use proper installation tools without sharp surfaces • store seals flat
H. HARDENING i. Dynamic seal face hard-ened causing glazing and cracks ii. Loss of elasticity and hardening of entire seal	✓ High stroke speed producing excess heat ✓ High fluid temperature Seal and fluid incompatible ✓ Deterioration of fluid	• slow stroke speed or use alternate sealing device • lower fluid temperature • change to alternate seal or fluid • replace fluid

Chart 8

9.0 APPLICATIONS

9.1 Introduction

The applications for Thorseal in hydraulic/pneumatic cylinders are numerous and the following list covers only a few of the more important industrial segments. Thorseals will perform well in hydraulic/pneumatic cylinders used in virtually any industry.

9.2 Steel Industry

The steel industry environment has some of the harshest operating conditions for cylinders or rams and the benefits are significant when high performance, reliable Thorseals are specified. The high loads, high temperatures and very abrasive environment demand the best in hydraulic/pneumatic seals.

Typical Applications Include:

- Roll Levelling Cylinders
- Upenders
- Roughing Mill Rolls
- Presses

9.3 Injection Molding Industry

The injection molding environment is much cleaner than the steel industry, but has other demanding requirements. Extremely high operating pressures, high soak back temperatures, polymer contamination and continuous operation are among the demanding operating conditions. Applications vary with the type of injection molding. ie: ram type or screw type, but most injection molding machines use cylinders in their operation.

Typical Applications Include:

- Main clamping cylinder
- Injection system
- Pull back system
- Ejection system
- Hot runner valve operation
- Gate valve operation
- Other cylinder operations

9.4 Power Plant Industry

A number of hydraulic cylinder applications are found in the power plant industry.

Typical Applications Include:

- Damper controls
- Burner system controls
- Conveyor handling controls
- Valve controls

9.5 Automotive Industry

The automotive industry is a heavy user of hydraulic/pneumatic cylinders. The applications range from relatively light to heavy duty but, due to the high downtime costs of unscheduled maintenance, reliability and long life are prime concerns making Thorseals an obvious choice.

Typical Applications Include:

- Stamping presses
- Material handling equipment
- Assembly equipment
- All types of robotic equipment

9.6 Metalworking Industry

The metalworking industry is literally driven by hydraulic cylinders operating under relatively high loads and continuous duty cycles.

Typical Applications Include:

- Presses
- Material handling equipment

9.7 Tiremaking Industry

Hydraulics are used extensively throughout the tire making business.

Typical Applications Include:

- Material handling equipment
- Presses

APPLICATIONS

9.8 Construction and Agricultural Equipment

Hydraulic cylinders are used extensively on virtually all construction equipment and most agricultural equipment. The applications are difficult with high abrasive levels, heavy shock loading and long duration duty cycles.

Typical Applications Include:

- Bulldozers
- Earthmovers
- Payloaders
- Dump trucks
- Pipeline and drainage equipment
- Combine harvesters
- Tillage equipment

9.9 Forestry Industry

Cutting and handling trees require the use of heavy industrial equipment with cylinders designed to handle impact loads and operate in extreme temperatures.

The equipment used includes the following typical applications:

- Kicker linkages
- Grapple cylinders
- Logging skidders
- Loaders

9.10 Hydro-Electric Industry

This industry has some of the best controlled systems in the world and demand performance from the cylinders, continuously, 24 hours a day.

Typical applications include:

- Wicket gate and operating mechanism bearing seals
- Servo-motor and hydraulic/pneumatic seals
- Kaplan turbine runner blade stern seals
- Blade pitch seals
- Brake/jack cylinders

9.11 Marine Industry

- Rudder seals
- Stern rollers
- Shipboard hydraulics
- Cargo handling

9.12 General Industry

There are many other applications in a wide variety of industries not mentioned above:

- Truck hoists
- Mining trucks
- Track vehicles
- Loading vehicles
- Robot systems
- Tow trucks
- Waste handling trucks
- Compactors
- Snow plows
- Plunger pumps

10.0 DESIGNS FOR SPECIAL APPLICATIONS

There are a number of special sealing applications for which both standard and custom designed Thorseals have been successfully specified. A listing of these applications with a reference number referring to the corresponding drawing follows.

10.1 Thorseal and Back-up Ring For Hydro-Turbine Servo-Motor

10.2 Thorseal For Hydro-Turbine Lower Wicket Gate Bearing

10.3 Split Gland-Mounted Flexlip Thorseal for Kaplan Style Hydro-Turbine Runner Blade Shaft

10.4 Flexlip Thorseal For Stern Rollers On Offshore Anchor Handling Vessel

10.5 Flexlip Thorseals For Wind Turbine Head Yaw Bearing

10.6 Heavy Duty Thorseal Pipe Test Seal

10.7 Standard Thorseal Pipe Test Seal

10.8 Flexlip Thorseal Gate Valve Seal

10.9 Flexlip Thorseal Pump Restrictor Seal

10.10 One Piece Flexlip Thorseal Double Acting Piston Seal

10.11 Special Flexlip Thorseal Cup Seal

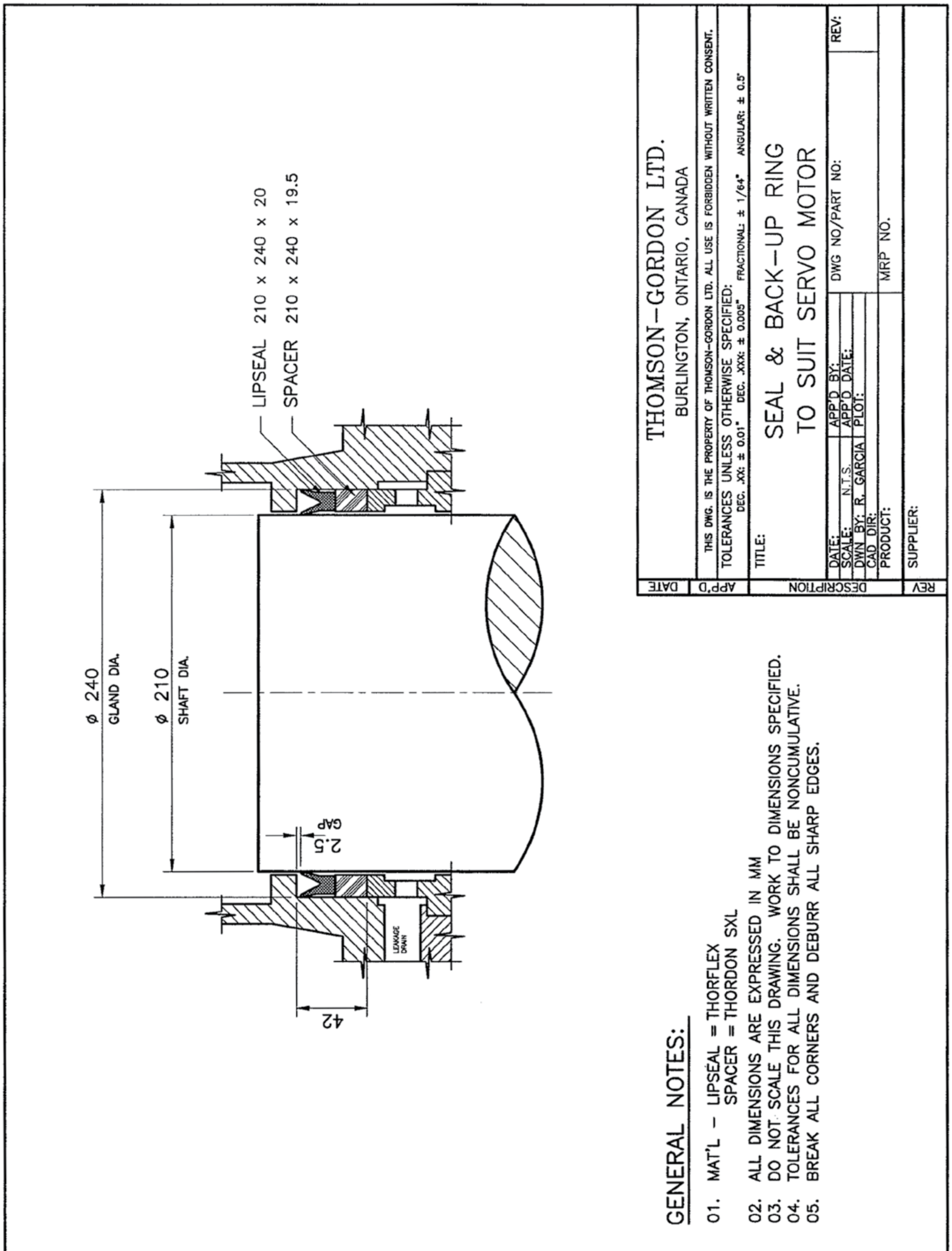
10.12 Combination Thorseal Seal and Wiper

10.13 Special Thorseal Telescopic Cylinder Static Seal

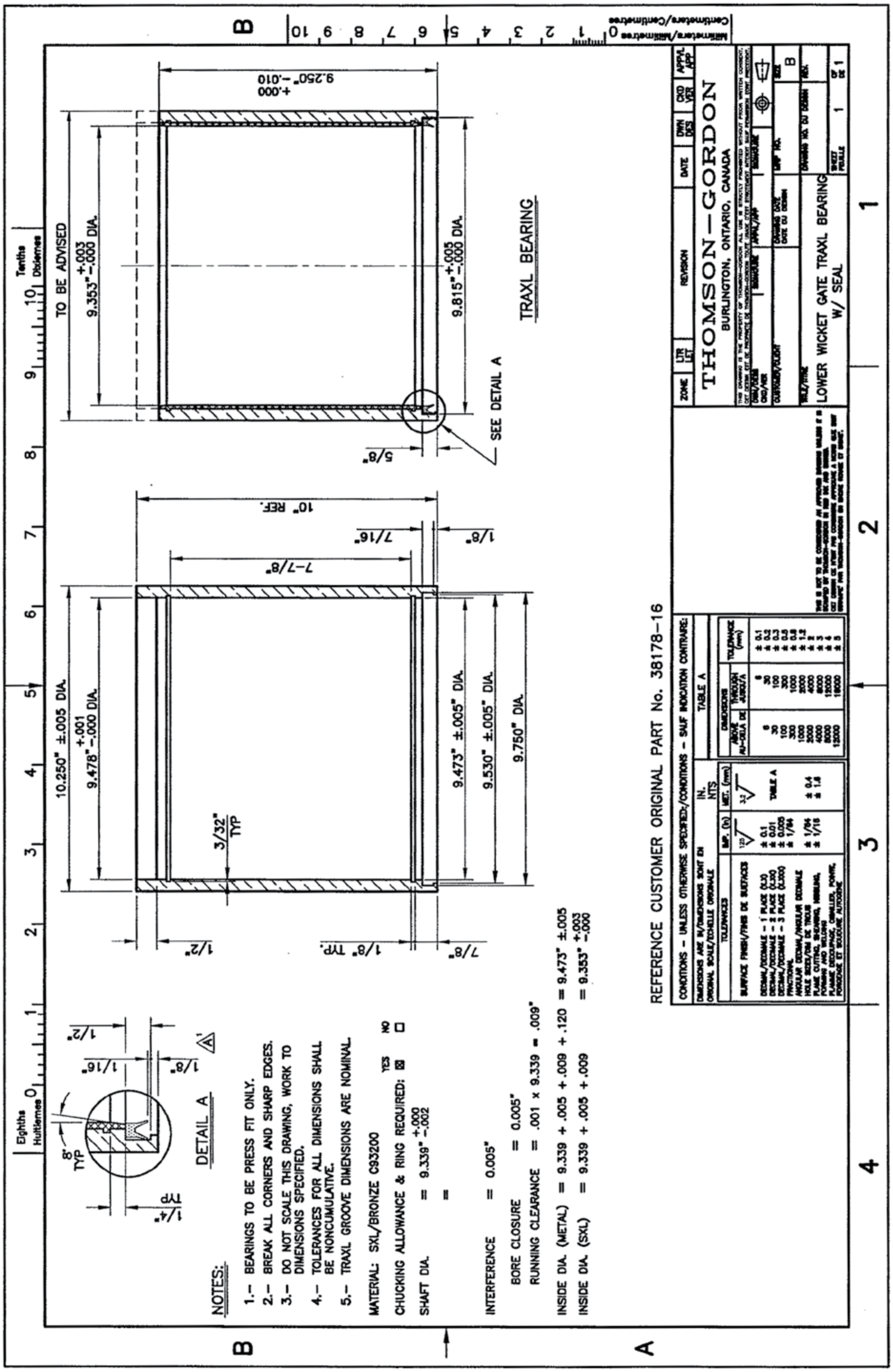
10.14 Dual Thorseals for Wicket Gate Bearing

