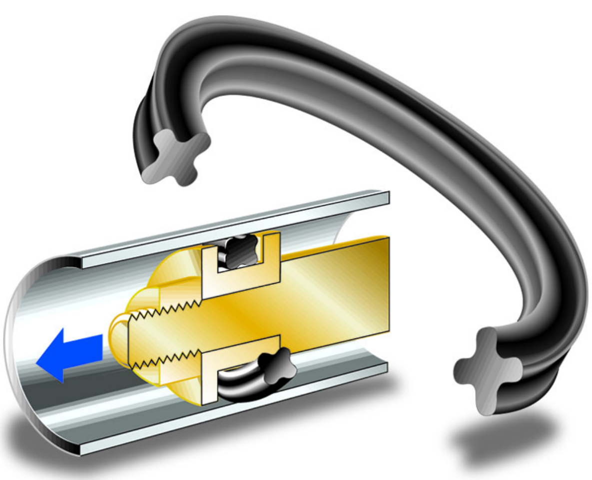
Section 6
Rubber/Standard Products



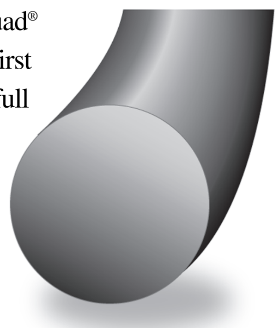
Rubber/Standard Products

The Quad® Brand Seal Family

Standard Products and Common Configurations

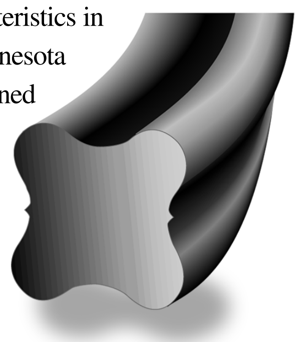
Minnesota Rubber produces a complete family of Standard O-Ring, Quad-Rings® Brand and custom seals to provide the optimum seal for a wide range of applications. Our original four-lobed Quad-Ring® Brand seal design has been expanded into a complete line of custom seals, some patented, with unique features to handle the most difficult sealing requirements.

Quad® Brand O-Rings (standard and custom molded)



For general sealing applications, Quad® Brand O-Rings usually are a good first choice. Minnesota Rubber offers a full range of sizes in Nitrile and Fluoroelastomer materials as standard products (p 6-22). If your application requires other elastomers, Minnesota Rubber will help you select the right material and custom mold it to the required specifications.

Quad-Ring® Brand Seals (standard and custom molded)



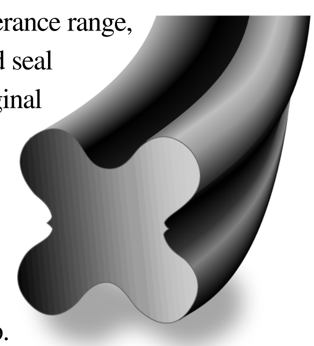
Providing excellent sealing characteristics in a broad range of applications, Minnesota Rubber's original four-lobed designed seals are available in a full range of standard sizes, in Nitrile and Fluoroelastomer materials (p 6-22). Should your application require other elastomers, Minnesota Rubber will help you select the right material and custom mold it to the required specifications.

Quad-Ring® Brand Seal Advantages over standard O-Rings:

1. Twice the Sealing Surface. Quad-Ring® Brand, seals have a unique multiple point seal contact design. With two sealing surfaces, there is greater seal protection when used as an ID seal, OD seal, or face seal.
2. Lower Friction because of the Quad-Ring® Brand seals multiple point seal contact design, less squeeze is required to maintain an effective seal. This lower squeeze results in lower friction, an important consideration for dynamic sealing applications.
3. Longer life because of reduced squeeze. Quad-Ring® Brand seals last longer and promote system "uptime." Equipment operates longer and requires less maintenance.
4. Seal surface free from parting line insures no leakage across the parting line. Parting line is in the valley not on the sealing surface like conventional O-Rings.

5) No spiral twist. Four lobe shaped Quad-Ring® Brand seals eliminate spiral twist which causes conventional O-Rings to rupture.

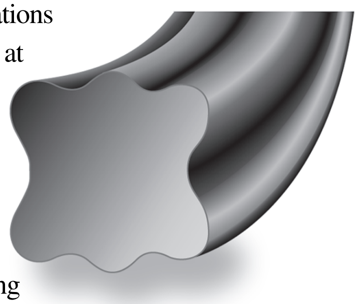
Modified Quad-Ring® Brand Seals (custom molded)



For sealing across a broader tolerance range, the Modified Quad-Ring® Brand seal has a deeper valley than the original Quad-Ring® Brand seal design, thereby producing a lower deflection force. In OEM applications such as plastic housings, this seal design has reduced load with less creep. Designed for pressures less than 120 psi (8.1 bar). Modified Quad-Ring® Brand seals recently were granted a new patent.

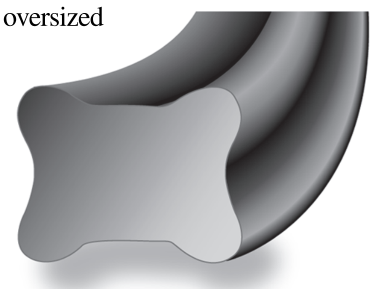
The Quad® Brand Seal Family - continued

Quad-O-Dyn® Brand Seals (custom molded)



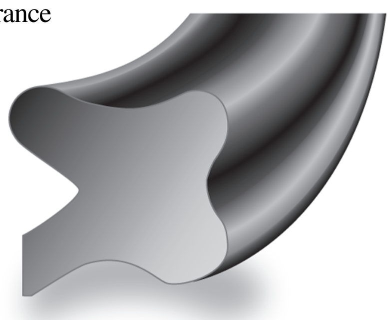
For dynamic sealing applications providing near zero leakage at pressures to 2000 psi (138 bar) and higher. This six-lobed configuration, designed with two primary and four backup sealing surfaces, has excellent sealing features in very difficult applications. It can be used with standard O-Ring grooves.

Quad-Bon® Brand Seals (custom molded)



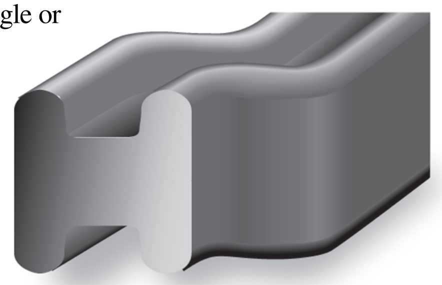
Ideal for applications with oversized grooves, strong spiraling pressures and as a retrofit for existing O-Ring applications. This four-lobed configuration has the widest valley in our custom cross section product line. It provides excellent sealing features.

Quad-Kup® Brand Seals (custom molded)



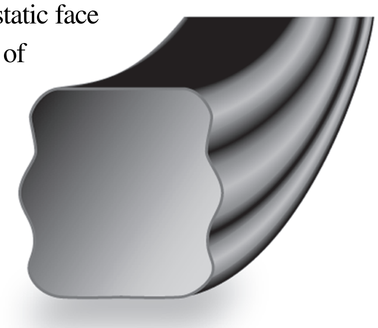
For high diameteric clearance applications and those requiring low operating friction. Provides low-pressure seal up to 150 psi (10.3 bar) in reciprocating and rotary applications. The combination lobed/cup configuration can be designed with the lip on any of the four surfaces, top or bottom, on the ID or OD.

H-Seals (custom molded)



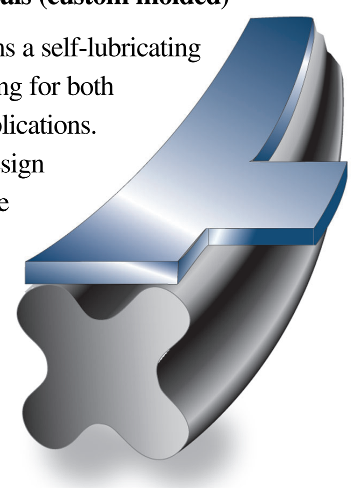
Ideal for intricate single or multiple groove configurations in static face seal applications. With the deepest valley of all Minnesota Rubber product designs, this configuration has superior sealing features in difficult applications.

Quad®-O-Stat Brand Seals (custom molded)



Designed specifically for static face sealing applications. Each of the six lobes serves as an individual seal with the corner lobes functioning as seal backups to the central lobes. If one lobe fails, the remaining lobes provide zero leakage sealing. Can be installed in standard O-Ring grooves.

Quad® P.E. Plus Brand Seals (custom molded)

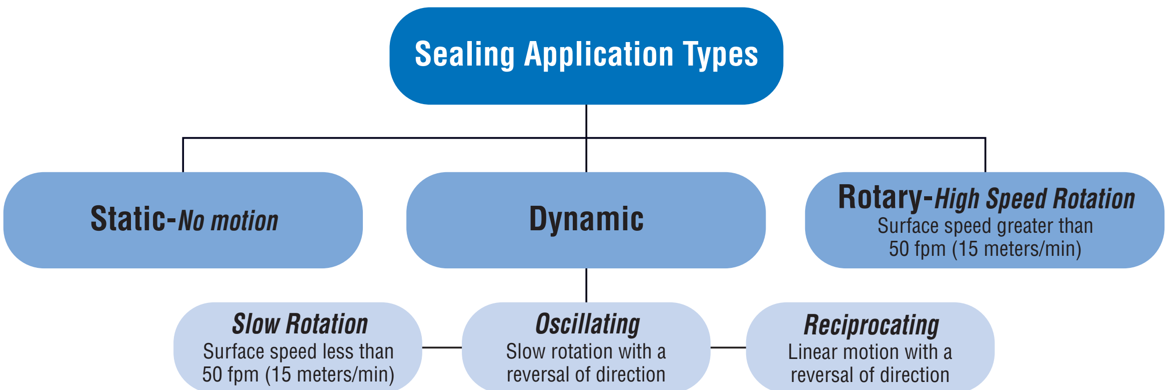


This dual-function seal forms a self-lubricating seal and an elastomeric spring for both rotary and reciprocating applications. Newly patented, this seal design combines injection moldable thermoplastic bearing material with a Quad-Ring® Brand seal. This seal is not intended for zero leakage applications.