10.15 Flexlip Thorseal for Brake Seal

10.16 Flexlip Thorseal for Clutch Seal

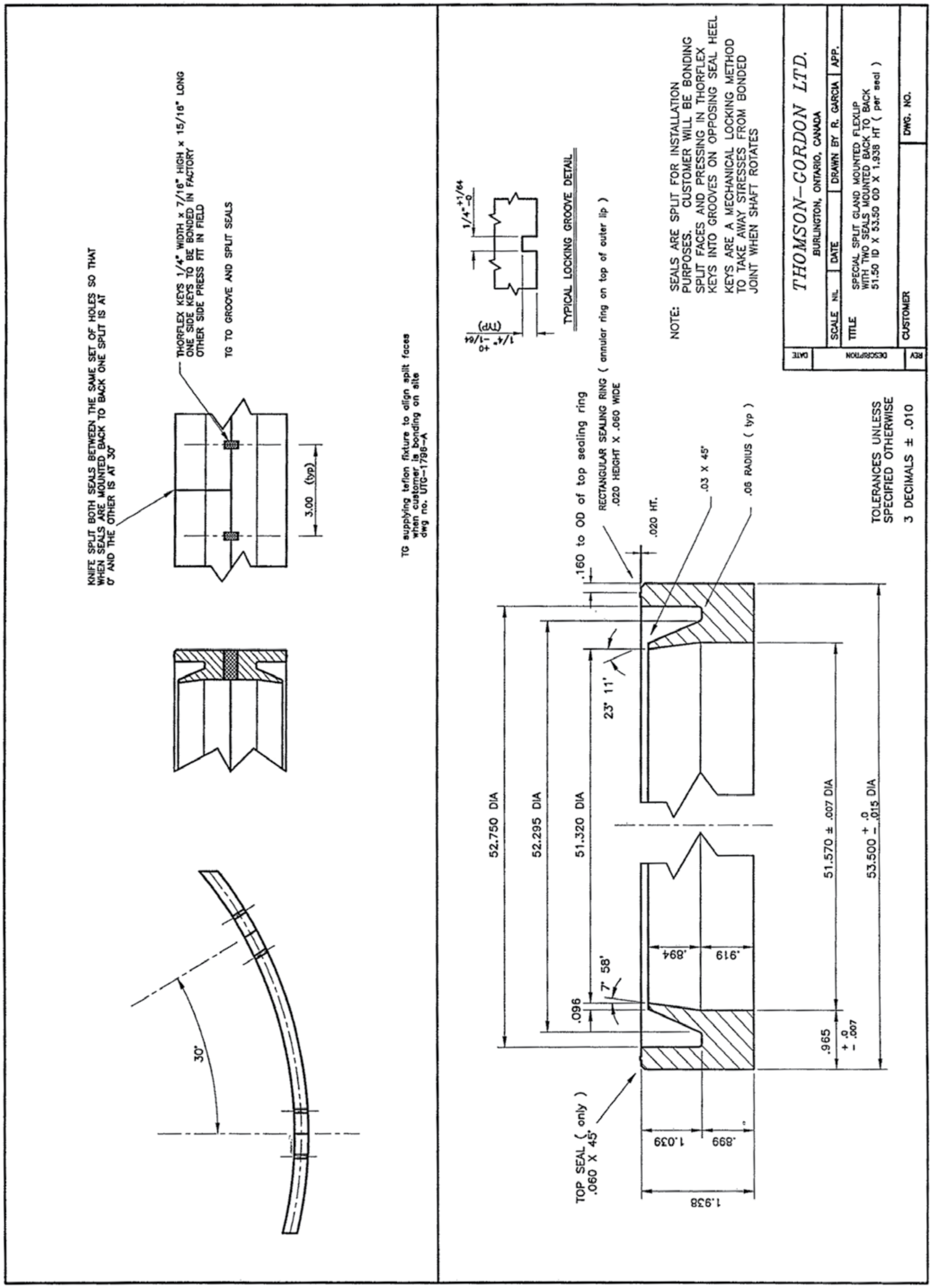

THOMSON-GORDON LTD.
BURLINGTON, ONTARIO, CANADA
THIS DWG. IS THE PROPERTY OF THOMSON-GORDON LTD. ALL USE IS FORBIDDEN WITHOUT WRITTEN CONSENT.
TOLERANCES UNLESS OTHERWISE SPECIFIED:
DEC. .XX: ± 0.01" DEC. .XXX: ± 0.005" FRACTIONAL: ± 1/64" ANGULAR: ± 0.5°
TITLE:
SEAL & BACK-UP RING
TO SUIT SERVO MOTOR
DATE:
SCALE: N.T.S.
DWN BY: R. GARCIA
CAD DIR:
APP'D BY:
APP'D DATE:
PLOT:
PRODUCT:
DWG NO/PART NO:
MRP NO.
SUPPLIER:
REV:
DATE
APP'D
DESCRIPTION
REV
LIPSEAL 210 x 240 x 20
SPACER 210 x 240 x 19.5
ϕ 240
GLAND DIA.
ϕ 210
SHAFT DIA.
2.5
GAP
LEAKAGE DRAIN
42
GENERAL NOTES:
01. MAT'L – LIPSEAL = THORFLEX
SPACER = THORDON SXL
02. ALL DIMENSIONS ARE EXPRESSED IN MM
03. DO NOT SCALE THIS DRAWING. WORK TO DIMENSIONS SPECIFIED.
04. TOLERANCES FOR ALL DIMENSIONS SHALL BE NONCUMULATIVE.
05. BREAK ALL CORNERS AND DEBURR ALL SHARP EDGES.

Drawing 10.1

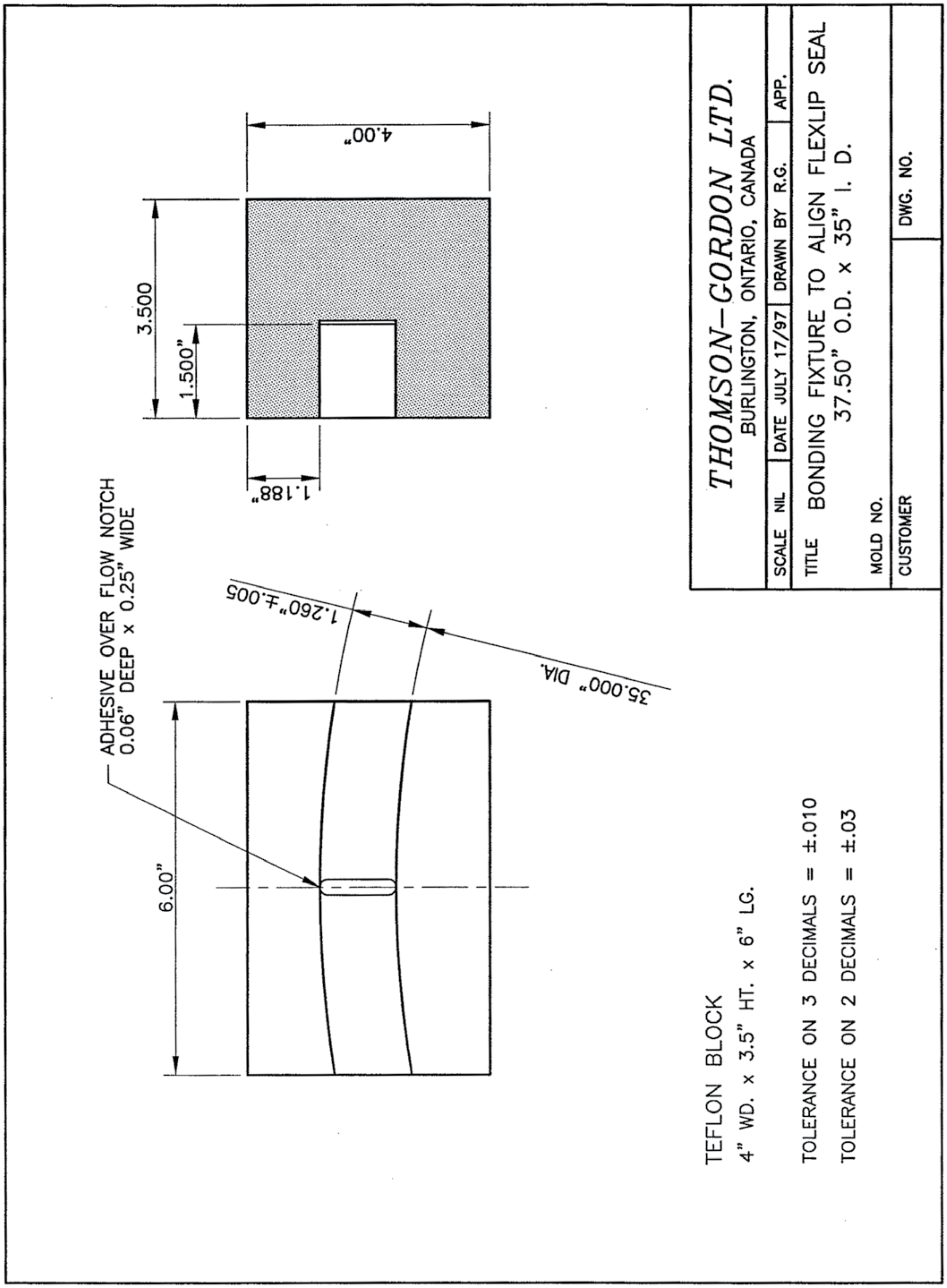


NOTES:
1.- BEARINGS TO BE PRESS FIT ONLY.
2.- BREAK ALL CORNERS AND SHARP EDGES.
3.- DO NOT SCALE THIS DRAWING, WORK TO DIMENSIONS SPECIFIED.
4.- TOLERANCES FOR ALL DIMENSIONS SHALL BE NONCUMULATIVE.
5.- TRAXL GROOVE DIMENSIONS ARE NOMINAL.
MATERIAL: SXL/BRONZE C93200
CHUCKING ALLOWANCE & RING REQUIRED:
INTERFERENCE = 0.005"
BORE CLOSURE = 0.005"
RUNNING CLEARANCE = .001 x 9.339 = .009"
INSIDE DIA. (METAL) = 9.339 + .005 + .009 + .120 = 9.473" ±.005
INSIDE DIA. (SXL) = 9.339 + .005 + .009 = 9.353"
DETAIL A
TRAXL BEARING
SEE DETAIL A
TO BE ADVISED
10.250" ±.005 DIA.
9.473" ±.005" DIA.
9.530" ±.005" DIA.
9.750" DIA.
10" REF.
REFERENCE CUSTOMER ORIGINAL PART No. 38178-16
THOMSON-GORDON
BURLINGTON, ONTARIO, CANADA
LOWER WICKET GATE TRAXL BEARING W/ SEAL