Identifying A Sealing Application Type

Although sealing applications can be classified in many different ways, a common method for classifying sealing applications is by the type of motion experienced by the application. The common application types are depicted below.

General sealing principles common to all of the seal types are discussed on the following pages.



Sealing Tips

- Provide detailed seal installation and assembly instructions, especially if the unit could be serviced by the end-user of the product. When appropriate or required, specify the use of OEM sealing parts.
- Within reason, the larger the cross-section, the more effective the seal.
- Do not seal axially and radially at the same time with the same O-Ring or Quad-Ring® Brand Seal.
- Don't use a seal as a bearing to support a load or center a shaft. This will eventually cause seal failure.
- Lubricate the seal and mating components with an appropriate lubricant before assembling the unit.
- Keep the seal stationary in its groove - don't let it spin with the rotating member.
- When using back-up rings, increase the groove width by the maximum thickness of the back-up ring.
- With a face seal, don't try to seal around a square corner. Corners must have a minimum radius of 4 times the seal cross-section.

Selecting the Seal Material

When selecting the seal material for the application, carefully consider:

- The primary fluids which the O-Ring or Quad-Ring® Brand will be sealing
- Other fluids to which the seal will be exposed, such as cleaning fluids or lubricants
- The suitability of the material for the application's temperature extremes - hot and cold
- The presence of abrasive external contaminants
- The presence of ozone from natural sources and electric motors, which can attack rubber
- Exposure to processes such as sterilization by gas, autoclaving, or radiation
- Exposure to ultraviolet light and sunlight, which can decompose rubber
- The potential for out-gassing in vacuum applications
- Don't forget about water - it covers two-thirds of the Earth's surface

Defining Factors In The Sealing Application

While small in cost, seals are often one of the most important components in a product. Seals must be carefully designed and produced to ensure superior performance of the product in which they are used. This section provides a review of the issues that need to be considered when making sealing decisions.

All sealing applications fall into one of three categories: (1) those in which there is no movement, (2) those in which there is linear motion or relatively slow rotation, or (3) those involving high speed rotation.

A sealing application in which there is no movement is termed a static seal. Examples include the face seal in an end cap, seals in a split connector, and enclosure cover seals.

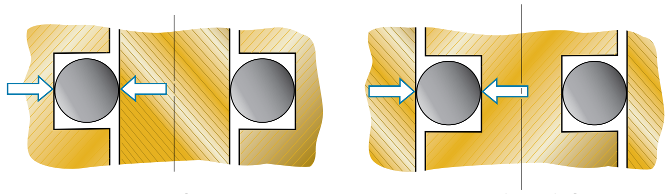
A sealing application in which there is linear motion (reciprocation) or relatively slow rotation or oscillation, is termed a dynamic seal. Applications involving slow rotation or oscillation are classified as a dynamic application if the surface speed is less than 50 fpm (15 meters/min).

Finally, a sealing application in which there is high speed rotation, is termed a rotary seal. Applications are classified as a rotary application if the surface speed is greater than 50 fpm (15 meters/min). It should be noted that both the seals and grooves used for dynamic and rotary applications are different in design and specification. These differences are explained in the following sections.

Seal Orientation and Type

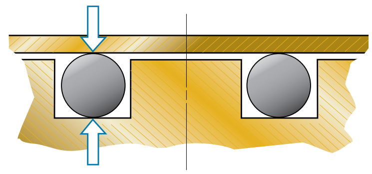
Quad-Ring® Brand and O-Ring seals can be oriented such that the seal compression, and therefore the sealing, is occurring in either a radial or axial direction. This is illustrated below. In the case of a radial seal, the primary sealing surface can occur at either the ID or the OD of the seal, with the common names for these seals being a rod seal and a piston seal respectively. An axial seal is commonly referred to as a face seal. Each of these seal types can be either a static, dynamic, or rotary seal, with the exception of a piston seal which is generally not recommended for a rotary application.

Radial Sealing Applications



Rod Seal *Piston (Bore) Seal*

Axial Sealing Applications



Face Seal

Surface Finish

Shorter than expected seal life is usually the result of too fine a finish on either the rod or the cylinder bore. A highly polished (non-porous) metal surface does not retain the lubricant necessary to control friction, whereas a rough or jagged surface will abrade the seal and lead to early seal failure.

To avoid these problems, we recommend an ideal surface finish of 20-24 µin (.5-.6 µm) Ra, with an acceptable range of 20-32 µin (.5-.81 µm) Ra. The surface finish should never be finer than 16 µin (.4 µm) Ra.

Pressure Energized Seals

It is more difficult to seal at low pressures than at high pressures. As pressure acts against a seal, the rubber material is deformed. With proper seal design, deformation can improve the seal. This concept is used in many seal designs. By adding seal beads or pressure intensification details to the seal, sealing improvements can be made to custom designs. For very low pressure or vacuum applications we recommend using a Quad-Ring® Brand seal over a O-Ring.

Defining Factors In The Sealing Application - continued

Friction

The functional life of a seal is affected by the level of friction to which it is exposed. Factors contributing to friction include seal design, lubrication, rubber hardness (the standard rubber hardness for most sealing applications is 70 durometer Shore A), surface finish, temperature extremes, high pressure and the amount of squeeze placed on the seal.

The use of "slippery rubber" compounds can help lessen friction and improve seal life. Surface coatings and seal treatments such as PTFE and molybdenum disulfide are also used to reduce seal friction.

It is difficult to accurately predict the seal friction which will be present in an application, given the many variables involved. When designing an application which will be sensitive to seal friction, testing will probably be required to determine the effect of seal friction.

Component Concentricity and Roundness

When evaluating an application, remember that components are not perfectly concentric or round. Concentricity and roundness can also change with changes in pressure and temperature. When sizing a seal, consider the worst case scenario for your application and make sure that the seal system you select will work in the worst case scenario.

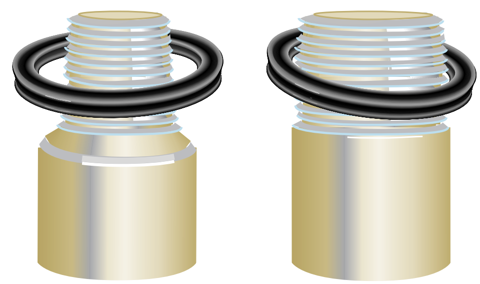
If, after reviewing the calculations on your application, you find that seal integrity may be compromised when dimensions approach a worst case scenario, consider making the following adjustments before recalculating:

1. Reduce the clearance between components.
2. Reduce the tolerances of the components.
3. Use a larger cross section seal to absorb the extra tolerance.
4. Increase the seal squeeze (which will also increase friction).
5. Improve component alignment and support to reduce the eccentricity.

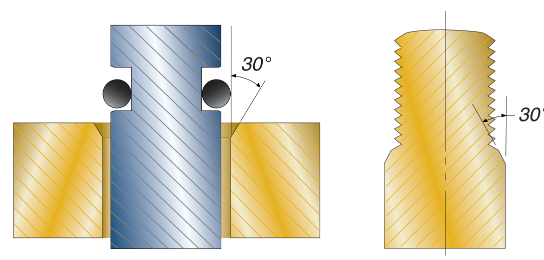
Seal Installation – Avoiding Damage

Seals can be easily damaged during installation. For example, a seal is often inserted onto a shaft by sliding it over a threaded surface. To avoid seal damage reduce the rod diameter in the threaded region. Also include a lead in chamfer for the seal and avoid sharp corners on grooves.

Easy Installation **Potential For Damage**



Use Lead-In Chamfer:



Peripheral Compression

In certain applications, such as with a rotary seal, the seal size is selected and the seal groove is designed such that the free-state diameter of the seal ring is larger than the groove diameter. Upon installation, the seal will be compressed by the groove to a smaller diameter. This is called "placing the seal under peripheral compression", or simply "peripheral compression."

Peripheral compressed seals are used in rotary applications to prevent heat-induced failure of the seal due to material contraction. They are also used in face seal applications when sealing a positive internal pressure. It should be noted that a peripherally compressed seal does not experience installed stretch, since the seal is being compressed rather than stretched during installation.

Percentage Gland Fill

Since rubber can generally be regarded as an incompressible material, there must always be sufficient space in the seal gland for the seal. When there is insufficient space for the seal, application problems including high assembly forces and seal and unit failure can occur. The ratio of seal volume to gland volume, which is frequently termed "gland fill" or less formally as "groove fill", is usually expressed as a percentage of the gland which is occupied by the seal. It is always desired to keep this percentage less than 100% under all application conditions and extremes of tolerance. To allow for a margin of safety, a good practice is to design to a maximum gland fill of 90% or less.

The gland fill can be easily determined by calculating the cross-sectional area of the seal and dividing it by the cross-sectional area of the gland. The cross-sectional area of the gland is its height times its width. The equations for the cross-sectional areas of an O-Ring and a Quad-Ring® Brand can be found on Page 6-8. When calculating the maximum gland fill, always use the worst-case tolerance situation which results in the smallest gland and largest seal.

Cross Section Size

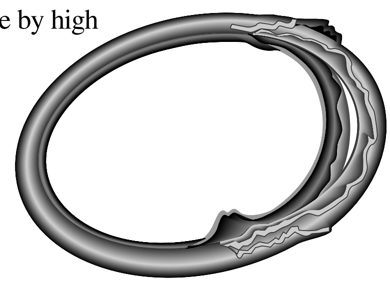
In applications in which the area to contain the seal is small, it is important to remember that smaller cross-section seals require much tighter tolerances on mating parts. Small cross-section seals cannot handle the large variation in part sizes, imperfections like scratches, and high pressure.