Drawing 10.2

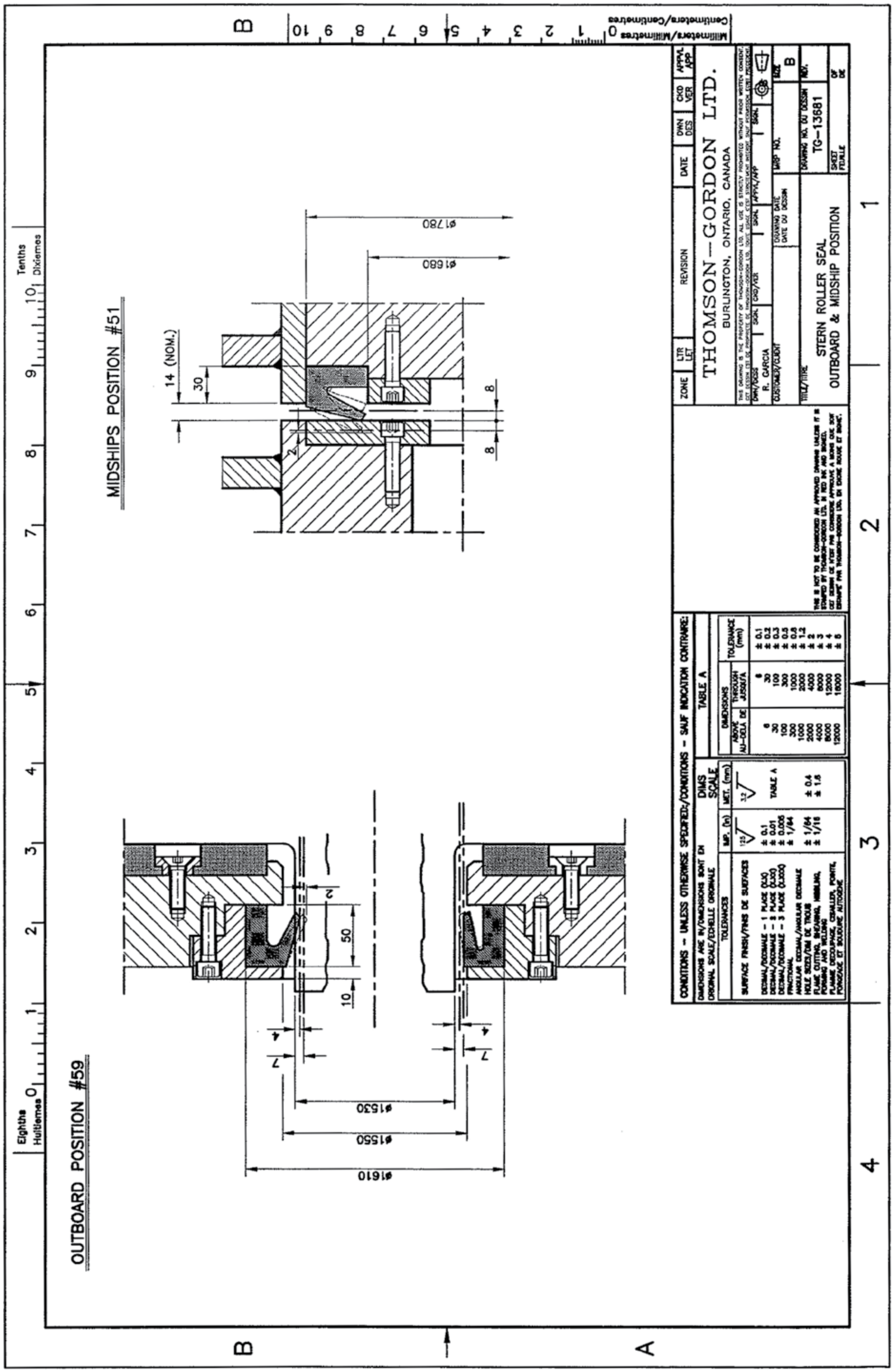


Drawing 10.3.1

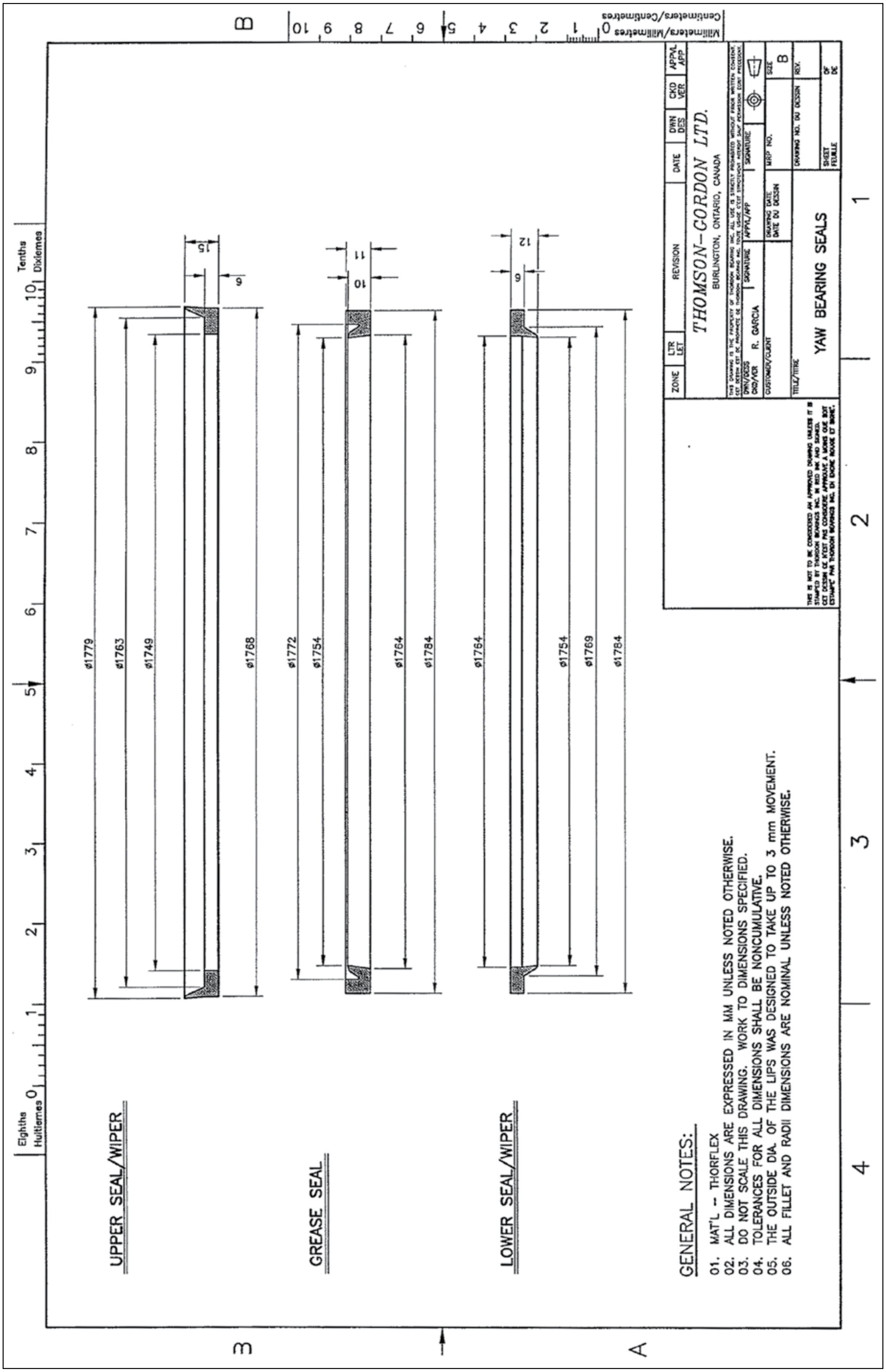


Drawing 10.3.2

P–10103B

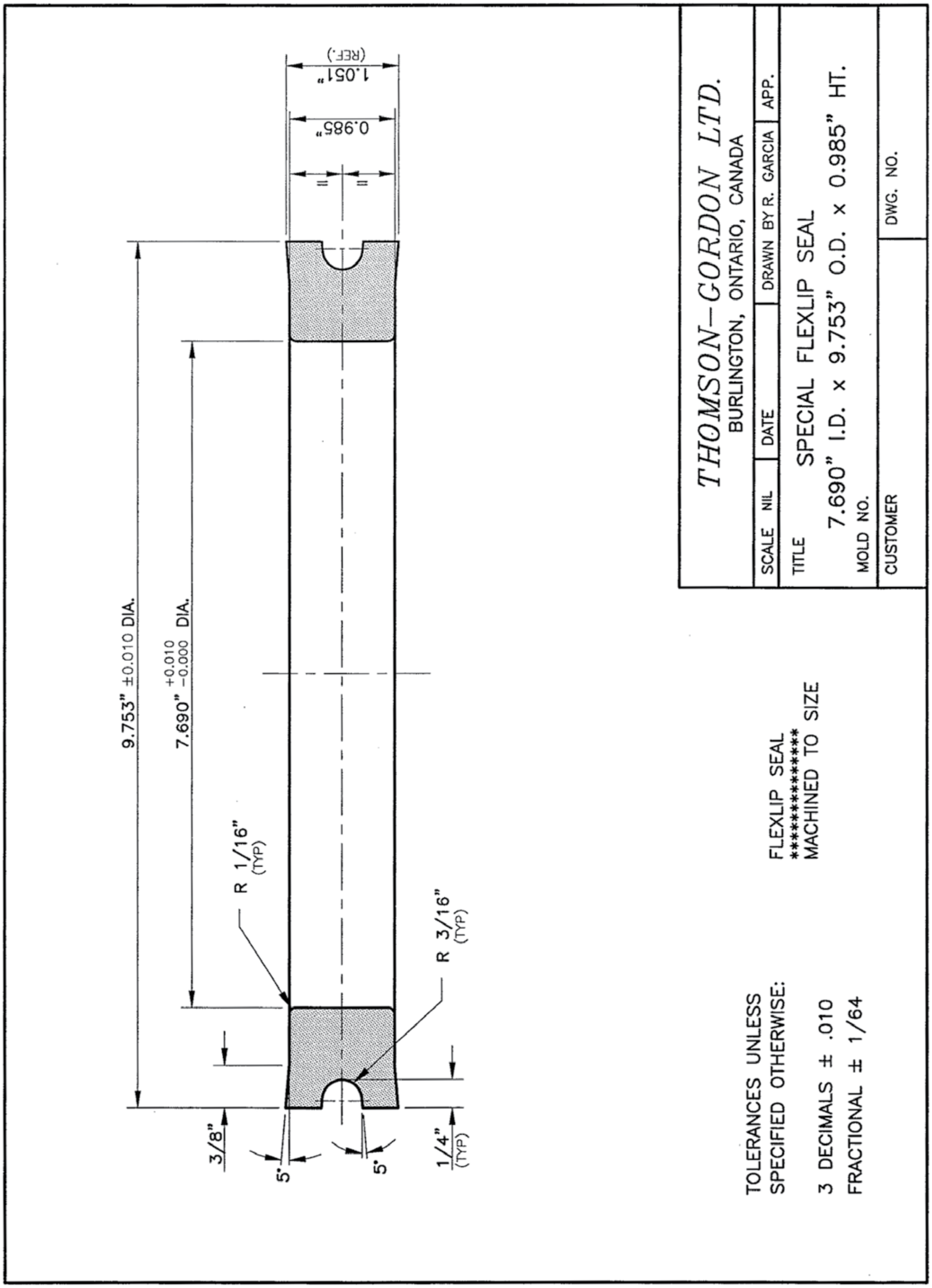

OUTBOARD POSITION #59
MIDSHIPS POSITION #51
THOMSON-GORDON LTD.
BURLINGTON, ONTARIO, CANADA
STERN ROLLER SEAL
OUTBOARD & MIDSHIP POSITION
TG-13681

Drawing 10.4

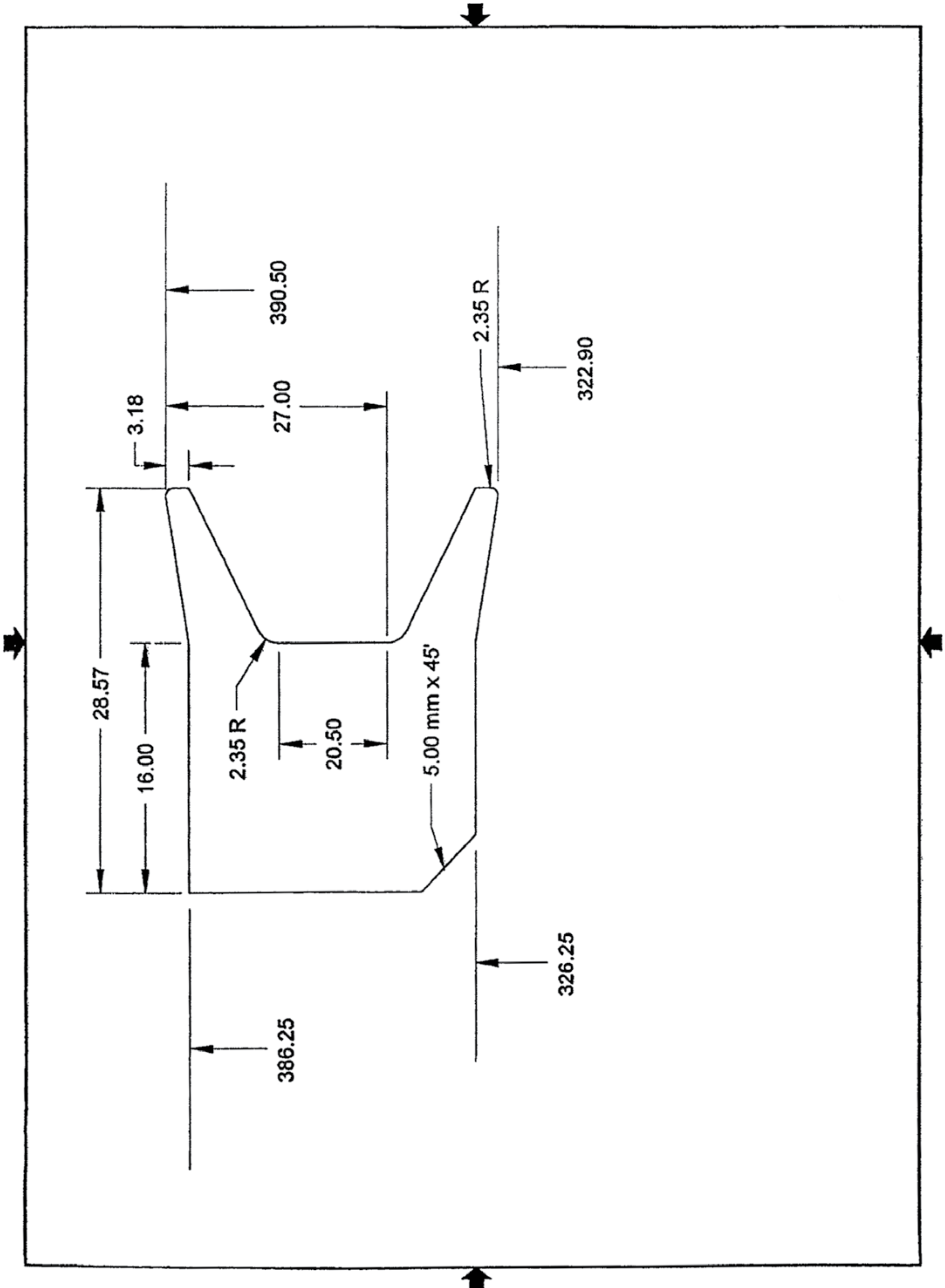


UPPER SEAL/WIPER
ø1779
ø1763
ø1749
ø1768
15
9
GREASE SEAL
ø1772
ø1754
ø1764
ø1784
11
10
LOWER SEAL/WIPER
ø1764
ø1754
ø1769
ø1784
12
9
GENERAL NOTES:
01. MAT'L -- THORFLEX
02. ALL DIMENSIONS ARE EXPRESSED IN MM UNLESS NOTED OTHERWISE.
03. DO NOT SCALE THIS DRAWING. WORK TO DIMENSIONS SPECIFIED.
04. TOLERANCES FOR ALL DIMENSIONS SHALL BE NONCUMULATIVE.
05. THE OUTSIDE DIA. OF THE LIPS WAS DESIGNED TO TAKE UP TO 3 mm MOVEMENT.
06. ALL FILLET AND RADII DIMENSIONS ARE NOMINAL UNLESS NOTED OTHERWISE.
THOMSON-GORDON LTD.
BURLINGTON, ONTARIO, CANADA
R. GARCIA
YAW BEARING SEALS

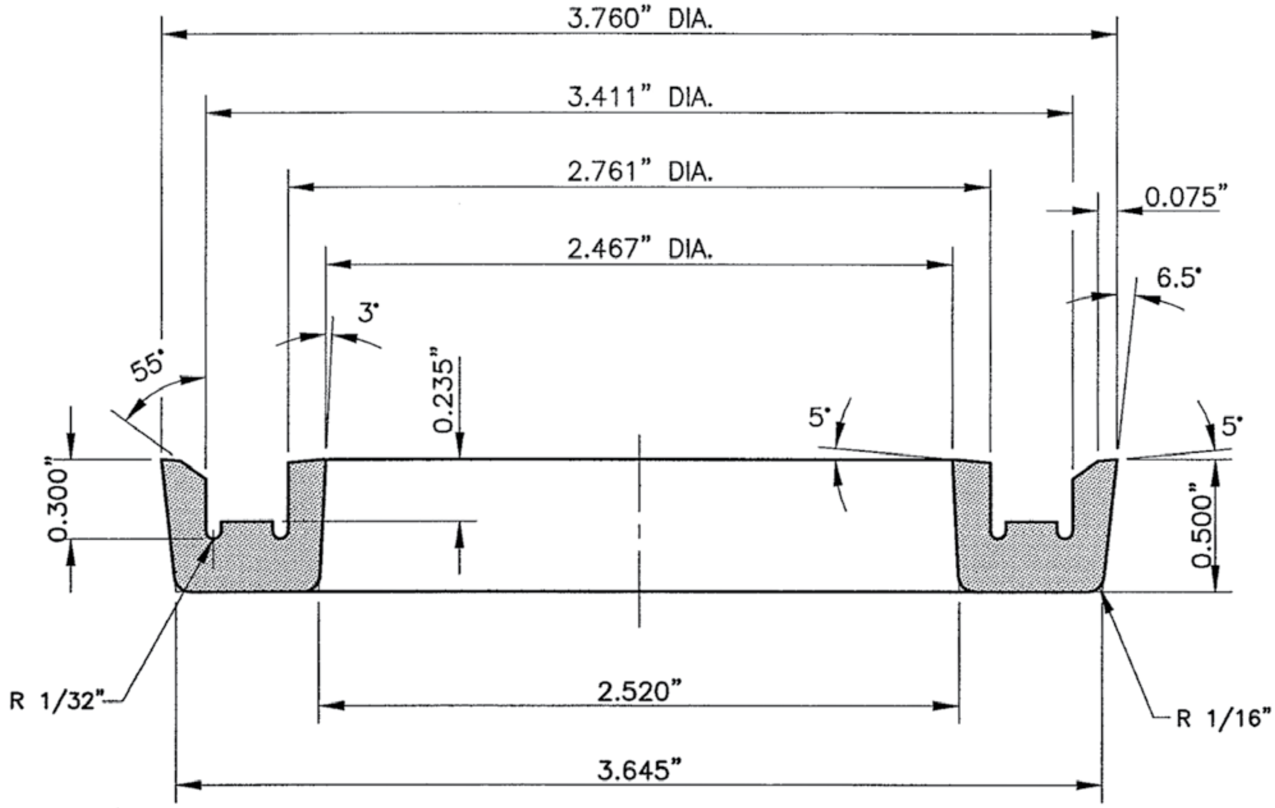
Drawing 10.5


THOMSON–GORDON LTD.
BURLINGTON, ONTARIO, CANADA
SCALE NIL
DATE
DRAWN BY R. GARCIA
APP.
TITLE
SPECIAL FLEXLIP SEAL
7.690" I.D. x 9.753" O.D. x 0.985" HT.
MOLD NO.
CUSTOMER
DWG. NO.
TOLERANCES UNLESS SPECIFIED OTHERWISE:
3 DECIMALS ± .010
FRACTIONAL ± 1/64
FLEXLIP SEAL
MACHINED TO SIZE
9.753" ±0.010 DIA.
7.690" +0.010 −0.000 DIA.
R 1/16" (TYP)
R 3/16" (TYP)
3/8"
1/4" (TYP)
5°
5°
0.985"
1.051" (REF.)