Installed Seal Stretch and Cross-sectional Reduction

Installed seal stretch is defined as the stretch experienced by a seal ring following installation into the seal groove. As a seal ring is stretched, there is a resulting reduction in the seal's cross-section. This reduction in cross-section will reduce the squeeze on a seal, which has the potential to create sealing problems, especially when using smaller diameter seal rings. To minimize the occurrence of cross-sectional reduction, a general "rule of thumb" to follow is to keep the installed seal stretch less than 3%. It should be noted that with standard seal sizes smaller than an -025 seal, the installed seal stretch will frequently be higher than 3%, even with a properly designed groove. In these situations, care should be taken to properly control component tolerances to prevent insufficient seal squeeze from occurring at the extremes of component tolerance. If necessary, component tolerances should be tightened to ensure an acceptable seal is obtained.

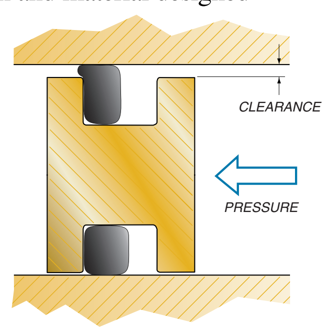
Seal Extrusion

Extrusion is a common source of seal failure in both static and dynamic applications. The O-Ring illustrated failed when it was extruded from the groove. Part or all of the seal is forced from the groove by high continuous or pulsating pressure on the seal. If left uncorrected, the entire cross-section will eventually disintegrate.



Follow these easy rules to minimize the risk of seal extrusion:

1. Choose a seal configuration and material designed to withstand the anticipated pressure.
2. Make sure the clearance between adjacent surfaces is appropriate for the hardness of the material. Clearance should be minimized and must not exceed recommended limits for the rubber hardness.



Defining Factors In The Sealing Application - continued

Anti-Extrusion (Back-up) Rings

The use of a back-up ring with an O-Ring or Quad-Ring® Brand seal can minimize or prevent the occurrence of seal extrusion in applications with higher pressure or higher than desirable clearance. Spiral-wound or washer-shaped back-up rings are installed next to the seal opposite the pressure side of the application. Back-up rings are recommended for applications with pressures in excess of 1500 psi.

Although back-up rings can be made from any material which is softer than the shaft, they are commonly made from poly-tetrafluoroethylene (PTFE), which provides low friction. PTFE back-up rings are available as solid rings, single-layer split rings, and two-layer spiral-wound split rings. Two-layer spiral-wound PTFE rings provide easy installation, protect the seal from damage, and are the recommended type. When using a back-up ring, always increase the seal groove width to account for the thickness of the back-up ring.

Seal Groove Design Equations

The equations on this page are used to calculate the different parameters of a seal groove. They are used in the explanations and the examples on the following pages.

Installed Seal Stretch

Equation 1

Percent Stretch = ((Installed Seal ID - Original Seal ID)/ Original Seal ID) x 100

Seal Cross-sectional Compression (Squeeze)

Equation 2

Percent Compression = (1 - (Gland Radial Width/Seal Cross-Section)) x 100

Equation 3

Max Percent Compression = (1 - (Min Gland Radial Width/Max Seal Cross-Section)) x 100

Equation 4

Min Percent Compression = (1 - (Max Gland Radial Width/Min Seal Cross-Section)) x 100

Seal Percent Gland Fill

Equation 5

Percent Gland Fill = (Seal Cross-sectional Area/(Gland Depth X Groove Width)) x 100

Equation 6

Max Percent Gland Fill = (Max Seal Cross-sectional Area/(Min Gland Depth X Min Groove Width)) x 100

Seal Cross-sectional Area

Equation 7

O-Ring Cross-sectional Area = (O-Ring Cross-section/2)^2 x 3.1415

Equation 8

Quad-Ring® Brand, Cross-sectional Area = (Quad-Ring® Brand Cross-section)^2 x .8215

(Note the intentional absence of the division term in the Quad-Ring® Brand formula)

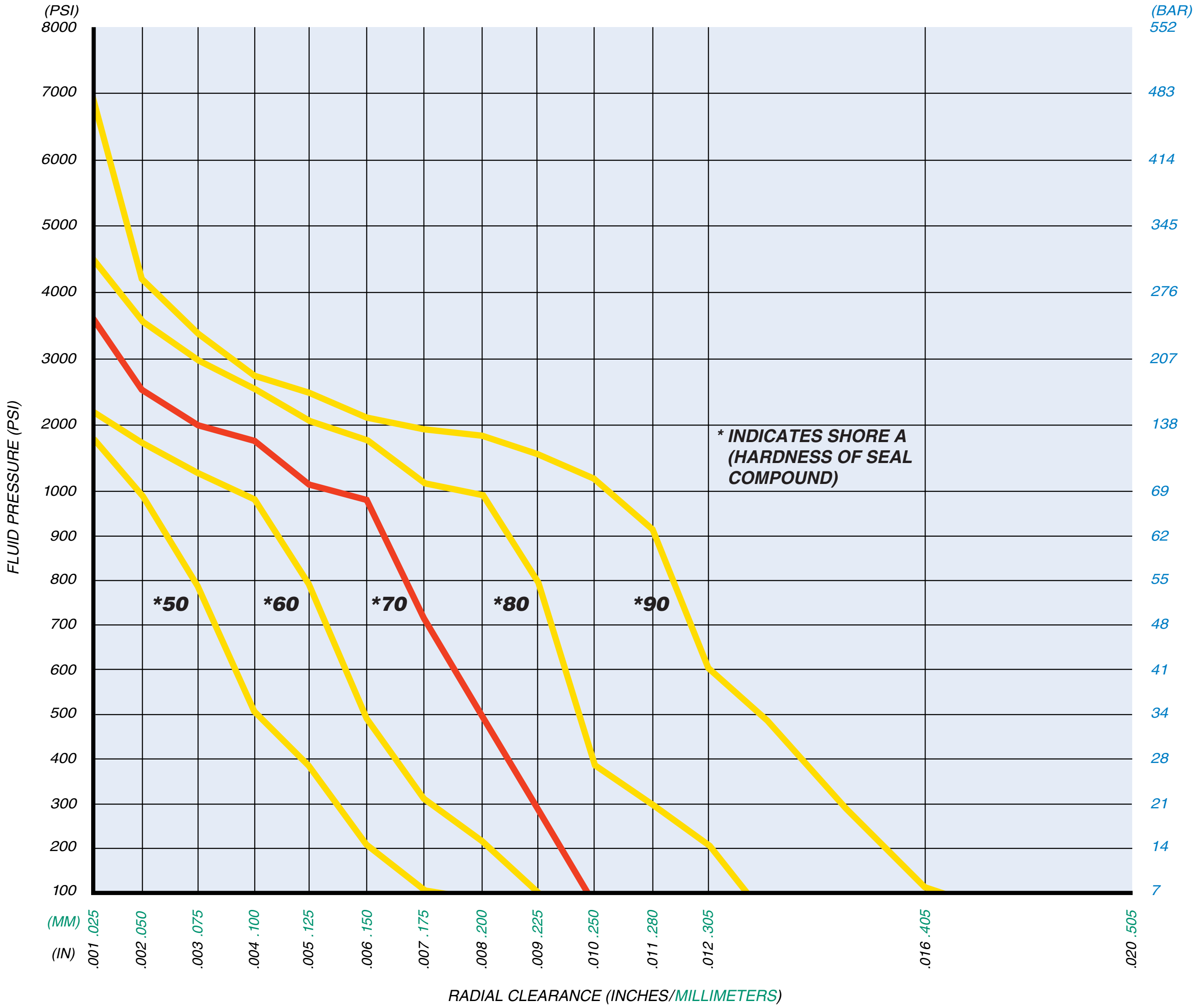
The maximum value for seal cross-sectional area can be obtained by using the maximum seal cross-section size (nominal size + tolerance) in Equations 7 and 8.

The following table provides the nominal and maximum seal cross-sectional areas for the standard seal cross-section sizes. This table can be used for quickly computing the percent gland fill.

Seal Cross-section	O-Ring Cross-sectional Area (in^2)		Quad-Ring® Brand Cross-sectional Area (in^2)	
	Nominal (in^2)	Maximum	Nominal	Maximum
.070±.003	.00385	0.00419	0.00403	0.00438
.103 ±.003	.00833	0.00882	0.00872	0.00923
.139 ±.004	.01517	0.01606	0.01587	0.01680
.210 ±.005	.03464	0.03631	0.03623	0.03797
.275 ±.006	.05940	0.06202	0.06213	0.06487

Recommended Radial Sealing Clearances for Quad-Ring® Brand and O-Ring Seals

This chart indicates the maximum permissible radial clearance as a function of application pressure and the seal rubber hardness.



Notes

1. This chart has been developed for seal cross-sections of .139" and larger. Smaller cross-section seals require less (tighter) clearance.
2. This chart is for applications in which the piston and bore are concentric. Radial clearance must be reduced in those applications with severe side loading or eccentric movement.
3. The data in this chart is for seals which are not using anti-extrusion back-up rings.
4. The data in this chart is for seals at room temperature. Since rubber becomes softer as temperature increases, clearances must be reduced when using seals at elevated temperatures.
5. The maximum permissible radial clearance would include any cylinder expansion due to pressure.

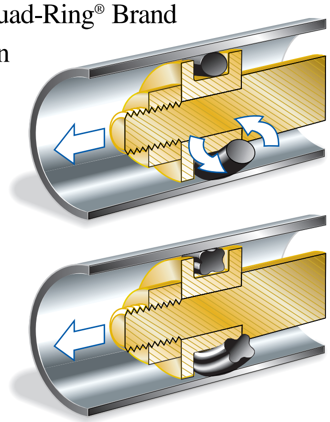
Quad-Ring® Brand Seals

Minnesota Rubber pioneered the design and production of four-lobed seals with the Quad-Ring® Brand seal design. These seals are used today around the world for a wide variety of static and dynamic sealing applications.

Avoiding Spiral Twist

To minimize breakaway friction, an O-Ring groove must be wide enough to allow rolling or twisting of the seal. In the long stroke of a reciprocating seal application, this twisting action can strain and eventually tear the rubber, causing a failure mode known as spiral twist.

To prevent spiral twist, the Quad-Ring® Brand seal's four-lobed configuration is designed to withstand the distortion and extrusion often caused by high or pulsating pressure. To accommodate these forces, a Quad-Ring® Brand seal uses a narrower groove than a comparable O-Ring seal.

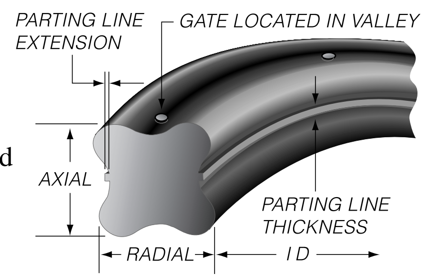


Longer Seal Life

Because less squeeze means less friction with the four-lobe design, seals last longer. This means equipment in which the Quad-Ring® Brand seal is installed will operate longer and require less maintenance.

No Parting Line on Sealing Surface

Unlike O-Rings, where parting lines are on the sealing surface, Quad-Ring® Brand seals' parting lines lie between the lobes, away from the sealing surface. This design eliminates the problems of leakage resulting from a parting line's irregular surface.



Groove Design: Quad-Ring® Brand Seals for Static and Non-Rotary Dynamic Applications

1. **Cross-section.** Select a Quad-Ring® Brand cross-section size from the available standard sizes. If you are unsure what cross-section size to use, see the discussion on Page 6-7.
2. **Clearance.** Determine the maximum clearance present in your application. For a radial seal, subtract the minimum rod (shaft) diameter from the maximum bore diameter. For a face seal, subtract the distance between the sealing surface and the mating surface.
3. **Check the Clearance.** Determine if the clearance is acceptable for the application pressures and the material hardness being used by checking the graph on Page 6-9. Minnesota Rubber Company standard-line products are made from materials having a hardness of 70 Shore A. If the clearance is unacceptable, component tolerance will have to be tightened, a harder material will have to be special ordered, or a back-up ring will have to be used. **Note:** The graph provides clearance values as radial values, so divide the number obtained in the preceding step by 2 to obtain your radial clearance.

Groove Design: Quad-Ring® Brand Seals for Static and Non-Rotary Dynamic Applications - continued

Recommended Starting Dimensions

RING SIZE	CROSS-SECTION (in)	CROSS-SECTION (mm)	DYNAMIC RECOMMENDED GLAND DEPTH "C" (in)	DYNAMIC RECOMMENDED GLAND DEPTH "C" (mm)	STATIC RECOMMENDED GLAND DEPTH "C" (in)	STATIC RECOMMENDED GLAND DEPTH "C" (mm)	AXIAL GROOVE WIDTH "D" (in) +.005/-.000	AXIAL GROOVE WIDTH "D" (mm) +0.13/0-.00	GROOVE ECCENTRICITY (TIR) (in)	GROOVE ECCENTRICITY (TIR) (mm)
Q4004 - Q4050	.070 ±.003	1.78 ±0.08	.061	1.55	.056	1.42	.080	2.03	.002	0.05
Q4102 - Q4178	.103 ±.003	2.62 ±0.08	.094	2.39	.089	2.26	.115	2.92	.002	0.05
Q4201 - Q4284	.139 ±.004	3.53 ±0.10	.128	3.25	.122	3.10	.155	3.94	.003	0.08
Q4309 - Q4395	.210 ±.005	5.33 ±0.13	.196	4.98	.188	4.78	.240	6.10	.004	0.10
Q4425 - Q4475	.275 ±.006	6.99 ±0.15	.256	6.50	.244	6.20	.310	7.87	.005	0.13

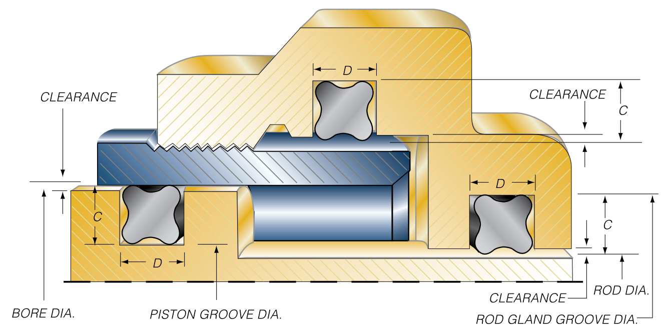
4. **Calculate the Quad-Ring® Brand groove dimensions.** Using the table above, determine the maximum recommended gland depth for your application. Then, calculate the Quad-Ring® Brand groove diameter as follows:
   a. For a rod (shaft) seal:
      Quad-Ring® Brand Groove Diameter = Min Shaft Diameter + (2 X Recommended Gland Depth)
   b. For a bore (piston) seal:
      Quad-Ring® Brand Groove Diameter = Max Bore Diameter - (2 X Recommended Gland Depth)
   c. For a face seal:
      Quad-Ring® Brand Groove Depth = Recommended Gland Depth - Application Clearance

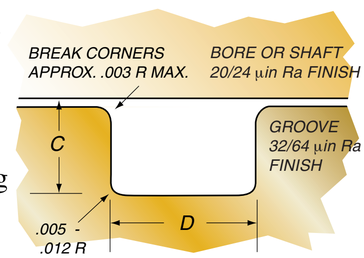
   With a face seal, if the two surfaces to be sealed are in direct contact (such as with a cover), the seal groove depth is simply the Recommended Gland Depth

5. **Groove Width.** Refer to the table above to determine the groove width for the Quad-Ring® Brand cross-section size you have selected. If you are using a back-up ring in your application, increase the groove width by the maximum thickness of the back-up ring.

6. **Percent Gland Fill.** Determine the maximum percent gland fill using Equation 6 from Page 4-8. If the gland fill exceeds 100%, the groove will have to be redesigned. A good "rule-of-thumb" is to not exceed about 90% gland fill.

7. **Calculate the Seal Squeeze.** Using Equations 3 and 4 (Page 6-8), calculate the minimum and maximum seal cross-sectional compression (squeeze). The recommended gland values in the table above have been developed to create a proper range of squeeze for many applications involving oil, hydraulic fluid, or normal lubricants, providing component tolerances are sufficiently controlled. In applications involving high pressure, large component tolerances, the need for very low frictional forces, or other types of fluids, the seal and groove design should be verified through an acceptable method, such as testing or engineering analysis.



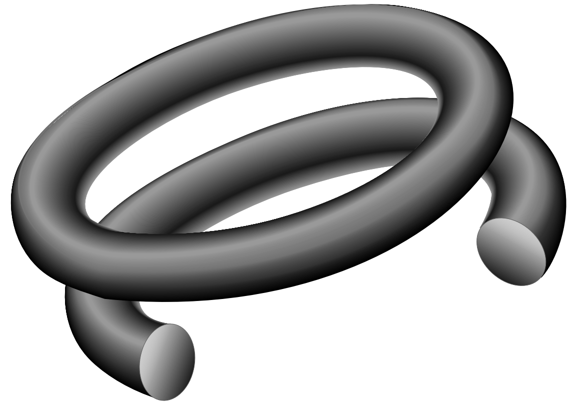


8. **Select the Seal.** Select the proper Quad-Ring® Brand size from the Standard Size table beginning on Page 6-22. Start by turning to the section of the table for the cross-section size you have selected, and then finding the Quad-Ring® Brand for the proper size bore or rod (shaft) you are sealing. If the bore or shaft size you are using is not listed, select the Quad-Ring® Brand with an inside diameter just smaller than the shaft you are using. If you are designing a face seal, select the Quad-Ring® Brand with an inside diameter which will position the Quad-Ring® Brand on the side of the groove opposite the pressure. See Page 6-16 for more information on face seal groove design. Note the Quad-Ring® Brand inside diameter for the next step.

9. **Calculate the Seal Stretch.** Using Equation 1 (Page 6-8), calculate the installed seal stretch. If the installed seal stretch is greater than about 3%, you may have to select the next larger Quad-Ring® Brand size or require a custom Quad-Ring® Brand for your application. If you are using a Quad-Ring® Brand size less than a number -025, See Page 6-7 for more information.

10. **Detail the Groove.** Complete the groove design by specifying the proper radii and finish as indicated in the figure above.

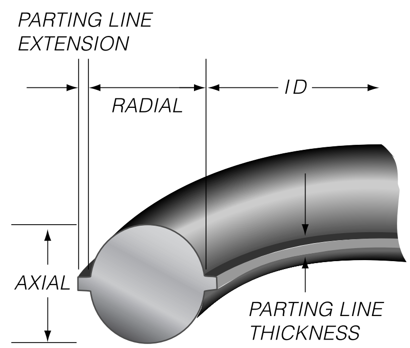
Quad® Brand O-Ring Seals



The O-Ring is usually the designer's first choice when a sealing application is encountered. Properly engineered to the application, an O-Ring will provide long-term performance in a variety of seal applications. O-Rings are well suited for use as static, reciprocal and oscillating seals in low speed and low pressure applications.

The O-Ring is a good general purpose seal in both air and gas systems, as well as in hydraulic applications. Air and gas system designs must include adequate lubrication of the O-Ring in order to prevent damage to the sealing surface.

The popular O-Ring cross-section is configured in a variety of shapes as a stand alone seal, or incorporated into other rubber sealing components such as gaskets and diaphragms. O-Ring cross-sections are molded or bonded to metal or plastic parts such as valve stems, quick-disconnect poppets and spool valve cylinders.



Groove Design: O-Ring Seals for Static and Non-Rotary Dynamic Applications

1. **Cross-section.** Select an O-Ring cross-section size from the available standard sizes. If you are unsure what cross-section size to use, see the discussion on Page 6-7.

2. **Clearance.** Determine the maximum clearance present in your application. For a radial seal, subtract the minimum rod (shaft) diameter from the maximum bore diameter. For a face seal, subtract the distance between the sealing surface and the mating surface.

3. **Check the Clearance.** Determine if the clearance is acceptable for the application pressures and the material hardness being used by checking the graph on Page 6-9. Minnesota Rubber Company standard-line products are made from materials having a hardness of 70 Shore A. If the clearance is unacceptable, component tolerance will have to be tightened, a harder material will have to be special ordered, or a back-up ring will have to be used. **Note:** The graph provides clearance values as radial values, so divide the number obtained in the preceding step by 2 to obtain your radial clearance.