Drawing 10.6


390.50
3.18
27.00
2.35 R
322.90
28.57
16.00
2.35 R
20.50
5.00 mm x 45'
326.25
386.25

Drawing 10.7



FLEXLIP SEAL
****
MACHINED TO SIZE

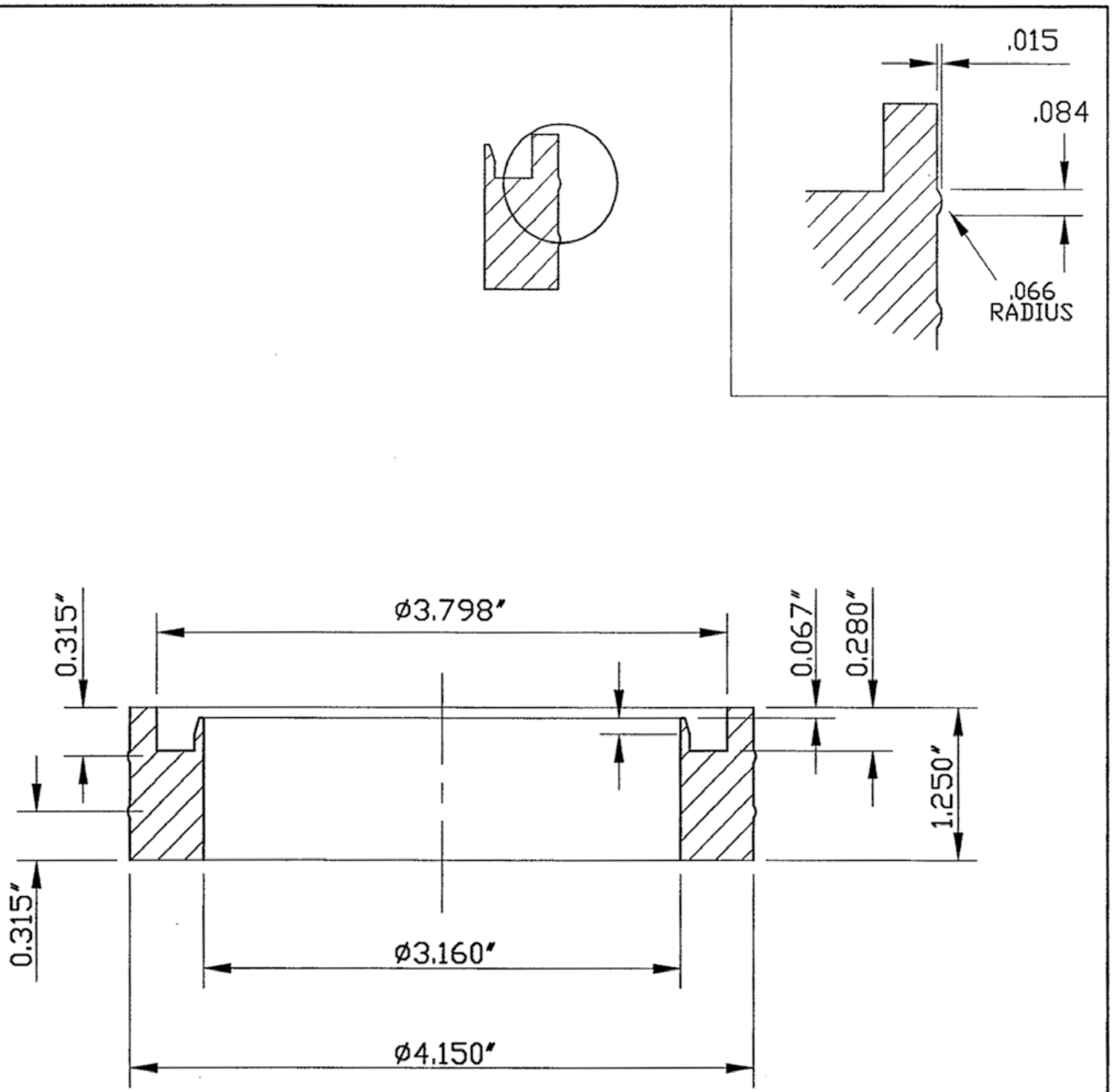
TOLERANCES UNLESS SPECIFIED OTHERWISE:

3 DECIMALS ± .010

FRACTIONAL ± 1/64

THOMSON–GORDON LTD. BURLINGTON, ONTARIO, CANADA			
SCALE NIL	DATE MAY 04/98	DRAWN BY R.G.	APP.
TITLE FLEXLIP SPECIAL VALVE SEAL			
MOLD NO.			
CUSTOMER		DWG. NO.	

Drawing 10.8



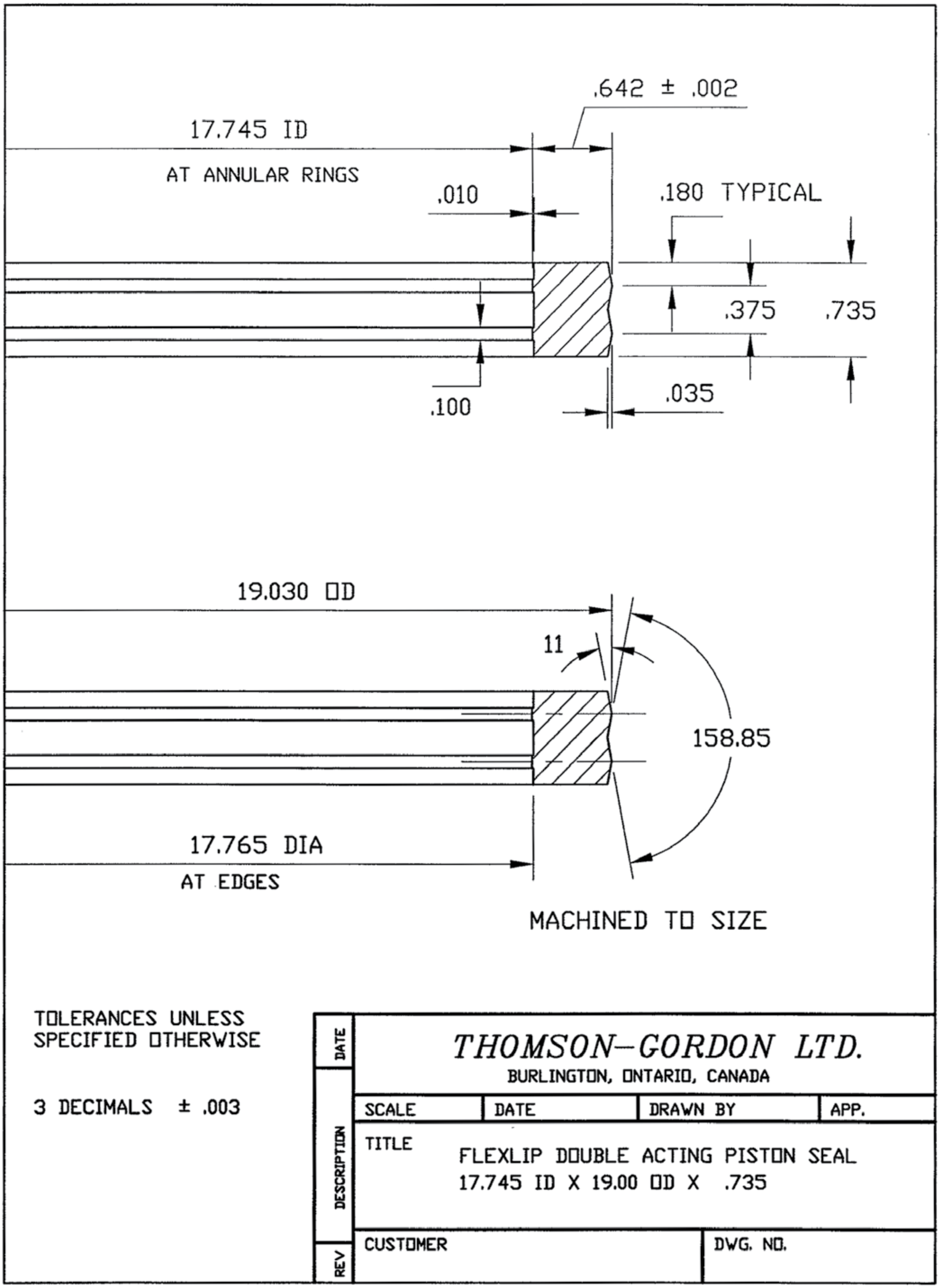
MACHINED TO SIZE WITH ONE 10° SPLIT

TOLERANCES UNLESS SPECIFIED OTHERWISE:

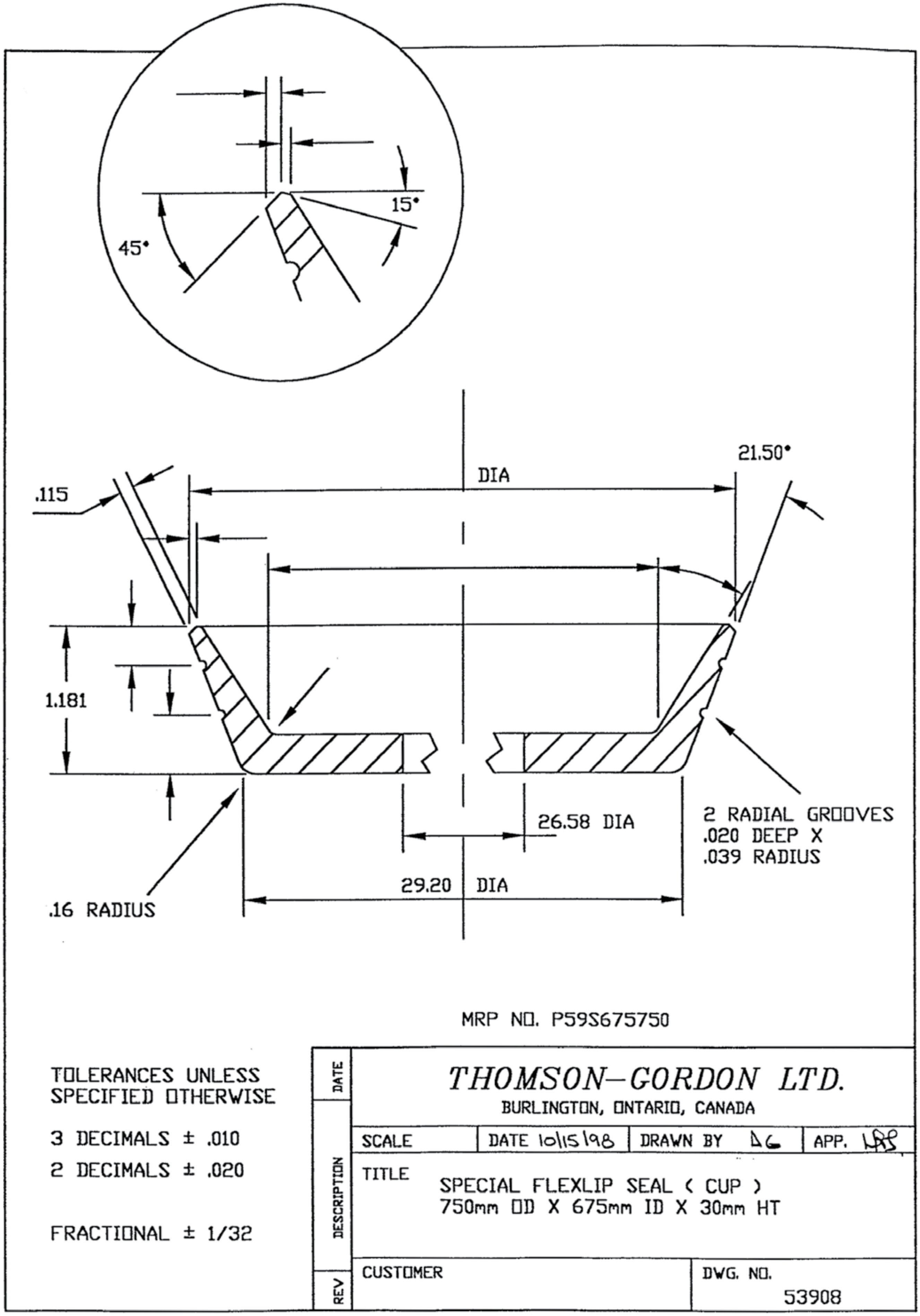
3 DECIMALS	± .005
2 DECIMALS	± .010
FRACTIONAL	± 1/64

DATE	*THOMSON–GORDON LTD.* BURLINGTON, ONTARIO, CANADA			
	SCALE	DATE	DRAWN BY	APP.
DESCRIPTION	TITLE SPECIAL FLEXLIP RESTRICTION SEAL 3.150 SHAFT X 4.150 HOUSING X 1.25 HT			
REV	CUSTOMER		DWG. NO.	