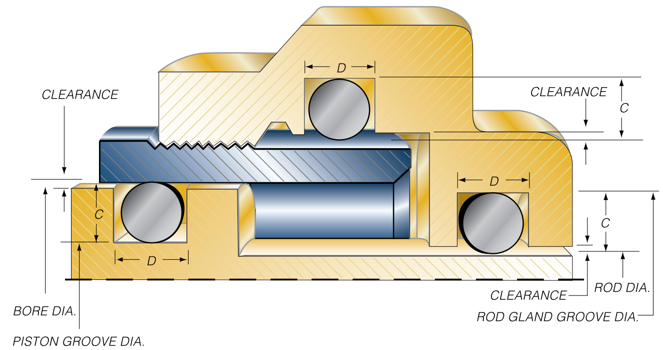
Groove Design: O-Ring Seals for Static and Non-Rotary Dynamic Applications - continued

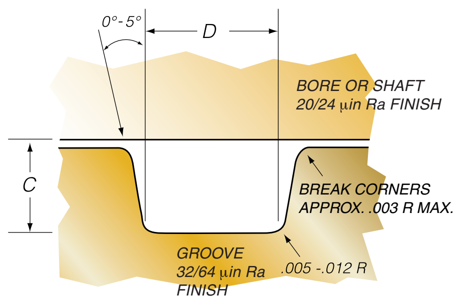
Recommended Starting Dimensions

RING SIZE	CROSS-SECTION (in)	CROSS-SECTION (mm)	DYNAMIC RECOMMENDED GLAND DEPTH "C" (in)	DYNAMIC RECOMMENDED GLAND DEPTH "C" (mm)	STATIC RECOMMENDED GLAND DEPTH "C" (in)	STATIC RECOMMENDED GLAND DEPTH "C" (mm)	DYNAMIC AXIAL GROOVE WIDTH "D" (in) +.005/-.000	DYNAMIC AXIAL GROOVE WIDTH "D" (mm) +0.13/-0.00	STATIC AXIAL GROOVE WIDTH "D" (in) +.005/-.000	STATIC AXIAL GROOVE WIDTH "D" (mm) +0.13/-0.00
Q8004 - Q8050	.070 ±.003	1.78 ±0.08	.056	1.42	.051	1.30	.094	2.39	.080	2.03
Q8102 - Q8178	.103 ±.003	2.62 ±0.08	.089	2.26	.082	2.08	.141	3.58	.115	2.92
Q8201 - Q8284	.139 ±.004	3.53 ±0.10	.122	3.10	.112	2.85	.188	4.78	.155	3.94
Q8309 - Q8395	.210 ±.005	5.33 ±0.13	.187	4.75	.172	4.37	.281	7.14	.240	6.10
Q8425 - Q8475	.275 ±.006	6.99 ±0.15	.239	6.07	.219	5.56	.375	9.53	.310	7.87

4. **Calculate the O-Ring groove dimensions.** Using the table above, determine the maximum recommended gland depth for your application. Then, calculate the O-Ring groove diameter as follows:
   a. For a rod (shaft) seal:
      O-Ring Max Groove Diameter = Min Shaft Diameter + (2 x Recommended Gland Depth)
   b. For a bore (piston) seal:
      O-Ring Min Groove Diameter = Max Bore Diameter - (2 x Recommended Gland Depth)
   c. For a face seal:
      O-Ring Max Groove Depth = Recommended Gland Depth - Application Clearance

   With a face seal, if the two surfaces to be sealed are in direct contact (such as with a cover), the seal groove depth is simply the Recommended Gland Depth
5. **Groove Width.** Refer to the table above to determine the groove width for the O-Ring cross-section size you have selected. If you are using a back-up ring in your application, increase the groove width by the maximum thickness of the back-up ring.
6. **Percent Gland Fill.** Determine the maximum percent gland fill using Equation 6 from Page 6-8. If the gland fill exceeds 100%, the groove will have to be redesigned. A good "rule-of-thumb" is to not exceed about 90% gland fill.
7. **Calculate the Seal Squeeze.** Using Equations 3 and 4 (Page 6-8), calculate the minimum and maximum seal cross-sectional compression (squeeze). The recommended gland values in the table above have been developed to create a proper range of squeeze for many applications involving oil, hydraulic fluid, or normal lubricants, providing component tolerances are sufficiently controlled. In applications involving high pressure, large component tolerances, the need for very low frictional forces, or other types of fluids, the seal and groove design should be verified through an acceptable method, such as testing or engineering analysis.



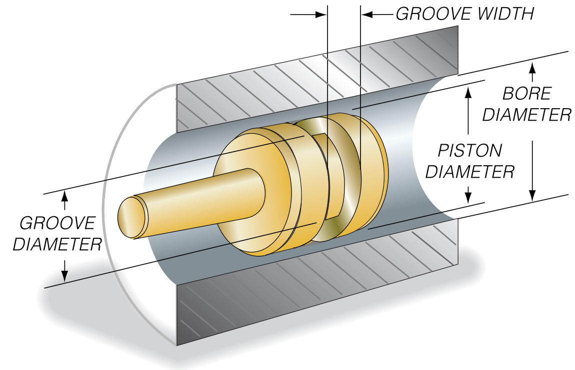


8. **Select the Seal.** Select the proper O-Ring size from the Standard Size table beginning on Page 6-22. Start by turning to the section of the table for the cross-section size you have selected, and then finding the O-Ring for the proper size bore or rod (shaft) you are sealing. If the bore or shaft size you are using is not listed, select the O-Ring with an inside diameter just smaller than the shaft you are using. If you are designing a face seal, select the O-Ring with an inside diameter which will position the O-Ring on the side of the groove opposite the pressure. See Page 6-16 for more information on face seal groove design. Note the O-Ring inside diameter for the next step.
9. **Calculate the Seal Stretch.** Using Equation 1 (Page 6-8), calculate the installed seal stretch. If the installed seal stretch is greater than about 3%, you may have to select the next larger O-Ring or require a custom O-Ring for your application. If you are using an O-Ring size less than a number -025, See Page 6-7 for more information.
10. **Detail the Groove.** Complete the groove design by specifying the proper radii and finish as indicated in the figure above.

Application Example: Piston Quad-Ring® Brand Seal

Application description: Hydraulic Cylinder, U. S. Customary Units (inches)

- 5" dynamic stroke
- Piston diameter: 2.992" ±.002
- Bore diameter: 3.000" ±.002
- 200 psi maximum pressure
- .103" cross-section Quad-Ring® Brand seal
- No side loading or eccentricity



RING SIZE	CROSS-SECTION	DYNAMIC RECOMMENDED GLAND DEPTH "C"	STATIC RECOMMENDED GLAND DEPTH "C"	AXIAL GROOVE WIDTH "D" +.005/-.000
Q4102 - Q4178	.103 ±.003	.094	.089	.115

1. Calculate the Seal Groove Diameter:

Groove Diameter
= Maximum Bore Diameter - (2 x Dynamic Gland Depth)
= 3.002 - (2 x .094)
= 2.814 -.000/+ .002

(Recall the gland depth values in the chart are given as radial values)

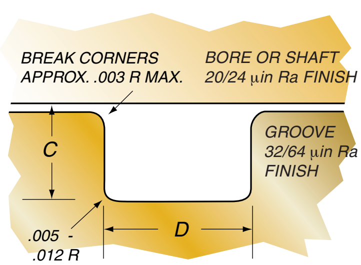
2. From the chart, the groove width is .115 -.000/+.005

3. Calculate the Minimum Gland Volume:

Minimum Gland Volume
= ((Min Bore Dia. - Max Groove Dia./ 2) x Min Groove Width
= ((2.998 - 2.816)/2) X .115
= .0105 in^2

4. Calculate the Maximum Quad-Ring® Brand Seal Volume:

Maximum Quad-Ring® Brand Volume
= (Max Quad-Ring® Brand Cross-section)^2 X .8215
= (.106)^2 X .8215
= .0092 in^2



5. Compare the Minimum Gland Volume to the Maximum Quad-Ring® Brand Volume

In this application the maximum seal volume is less than the minimum gland volume, so the seal should function satisfactorily.

6. Calculate the Minimum and Maximum Seal Squeeze

a. Max Seal Squeeze = 1 - (Min Gland Depth / Max Seal Cross-section)
Min Gland Depth = (Min Bore Dia. - Max Groove Dia.) / 2
= (2.998 - 2.816) / 2
= .091
Max Seal Squeeze = 1 - (.091/.106)
= .141
= 14.1%

b. Min Seal Squeeze = 1 - (Max Gland Depth / Min Seal Cross-section)
Max Gland Depth = (Max Bore Dia. - Min Groove Dia.) / 2
= (3.002 - 2.814) / 2
= .094
Min Seal Squeeze = 1 - (.094/.100)
= .06
= 6%

Therefore, sufficient squeeze should exist to seal this application.

7. Calculate the Maximum Clearance and evaluate possible extrusion problems

Max Radial Clearance = (Max Bore Dia. - Min Piston Dia.) / 2
= (3.002 - 2.990) /2
= .006

From the Clearance Chart on Page 6-9, the recommended max clearance for a Quad-Ring® Brand with a hardness of 70 Shore A at 200 psi is .009. The seal should function properly.

8. Select the Seal Size

Refer to the Selection Guide beginning on page 6-22 and turn to the section which lists the seals having a .103 cross-section. Since in this application the sealing is occurring on the bore, use the Bore column to look up the seal size for a 3.000" bore. The correct seal is a number 4 -149 (with the 4 prefix signifying a Quad-Ring® Brand seal). Note the seal inside diameter, which is 2.800 ±.022. This will be used below.

9. Calculate the Installed Seal Stretch

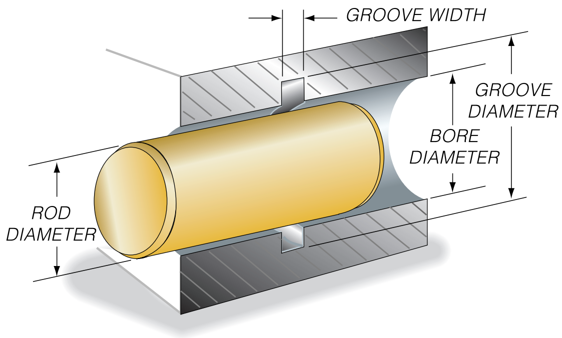
Stretch % = ((Installed Seal ID - Original Seal Inside Diameter) / Original Seal Diameter) x 100
= ((Groove Diameter - Original Seal Inside Diameter) / Original Seal Diameter) x 100
= ((2.814 - 2.800) / 2.800) x 100
= (.014 / 2.800) * 100 = .5 %

This stretch is low and will not cause significant cross-sectional reduction.

Application Example: Rod Quad-Ring® Brand Seal

Application description: Water faucet valve, U. S. Customary Units (inches)

- .25" dynamic stroke
- Rod (shaft) diameter: .374" ±.003
- Bore diameter: .385" ±.003
- 150 psi maximum pressure
- .070" cross-section Quad-Ring® Brand seal
- No side loading



RING SIZE	CROSS-SECTION	DYNAMIC RECOMMENDED GLAND DEPTH "C"	STATIC RECOMMENDED GLAND DEPTH "C"	AXIAL GROOVE WIDTH "D" +.005/-.000
Q4004 - Q4050	.070 ±.003	.061	.056	.080

1. Calculate the Seal Groove Diameter:

Groove Diameter
= Min Shaft Diameter + (2 X Dynamic Gland Depth)
= .371 + (2 X .061)
= .493 +.000 / -.002
(Recall the gland depth values in the chart are given as radial values)

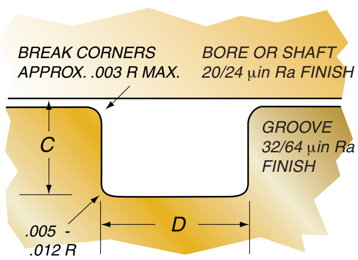
2. From the chart, the groove width is .080 -.000/+.005

3. Calculate the Minimum Gland Volume:

Minimum Gland Volume
= ((Min Groove Dia - Max Rod Dia. / 2) X Min Groove Width
= ((.491 - .377) / 2) X .080
= .00456 in^2

4. Calculate the Maximum Quad-Ring® Brand Seal, Volume:

Maximum Quad-Ring® Brand Seal Volume
= (Max Quad-Ring® Brand Cross-section)^2 X .8215
= $(.073)^2$ X .8215
= .0044 in^2



5. Compare the Minimum Gland Volume to the Maximum Quad-Ring® Brand Volume

In this application the maximum seal volume is less than the minimum gland volume, so the seal should function satisfactorily.

6. Calculate the Minimum and Maximum Seal Squeeze

a. Max Seal Squeeze = 1 - (Min Gland Depth / Max Seal Cross-section)
Min Gland Depth = (Min Groove Dia. - Max Rod Dia.) / 2
= (.491 - .377) / 2
= .057
Max Seal Squeeze = 1 - (.057 /.073)
= .219
= 21.9 %

b. Min Seal Squeeze = 1 - (Max Gland Depth / Min Seal Cross-section)
Max Gland Depth = (Max Groove Dia. - Min Rod Dia.)
= (.493 - .371) / 2
= .061
Min Seal Squeeze = 1 - (.061/.067)
= .09
= 9.0%
Therefore, sufficient squeeze should exist to seal this application.

7. Calculate the Maximum Clearance and evaluate possible extrusion problems

Max Radial Clearance = (Max Bore Dia. - Min Rod Dia.) / 2
= (.388 - .371) / 2
= .0085
From the Clearance Chart on Page 6-9, the recommended maximum radial clearance for a Quad-Ring® Brand seal with a hardness of 70 Shore A at 150 psi is slightly greater than .009 inches. The seal should work in this application.

8. Select the Seal Size

Refer to the Selection Guide beginning on page 6-22 and turn to the section which lists the seals having a .070 cross-section. This example's rod size of .374 is very close to the standard size of .375, so the standard seal for a .375 rod will probably work. Since in this application the sealing is occurring on the rod, use the Rod column to look up the seal size for a .375 rod. The correct seal is a number 4 -012 (with the 4 prefix signifying a Quad-Ring® Brand seal). Note the seal inside diameter, which is .364 ± .005. This will be used below.

9. Calculate the Installed Seal Stretch

Stretch % = ((Installed Seal ID - Original Seal Inside Diameter) / Original Seal Inside Diameter) x 100
= ((Rod Diameter - Original Seal Inside Diameter) / Original Seal Inside Diameter) x 100
= ((.374 - .364) / .364) x 100
= (.010 / .364) x 100 = 2.7 %

Quad-Ring® Brand and O-Ring Seals for Face Seal Applications

Quad-Rings® Brand and O-Rings seals are routinely used for face seal applications, which can be either static or dynamic applications.

General Considerations

The seal should be selected and the groove should be designed so the seal is always positioned against the side of the groove opposite the pressure. This prevents the applied pressure (or vacuum) from moving the seal which can lead to seal failure. When selecting the seal and designing the groove, use the groove and seal size tolerance conditions which will result in the seal always being positioned against the side of the groove opposite the applied pressure.

When designing face seal grooves, be careful to distinguish between the axial groove depth, which is the depth of the slot machined into the components for the seal, and the axial gland depth, which is the total axial space allowed for the seal (see opposite page). If necessary, refer to the glossary for a more detailed description of the two terms.

The groove diameters for a face seal are usually established based upon one of the following:

- A predetermined groove ID or OD has been selected based upon other design criteria (size of the unit, minimum amount of wall thickness necessary, etc). The groove width "D", taken from the O-Ring or Quad-Ring® Brand seal table, for the selected seal cross-section size is then used to calculated the groove diameters by either adding or subtracting twice its value from the predetermined groove dimension. The seal size is then selected to position it properly as described above.
- A particular seal has been pre-selected or is already available.

  Internal Pressure: The minimum seal OD is calculated and then the groove OD is established so the seal is always seated against it. The groove ID is calculated by subtracting twice the appropriate groove width.

  External Pressure: The maximum seal ID is calculated and then the groove ID is established so the seal is always seated against it. The groove OD is calculated by adding twice the appropriate groove width.

The recommended gland depths for Quad-Ring® Brand seal and O-Ring face seal applications are the same as for radial applications. Recommended gland depths can be found in the tables on Page 6-11 for a Quad-Ring® Brand seal and Page 6-13 for an O-Ring. However, the orientation of a face seal groove is axial instead of radial.

In an application where there is direct contact between the mating surfaces, such as with a cover, the groove depth is simply the recommended gland depth. In an application where there is clearance between the mating surfaces, the groove depth is calculated by subtracting the appropriate static or dynamic recommended gland depth from the absolute position of the sealing surface.

Groove Design for Face Seal Applications

1. **Cross-section.** Select a seal cross-section size from the available standard sizes. If you are unsure what cross-section size to use, see the discussion on Page 6-7.
2. **Clearance.** Determine the maximum clearance present in your application. In a direct contact application, consider the potential for variations in the surface flatness.
3. **Check the Clearance.** Determine if the clearance is acceptable for the application pressures and the material hardness being used by checking the graph on Page 6-9. Minnesota Rubber Company standard-line products are made from materials having a hardness of 70 Shore A. If the clearance is unacceptable, component tolerance will have to be tightened or a harder seal material will have to be special ordered. For a face seal, use the clearance determined in Step 2 and read its value directly from the graph.
4. **Calculate the seal groove dimensions.** Using either the Quad-Ring® Brand table (Page 6-11) or the O-Ring table (Page 6-13), determine the groove width "D" for the seal cross-section size you have selected. Determine the seal groove diameter as described in the paragraph above.
5. **Groove Depth.** Using either the Quad-Ring® Brand seal table (Page 6-11) or the O-Ring table (Page 6-13), select the recommended gland depth for a static or dynamic application.
6. **Percent Gland Fill.** Determine the maximum percent gland fill If the gland fill exceeds 100%, the groove will have to be redesigned. A good "rule-of-thumb" is to not exceed about 90% gland fill.
7. **Calculate the Seal Squeeze.** Calculate the minimum and maximum seal cross-sectional compression (squeeze). The recommended gland values in the seal tables have been developed to create a proper range of squeeze for many applications. In applications involving high pressure, large component tolerances, or other extreme conditions, the seal and groove design should be verified through an acceptable method, such as testing or engineering analysis.

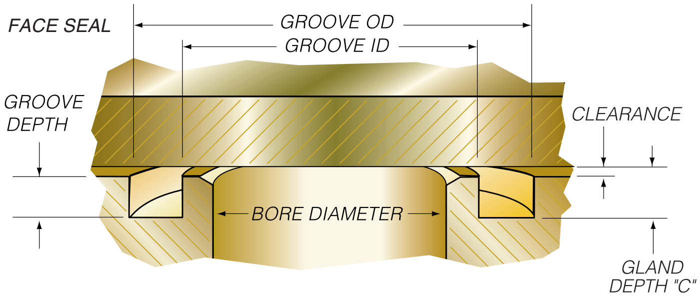
   Maximum Percent Compression = (1 - (Min Gland Depth/ Max Seal Cross-Section)) x 100

   Minimum Percent Compression = (1 - (Max Gland Depth/ Min Seal Cross-Section)) x 100
8. **Select the Seal.** Select the Quad-Ring® Brand seal with an inside diameter which will position the Quad-Ring® Brand seal on the side of the groove opposite the pressure.
9. **Detail the Groove.** Complete the groove design by specifying the proper radii and finish as indicated in the appropriate figure on page 6-11 or 6-13.