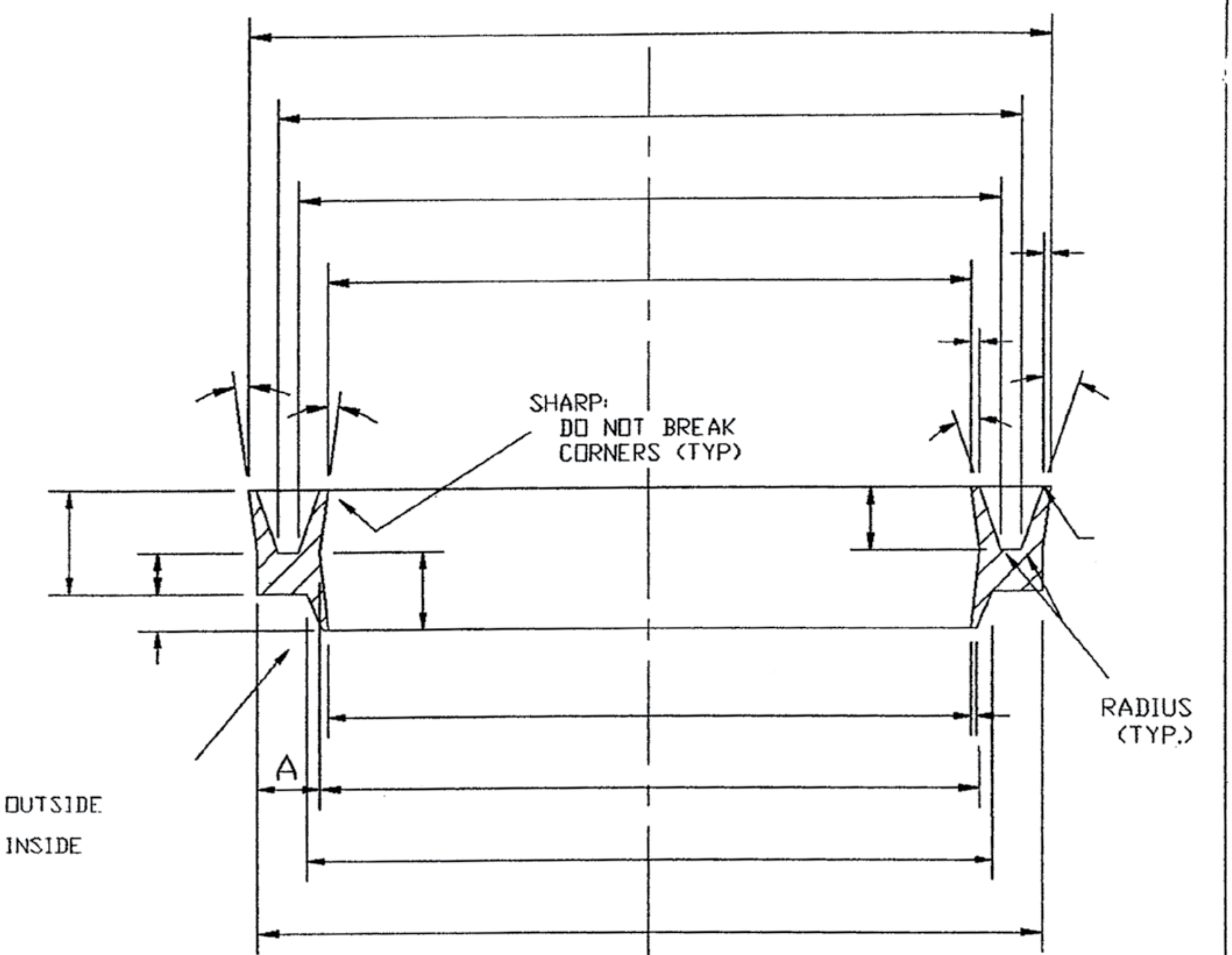
Drawing 10.9



Drawing 10.10



Drawing 10.11



DIMENSION "A" MUST BE ______

TOLERANCES UNLESS SPECIFIED OTHERWISE:

3 DECIMALS ±

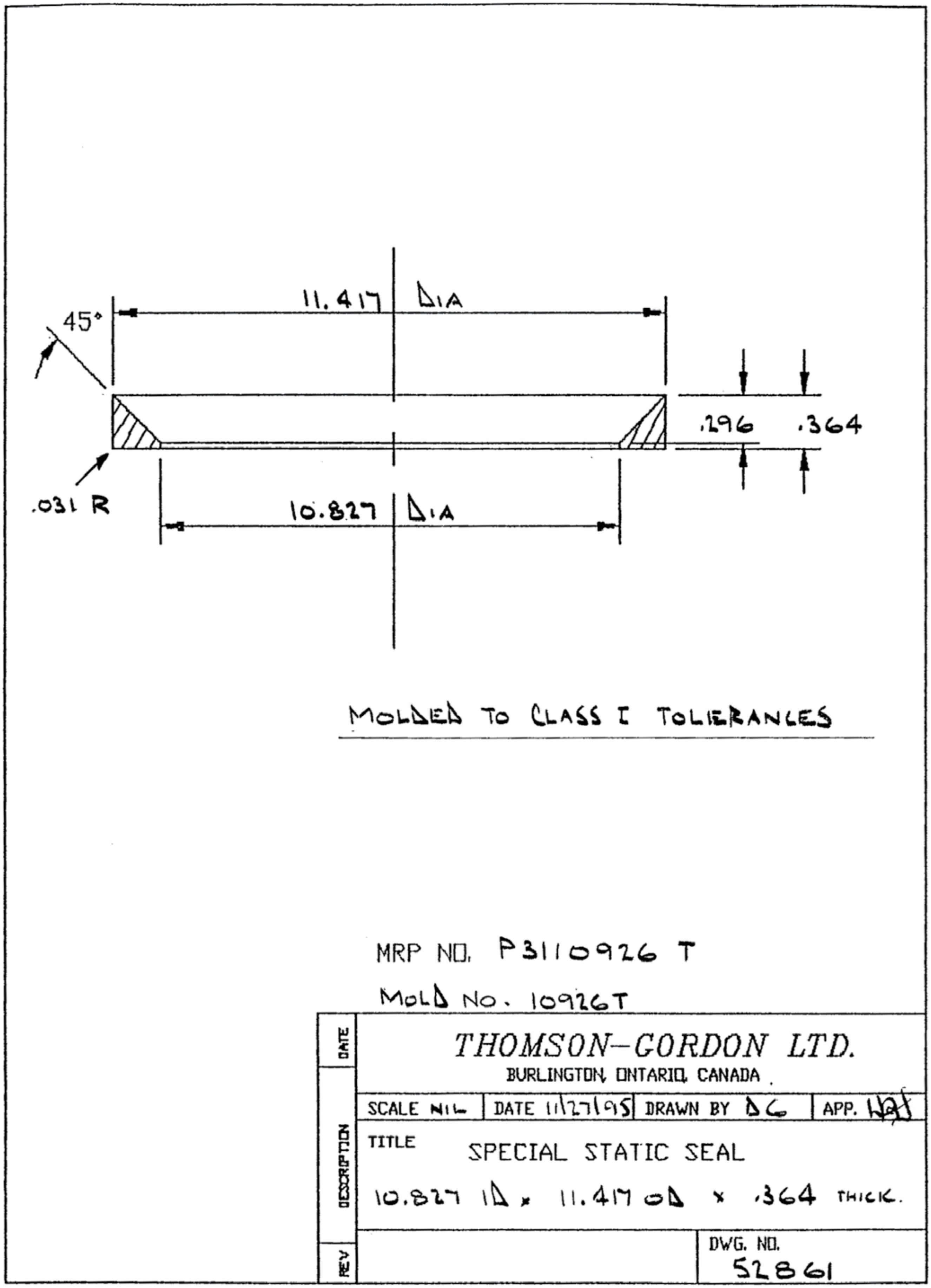
2 DECIMALS ±

FRACTIONAL ± 1/64

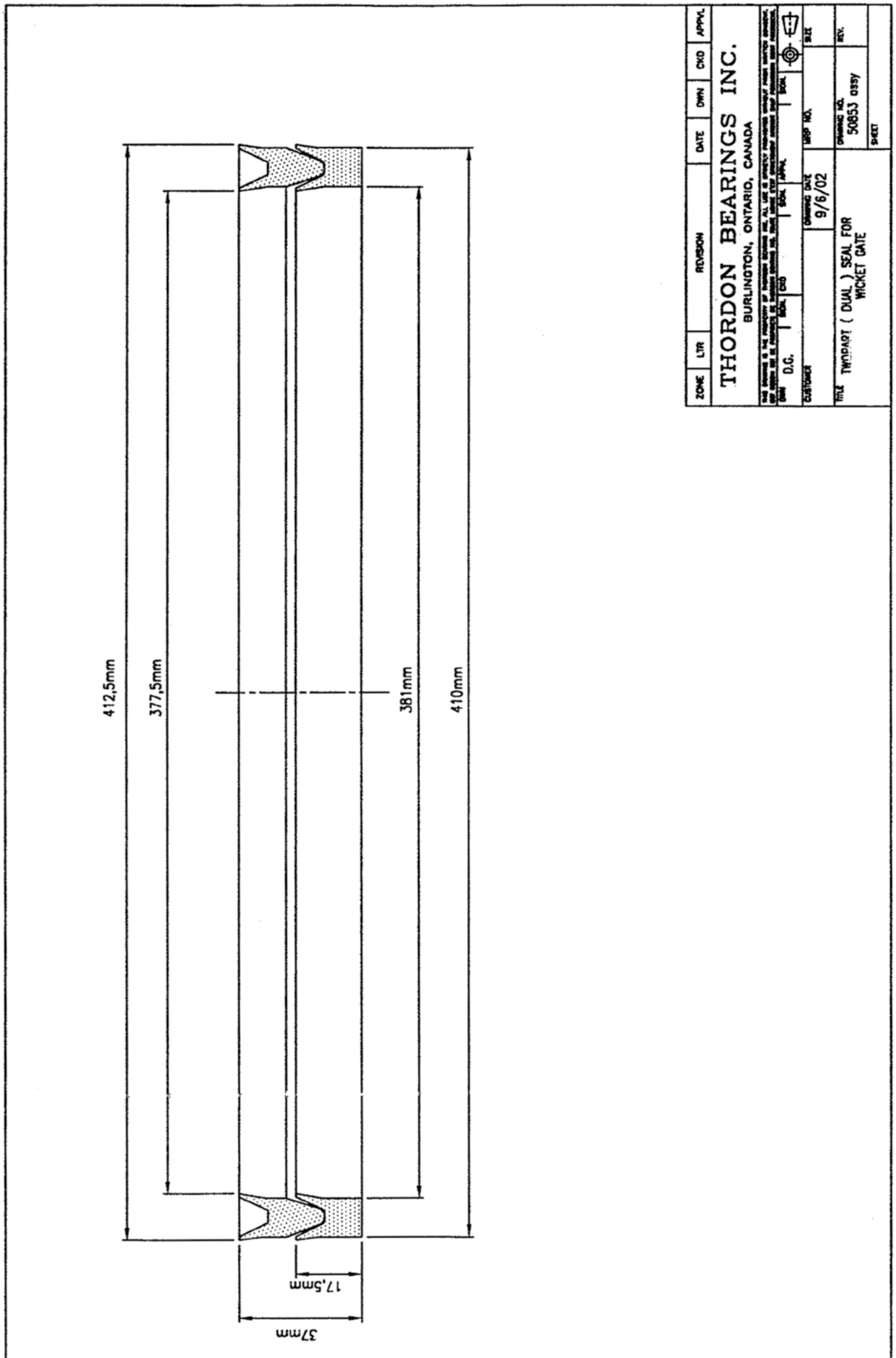
THOMSON–GORDON LTD.
BURLINGTON, ONTARIO, CANADA

SCALE NIL	DATE	DRAWN BY	APP.
TITLE			
MOLD NO.			
CUSTOMER		DWG. NO.	