Application Example: Quad-Ring® Brand Face Seal

Application description: Cover for a Static Pressure Vessel, U. S. Customary Units (inches)

- Inside pressure of 50 psi
- Bore diameter .500" ±.005
- Desired Maximum groove OD of .750" -.005/+.000
- .103" cross-section Quad-Ring® Brand seal
- Cover is flat



RING SIZE	CROSS-SECTION	**AXIAL** STATIC RECOMMENDED GLAND DEPTH "C"	**RADIAL** STATIC SQUEEZE GROOVE WIDTH "D" +.005/-.000
Q4102 - Q4178	.103 ±.003	.082	.115

1. Determine the groove depth:

   Since the cover is flat, the groove depth is simply the gland depth. For this static application, the recommended gland depth from the table is .082.

   Groove Depth = Gland Depth = .089 -.002/+.000

   For the purpose of this example, a tolerance on this dimension of -.002/+.000 is assumed.

2. Calculate the groove inside diameter.

   From the table, the groove width for a .103 cross-section seal is .115 -.000/+.005.

   Groove I.D. = Minimum Groove O.D. - (2 x Groove Width)
   = .745 - (2 X .115)
   = .515 -.005/+.000

   For the purpose of this example, a tolerance on this dimension of -.000/+.005 is assumed.

3. Calculate the Minimum Gland Volume:

   Minimum Gland Volume = ((Min Groove O.D. - Max Groove I.D.) / 2) x Min Gland Depth
   = ((.745 - .515)/2) X .087
   = .010 in^2

4. Calculate the Maximum Quad-Ring® Brand Seal Volume:

   Maximum Quad-Ring® Brand Seal Volume = (Max Quad-Ring® Brand Cross-section)^2 X .8215
   = (.106)^2 X .8215
   = .00923 in^2

5. Compare the Minimum Gland Volume to the Maximum Quad-Ring® Brand Seal Volume

   In this application the maximum seal volume is less than the minimum gland volume, so the seal should function satisfactorily.

6. Calculate the Minimum and Maximum Seal Squeeze

   a. Max Seal Squeeze = 1 - (Min Gland Depth / Max Seal Cross-section
   = 1 - (.087 / .106)
   = .179 = 17.9%

   b. Min Seal Squeeze = 1 - (Max Gland Depth / Min Seal Cross-section)
   = 1 - (.089/.100)
   = .11 = 11%

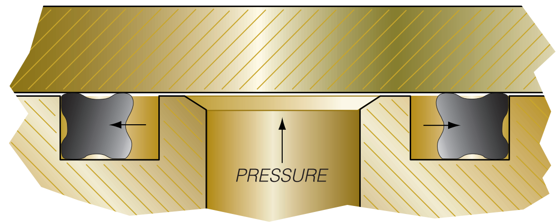
   Therefore, sufficient squeeze should exist to seal this application.

8. Select the Seal Size

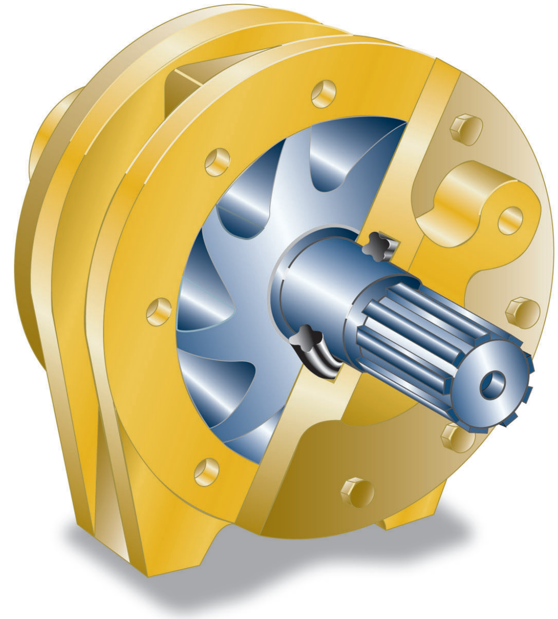
   Refer to the Selection Guide beginning on page 6-22 and turn to the section which lists the seals having a .103 cross-section. Since this is an internal pressure application, the seal OD should always be seated against the groove OD, which has a maximum size of .750. Since the Selection Guide Table provides seal ID information, determine the minimum required ID by subtracting the minimum seal cross-section:

   Min ID= .750 - 2 x Min seal Cross-section = .750 X (2 X .100) = .550

   A 4114 seal would always have a minimum ID greater than .550.



Rotary Seals



Rotary Seal Considerations

Rotary seal applications offer unique challenges to seal manufacturers. Friction produced heat can quickly exceed the materials' maximum temperature if careful consideration is not made to minimize friction. Consider the following issues with rotary seal applications.

Heat Dissipation

The most common failure mode for a rotary seal is heat failure of the material. The most effective method of reducing heat build up is to reduce friction. This can be accomplished in many ways. Consider the chart below.

Difficult to Seal	Easy to Seal
▪ High shaft speed	▪ Low shaft speed
▪ Non-lubricating seal medium	▪ Lubricating seal medium
▪ Loose component tolerances	▪ Tight component tolerances
▪ Incorrect shaft surface finish	▪ Correct surface finish
▪ Insulating materials	▪ Conductive materials
▪ High temperature	▪ Lower temperature
▪ Pressure less than 10 psi	▪ Pressure between 10 and 750 psi
▪ Pressure greater than 750 psi	

Mating Part Tolerance

To maintain a good seal with minimum friction, rotary applications require mating parts to be manufactured with tight tolerances. The shaft and bore should have a tolerance of ±.001 or better. Using tight tolerances reduces the amount of squeeze needed to seal in the worst case tolerance stackup.

Select Cross-section Size

When specifying a seal, choose the largest cross-section possible. The greater the cross-section, the more effective the seal and the longer the service life.

Shaft Speed

Whenever a choice exists, seal on the smallest diameter of the shaft to minimize friction and reduce surface speed. Shaft speeds of 900 FPM (15.2-274.3 m/min) are possible in pressure lubricated hydraulic applications. For shaft speeds of less than 20 FPM (15.2 m/min) and greater than 900 FPM (15.2-274.3 m/min) please contact our engineering department for technical assistance.

Feet / Minute (FPM) =
Shaft diameter (in inches) x 3.1415 x RPM) / 12

Meters / Minute (m/min) =
Shaft diameter (in meters) x 3.1415 x RPM

Seal Lubrication

Because heat related failure is the most common rotary seal failure mode, seal lubrication is extremely important. As friction increases so does heat buildup, decreasing seal life. Every application is different, but with increased surface speed lubrication is increasingly important. Also consider it takes lubrication pressure to get the lubrication forced into the dynamic seal interface. This pressure needs to be a minimum of 10 psi. When sealing non-lubricating fluids (milk, water, air, etc.) the seal life will be reduced significantly.

Surface Finish and Hardness

To reduce friction, the surface finish of the shaft should ideally be 20-24 µin Ra (.5-.6 µm) to improve its lubrication holding ability, 20-32 µin Ra (.5-.7 µm) is acceptable. Having a surface finish that is too smooth stops lubrication from getting to the sealing surface. Surface finish in the groove should be 63-85 µin Ra (1.6-2.1 µm) to prevent the seal from rotating in the groove. The minimum recommended hardness for the shaft material is 35 Rc.

Peripheral Compression

In a rotary application, the inside diameter of a free, uninstalled, Quad-Ring® Brand seal should always be larger than the OD of the shaft. After installation, the inside diameter will be peripherally compressed to be small enough to provide the squeeze necessary for sealing. This holds the seal in the groove and makes the dynamic surface between the seal and the shaft, not between the seal and the groove.

Seal Movement

Placing the groove in the housing, peripherally compressing the seal into the groove, and maximizing component concentricity maximizes seal life. Component eccentricity in rotary applications will cause the seal to act as a pump causing the seal to leak.

Materials

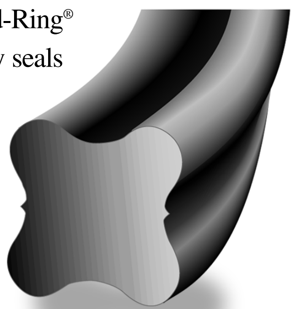
Our compounds 525LP and 525L are recommended for rotary applications. These carboxylated nitrile formulations offer excellent abrasion resistance and are compatible for use with most hydraulic fluids. Compound 525LP is generally used in applications to 300 psi (20.7 bar), while 525L is preferred for pressures of 300-750 psi (20.7-51.7 bar).

Avoiding Seal Installation Damage

Seals can be easily damaged during installation. For example, a seal is often inserted onto a shaft by sliding it over a threaded or splined surface. To avoid seal damage, reduce the shaft diameter in the threaded region. Also include a lead-in chamfer for the seal and avoid sharp corners on grooves.When possible, consider using a cone-shaped installation tool to help install the seal.

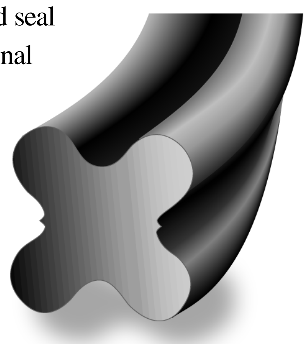
Sealing Systems for the Rotary Application

Quad-Ring® Brand Seals (standard and custom molded)



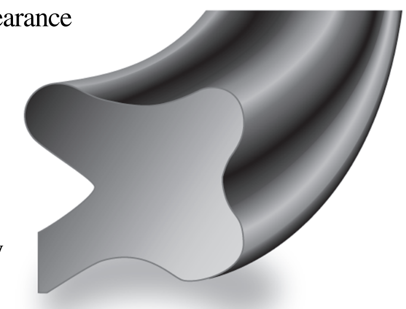
If applied correctly, standard Quad-Ring® Brand seals can be excellent rotary seals as compared to more expensive alternatives. They offer low friction for long life in hydraulic systems with speeds up to 900 FPM (4.5 M/Sec) and a maximum pressure of 750 psi (52 bar). Refer to the table on the following page for correct sizing of Quad-Ring® Brand seals for your application.