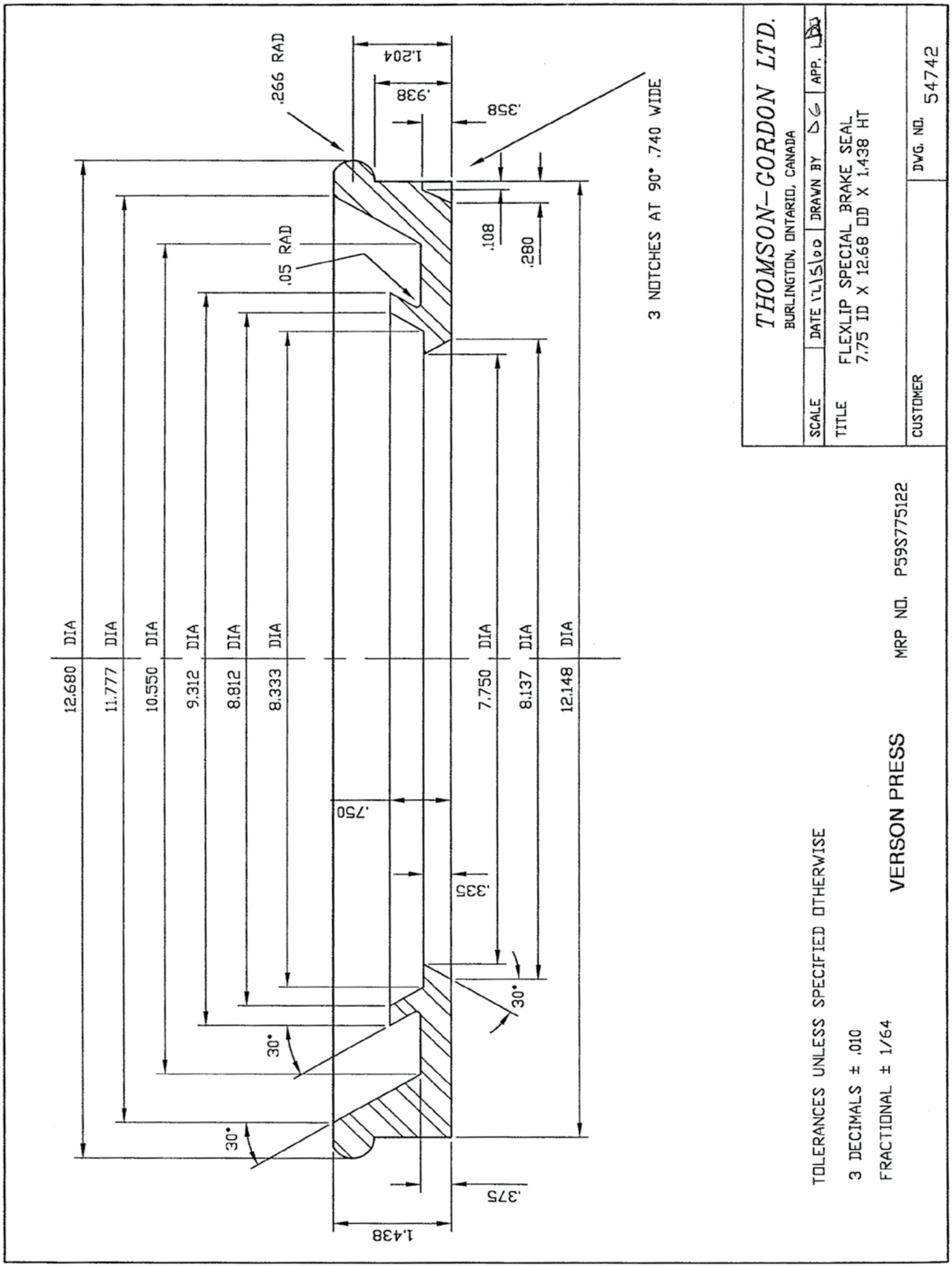
Drawing 10.12



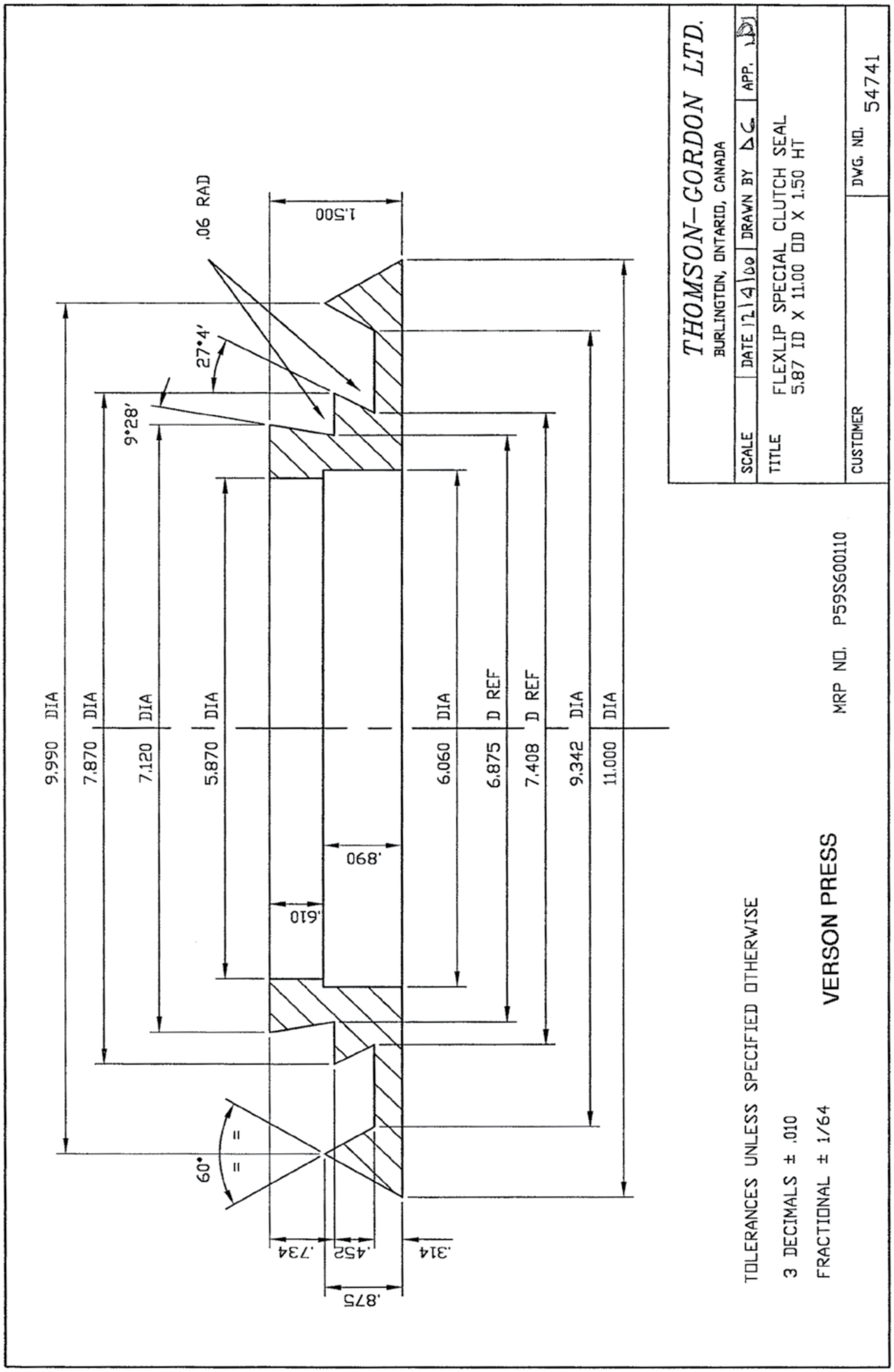
Drawing 10.13



Drawing 10.14



Drawing 10.15



Drawing 10.16

APPENDIX I

GLOSSARY OF TERMS

Abrasion
Mechanical wearing away of material.

Abrasion Resistance
The ability of a material to resist mechanical wear.

Acid Resistant
The ability to withstand the action of acid.

Aliphatic
Organic compounds whose molecules do not have their carbon atoms arranged in a ring structure. This category includes all the paraffin hydrocarbons and their saturated and unsaturated derivatives of all types.

Aromatic
A chemical compound containing as its primary structure one or more unsaturated 6 carbon ring structures. For example: benzene, naphthalene, etc. or compounds derived from them.

A.S.T.M. - American Society of Testing Materials
This organization is devoted to establishing testing specifications for various materials.

Cross-Section
A part as viewed if cut in the plane of the axis. This shows the internal structure.

Cup Seal
A particular type of pneumatic or hydraulic sealing device which seals primarily on its outside diameter.

Durometer
A measure of hardness used in describing a rubber-like material.

Dynamic Seal
A device required to prevent leakage past parts in relative motion.

Extrusion
Distortion, under pressure, of a portion of a seal into the clearance between mating metal parts.

Finish
Surface condition of materials; for metals, measured in terms of RMS.

Friction
Resistance to motion due to the contact of surfaces.

Fuel, Aromatic
Fuel which contains benzene or aromatic hydrocarbons.

Fuel, Non-Aromatic
Fuel which is composed of straight chain hydrocarbons.

Gland
A movable part that compresses or retains a seal in a stuffing box.

Hardness
Property or extent of failure of the indentor point of a standard hardness testing instrument to penetrate the product.

Homogeneous
The condition of uniform composition throughout a material.

Piston
Reciprocating member mounted inside a cylinder where it is driven by or against the pressure medium.

Polymer
A chemical compound or mixture of compounds formed by polymerization and consisting essentially of repeating structural units.

Pressure
Force per unit area, usually expressed in pounds per square inch (psi) or mega pascals (MPa).

Resilience
Capable of returning to original size and shape after deformation.

R.M.S. - Root mean sqaure
or average deviation from a theoretically perfect surface, is used to define surface finish roughness.

Seal
A flexible device used to retain fluids under pressure or seal out foreign material.

Swell
Increased volume of a seal caused by immersion in fluid.

"U" Cup
A specific type of pneumatic or hydraulic seal which makes its seal on the inside and outside diameter lips.

APPENDIX II

THORSEAL, THORCUP, THORWIPER & THORPAK CHEMICAL COMPATIBILITY CHART

Aero Lubriplate	1
Aero Lubriplate	1
Aero Shell IAC	1
Aero Shell ?A Grease	1
Aero Shell 17 Grease	1
Air, 200°F	1
Atlantic Utro Gear EP Lube	1
Aluminum Bromide	1
Aluminum Chloride	1
Aluminum Fluoride	1
Aluminum Salts	1
Aluminum Sulphate	1
Alums-NH-CR-K	1
Ambrex 830 (Mobil)	1
Amyl Acetate	1
AN-O-3 Grade M	1
AN-0-6	1
ANO-366	1
Argon	1
Aurex 903R (Mobil)	1
ASTMOil, No.1	1
ASTM Reference Fuel A	1
Barium Chloride	1
Barium Salts	1
Barium Sulfide	1
Borax	1
Boric Acid	1
Brayco 885 (MIL-L-6085A)	1
Butter-Animal Fat	1
Calcium Bisulfite	1
Calcium Chloride	1
Calcium Nitrate	1
Calcium Phosphate	1
Calcium Salts	1
Calcium Sulfide	1
Calcium Sulfite	1
Calcium Thiosulfate	1
Caliche Liquors	1
Carbon Dioxide, Dry	1
Carbon Monoxide	1
Carbonic Acid	1
Castor Oil	1
Circo Light Process Oil	1
City Service Koolmotor-AP Gear Oil 140-E.P. Lube	1
Cobalt Chloride	1
Cod Liver Oil	1
Copper Chloride	1
Copper Cyanide	1
Copper Salts	1
Copper Sulfate	1
Cutting Oil	1
Cyclohexane	1
Diethyl Ether	1
Dow Corning -3	1
-4	1
-5	1
-11	1
-33	1
-44	1
-55	1
-200	1
-510	1
-710	1
-1208	1
-4050	1
-6620	1
-F60	1
-F61	1
-XF60	1
Elco 28-Ep Lubricant	1
Esso XP90-EP Lubricant	1
Ethylcyclopentane	1
Ethylene Glycol	2
F-60 Fluid (Dow Corning)	1
F-61 Fluid (Dow Corning)	1
Ferric Chloride	1
Ferric Nitrate	1
Freon, 12	1
Freon, 14	1
Freon, 113	1
Freon, PCA, TF	1
Fyrquel A60, 90, 100, 150, 220, 30, 500	4
Glycols	4
Green Sulphate Liquor	3
Gulfcrown Grease	1
Gulf Endurance Oils	1
Gulf FR Fluids (Emulsion)	1
Gulf Harmony Oils	1
Gulf High Temp. Grease	1
Gulf Legion Oils	1
Hannifin Lube A	1
Helium	1
Hydraulic Oil (Petroleum Base)	1
Hydrogen Gas, Cold, Hot	1
Hydrolube Water/Ethylene Glycol	4
Kerosene (Similar to RP-1 and JP-1)	1
Keystone #87HX-Grease	1
Lard, Animal Fat	1
Lehigh X1169	1
Lehigh X1170	1
Light Grease	1
Liquid Petroleum Gas (LPG)	1
Magnesium Chloride	1
Magnesium Salts	1
MIL-L-2104	1
MIL-S-3136	1
Type I Fuel	1
Type III Fuel	1
Type IV Oil, Low Swell	1
Type V Oil, Med Swell	1
Type VI Oil, High Swell	1
MIL-O-3503	1
MIL-G-3545	1
MIL-L-4343	1
MIL-L-6081	1
MIL-L-6082	1
MIL-L-6083	1
MIL-L-6085	1
MIL-L-6387	1
MIL-C-7024	1
MIL-G-7118	1
MIL-G-7187	1
MIL-G-7711	1
MIL-H-8446 (MLO-8515)	1
MIL-L-9000	1
MIL-G-10924	1
MIL-L-15016	1
MIL-L-15017	1
MIL-G-15793	1
MIL-L-17331	1
MIL-L-21260	1
MIL-G-21568	1
MIL-G-25013	1
MIL-G-25537	1
MIL-F-25558 (RJ-1)	1
MIL-R-25576 (RP-1)	1
MIL-S-81087	1
Mineral Oils	1
MLO-8200 Hydr.	1
MLO-8515	1
Mobiloil SAE 20	1
Neatsfoot Oil	1
Neon	1
Niter Cake	1
Nitrogen	1
Octadecane	1
Olive Oil	1
Oronite 8200	1
Oronite 8515	1
Ozone	1
Parker O Lube	1
Petrolatum	1
Petroleum Oil, Crude	1
Pneumatic Service	1
Potassium Chloride	1
Potassium Cupro Cyanide	1
Potassium Cyanide	1
Potassium Nitrate	1
Potassium Salts	1
Potassium Sulphate	1
Potassium Sulphite or Nitrate	1
Producer Gas	1
Pydraul, 10E, 29ELT	4
Pydraul 30E, SOE, 65E, 90E, 115E, 230E, 312C, 540C	4
Pyrogard 42, 43, 53, 55	4
Pyrogard C, D	4
Red Oil (MIL-H-5606)	1
Red Line100 Oil	1
RJ-1 (MIL-F-25558)	1
RP-1 (MIl-R-25576)	1
Sal Ammoniac	1
Shell Alvania Grease #2	1
Shell Iris 905	1
Tellus #27, Pet, Base	1
Tellus #33	1
UMF(5% Aromatic)	1
Silicate Esters	1
Silicone Greases	1
Silicone Oils	1
Silver Nitrate	1
Sinclair Opaline CX-EP Lube	1
Skydrol 500	4
Skydrol 7000	4
Socony Mobile Type A Vacuum PD9598	1
Sodium-Chloride	1
Sodium Phosphate (Mono)	1
Sodium Phosphate (Dibasic)	1
Sodium Phosphate (Tribasic)	1
Sodium Salts	1
Sodium Sulphate	1
Sodium Sulphide and Sulfite	1
Sodium Thiosulfate	1
Spry	1
Standard Oil Mobilube GX90-EP Lube	1
Stoddard Solvent	1
Sunoco SAE 10 #3661 All Purpose Grease	1
Swan Finch EP Lube Hypoid-90	1
Texaco 3450 Gear Oil	1
Texaco Regal B	1
Texaco Uni-Temp Grease	1
Texas 1500 Oil	1
Tidewater Oil-Beedol	1
Multigear 140, EP Lube	1
Transformer Oil	1
Transmission Fluid Type A	1
Turbine Oil	1
Turbo Oil #35	1
Type I Fuel (MIL-S-3136)	1
Univis 40 (Hydr. Fluid)	1
Univolt #35 (Mineral Oil)	1
Versilube F-50	1
WemcoC	1
White Oil	1
WolmarSalt	1
Xenon	1
Zinc Salts	1

Compatibility Rating: 1. Satisfactory 2. Fair 3. Insufficient Data 4. Unsatisfactory

APPENDIX III

THORPAK - APPROXIMATE STACK HEIGHTS

Radial Cross Section	Number of Sealing Rings								Stack Height of Top & Bottom Adaoters	Additional Per Sealina Rina
Inches (mm)	3	4	5	6	7	8	9	10	Inches (mm)	Inches (mm)
.187 thru 0.249 (4.75 thru 6.35)	0.343 (8. 712)	0.468 (11.887)	0.593 (15.062)	0.718 (18.237)	0.843 (21.412)	0.968 (24.587)	1.093 (27.762)	1.218 (30.937)	0.218 (5.537)	0.125 (3.175)
0.250 thru 0.311 (6.35 thru 7.93)	0.406 (10.312)	0.531 (13.487)	0.656 (16.662)	0.781 (19.837)	0.906 (23.012)	1.031 (26.187)	1.156 (29.362)	1.281 (32.537)	0.281 (7.137)	0.125 (3.175)
0.312 thru 0.374 (7.93 thru 9.52)	0.500 (12.700)	0.656 (16.662)	0.812 (20.625)	0.968 (24.587)	1.125 (28.575)	1.281 (32.537)	1.437 (36.500)	1.593 (40.462)	0.343 (8.712)	0.156 (3.962)
0.375 thru 0.436 (9.53 thru 11.1)	0.531 (13.487)	0.687 (17.450)	0.843 (21.412)	1.000 (25.400)	1.156 (29.362)	1.312 (33.325)	1.468 (37.287)	1.625 (41.275)	0.375 (9,525)	0.156 (3.962)
0.437 thru 0.499 (11.1 thru 12.7)	0.562 (14.275)	0.718 (18.237)	0.875 (22.225)	1.031 (26.187)	1.187 (30.150)	1.343 (34.112)	1.500 (38.100)	1.656 (42.062)	0.406 (10.312)	0.156 (3.962)
0.500 thru 0.561 (12.7 thru 14.3)	0.625 (15.875)	0.812 (20.625)	1.000 (25.400)	1.187 (30.150)	1.375 {34.925)	1.562 (39.675)	1.750 {44.450)	1.937 {49.200)	0.437 (11.100)	0.187 (4.750)
0.562 thru 0.624 (14.3 thru 15.9)	0.656 (16.662)	0.843 (21.412)	1.031 (26.187)	1.218 (30.937)	1.406 (35.712)	1.593 (40.462)	1.781 (45.237)	1.968 (49.987)	0.468 (11.887)	0.187 (4.750)
0.625 thru 0.686 (15.9 thru 17.4)	0.687 (17.450)	0.875 (22.225)	1.062 (26.975)	1.250 (31.750)	1.437 (36.500)	1.625 (41.275)	1.812 (46.025)	2.000 (50.800)	0.500 (12.700)	0.187 (4.750)
0.687 thru 0.749 (17.4 thru 19.0)	0.843 (21.412)	1.093 (27.762)	1.343 (34.112)	1.593 (40.462)	1.843 (46.8121	2.093 (53.162)	2.343 (59.512)	2.593 (65.862)	0.593 (15.062)	0.250 (6.350)
0.750 thru 0.874 (19.0 thru 22.2)	0.875 (22.225)	1.125 (28.575)	1.375 (34.928)	1.625 (41.275)	1.875 (47.625)	2.125 (53.975)	2.375 (60.325)	2.625 (66.675)	0.625 (15.875)	0.25 (6.350)
0.875 thru 0.999 (22.2 thru 25.4)	1.000 (25.400)	1.312 (33.325)	1.625 (41.275)	1.937 (49.200)	2.250 (57.150)	2.562 (65.075)	2.875 (73.025)	3.187 (80.950)	0.687 (17.450)	0.312 (7,925)
1.00 (25.4)	1.062 (26.975)	1.375 (34.912)	1.687 (42.850)	2.000 (50.800)	2.312 (58.725)	2.625 (66.675)	2.937 (74.600)	3.250 (82.550)	0.750 (19.050)	0.312 (7.925)

Stack heights beyond the table range can be calculated by adding the stack height of the top and bottom adapter to the height per sealing ring as listed above.

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

THORDON

THORDON BEARINGS INC.

3225 Mainway, Burlington, Ontario L7M 1A6 Canada

Tel: +1.905.335.1440 Fax: +1.905.335.4033 Email: info@thordonbearings.com Website: www.ThordonBearings.com

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