Modified Quad-Ring® Brand Seals (custom molded)



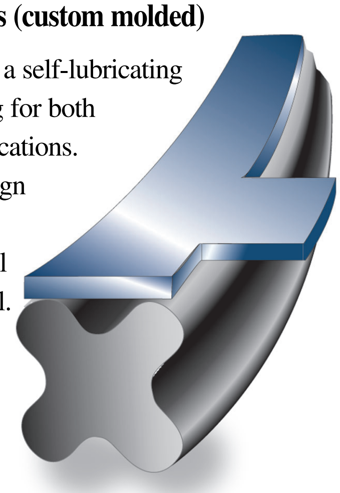
This modified Quad-Ring® Brand seal has a deeper valley than the original Quad-Ring® Brand seal design, thereby producing lower deflection force value and reduced friction. Using Modified Quad-Ring® Brand seals will extend the seal life of rotary applications with pressures less than 100 psi.

Quad-Kup® Brand Seals (custom molded)



For high diametrical clearance applications and those requiring low operating friction. Provides low-pressure seal up to 150 psi (10.3 bar) in reciprocating and rotary applications. The combination lobed/cup configuration can be designed with the lip on any of the four surfaces, top or bottom, on the ID or OD.

Quad® P.E Plus Brand Seals (custom molded)



This dual-function seal forms a self-lubricating seal and an elastomeric spring for both rotary and reciprocating applications. Newly patented, this seal design combines injection moldable thermoplastic bearing material with a Quad-Ring® Brand seal. This seal is not intended for zero leakage applications.

Specialized Seals for Demanding Applications

Each rotary application is unique, often involving media other than oil or extreme conditions of temperature, pressure, or friction. Special seals are available to meet these demanding requirements.

Quad-Ring® Brand Seals for Rotary Applications With Oil

Quad-Ring® Brand seals offer low friction for long life in hydraulic systems with surface speeds up to 900 FPM (4.5 m/sec)

Quad-Ring® Brand seals should operate in a seal groove with a maximum diametral clearance of .004 in (0.10 mm) and a maximum pressure of 750 psi (52 bar). There must be a minimum of 10 psi oil pressure to properly lubricate the seal.

The table below contains groove dimensions for some common shaft sizes. The example on the opposite page illustrates how to calculate the groove dimensions for other shaft sizes. To calculate the proper groove diameter, select a Quad-Ring® Brand seal from the Standard Size Seal Table on Page 6-22 with the desired cross-section having an ID slightly larger than the maximum shaft diameter (shaft diameter at the high end of its tolerance). The rotary seal groove diameter is calculated as:

Maximum Groove Diameter = Minimum Shaft Diameter + (2 x Minimum Seal Cross-section) - .004 inches [0.10 mm]

Tip: To quickly locate the proper rotary seal Quad-Ring® Brand size in the Standard Size Seal Table on Page 6-22, turn to the section of the table for the seal cross-section size you have chosen. Then, using the Rod (shaft) size column, find the seal number for the shaft size you are using, as listed in the table. Move down one row in the table and check the seal ID for the next larger seal size. This will usually be the correct seal for a rotary application. Remember that as explained on page 6-19, for a rotary seal application the uninstalled Quad-Ring® Brand seal inside diameter should always be larger than the shaft diameter.

Recommended Initial Groove Design Dimensions for Rotary Applications

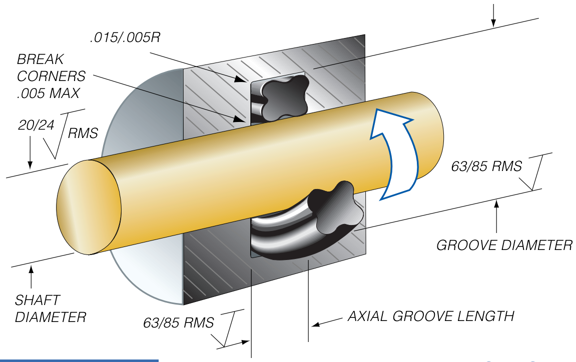
Note: This table is for use with rotary applications only.

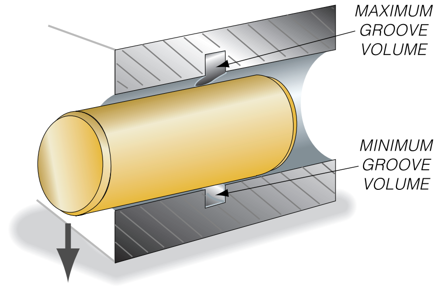
ROTARY SEAL QUAD-RING® BRAND SIZE	SHAFT DIA. (in)	SHAFT DIA. (mm)	SEAL CROSS-SECTION (in)	SEAL CROSS-SECTION (mm)	GROOVE DIA. (in) +.001/-.001	GROOVE DIA. (mm) +0.03/-0.03	AXIAL GROOVE WIDTH (in) +.005/-.000	AXIAL GROOVE WIDTH (mm) +0.13/-0.00
Q4007	.125	3.18	.070 ±.003	1.78 ±0.08	.255	6.48	.080	2.03
Q4008	.156	3.96	.070 ±.003	1.78 ±0.08	.286	7.26	.080	2.03
Q4009	.188	4.78	.070 ±.003	1.78 ±0.08	.318	8.08	.080	2.03
Q4010	.218	5.54	.070 ±.003	1.78 ±0.08	.348	8.84	.080	2.03
Q4011	.250	6.35	.070 ±.003	1.78 ±0.08	.380	9.65	.080	2.03
Q4011	.281	7.14	.070 ±.003	1.78 ±0.08	.411	10.44	.080	2.03
Q4110	.312	7.92	.103 ±.003	2.62 ±0.08	.508	12.90	.110	2.79
Q4111	.375	9.53	.103 ±.003	2.62 ±0.08	.571	14.50	.110	2.79
Q4112	.437	11.10	.103 ±.003	2.62 ±0.08	.633	16.08	.110	2.79
Q4113	.500	12.70	.103 ±.003	2.62 ±0.08	.696	17.68	.110	2.79
Q4114	.562	14.27	.103 ±.003	2.62 ±0.08	.758	19.25	.110	2.79
Q4115	.625	15.88	.103 ±.003	2.62 ±0.08	.821	20.85	.110	2.79
Q4117	.750	19.05	.103 ±.003	2.62 ±0.08	.946	24.03	.110	2.79
Q4118	.812	20.62	.103 ±.003	2.62 ±0.08	1.008	25.60	.110	2.79
Q4119	.875	22.23	.103 ±.003	2.62 ±0.08	1.071	27.20	.110	2.79
Q4120	.937	23.80	.103 ±.003	2.62 ±0.08	1.133	28.78	.110	2.79
Q4121	1.000	25.40	.103 ±.003	2.62 ±0.08	1.196	30.38	.110	2.79
Q4122	1.062	26.97	.103 ±.003	2.62 ±0.08	1.258	31.95	.110	2.79
Q4123	1.125	28.58	.103 ±.003	2.62 ±0.08	1.321	33.55	.110	2.79
Q4124	1.187	30.15	.103 ±.003	2.62 ±0.08	1.383	35.13	.110	2.79
Q4125	1.250	31.75	.103 ±.003	2.62 ±0.08	1.446	36.73	.110	2.79
Q4126	1.312	33.32	.103 ±.003	2.62 ±0.08	1.508	38.30	.110	2.79
Q4127	1.375	34.93	.103 ±.003	2.62 ±0.08	1.571	39.90	.110	2.79
Q4129	1.500	38.10	.103 ±.003	2.62 ±0.08	1.696	43.08	.110	2.79
Q4133	1.750	44.45	.103 ±.003	2.62 ±0.08	1.946	49.43	.110	2.79
Q4137	2.000	50.80	.103 ±.003	2.62 ±0.08	2.196	55.78	.110	2.79

Application Example: Quad-Ring® Brand Rotary Seal

Application description: Hydraulic Pump

- Shaft diameter .750" ±.001
- Bore diameter OD .753" ±.001
- 150 psi Hydraulic oil
- .103" cross-section
  Quad-Ring® Brand seal





RING SIZE	CROSS-SECTION	AXIAL GROOVE WIDTH "D" +.005/-.000
Q4102 - Q4178	.103 ±.003	.110

1. Calculate groove dimensions

   Groove Diameter = Minimum Shaft Diameter + (2 x Min Cross-Section) - .004"
   Groove Diameter = .749 + (2 x .100) - .004
   Groove Diameter = .945 in ± .001

2. Groove width = .110" -.000/+.005 - see chart on page 4-20

3. Calculate Minimum Groove Volume

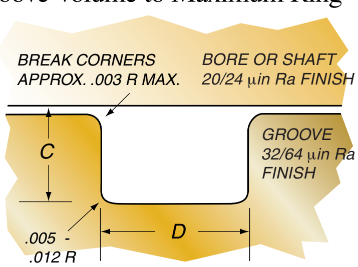
   Minimum Groove Volume = ((Min Groove Dia. - Max. Bore Dia.)/2) x Groove Width
   Minimum Groove Volume = ((.944 - .754)/2) x .115
   Minimum Groove Volume = .0109 in^2

4. Calculate Maximum Quad-Ring® Brand Seal Volume

   Maximum Quad-Ring® Brand Volume = (Maximum Cross-Section)^2 x .8215
   Maximum Quad-Ring® Brand Volume = .106^2 x .8215
   Maximum Quad-Ring® Brand Volume = .0092 in^2

5. Compare Minimum Groove Volume to Maximum Ring Volume

   In this application the Maximum Ring Volume is less than the Minimum Groove Volume, everything appears to be OK.



6. Calculate Minimum and Maximum seal squeeze

   These calculations look at both ends of the worst case stack up tolerance, including rod shift to determine the maximum and minimum ring squeeze.

   Maximum Seal Squeeze =
   1 - (Minimum Groove Depth / Maximum Ring Cross-Section)
   Minimum Groove Depth = (Minimum Groove diameter – Maximum Bore)/2
   Minimum Groove Depth = (.944 - .754)/2
   Minimum Groove Depth = .095
   Maximum Seal Squeeze = 1 - (.095 / .106)
   Maximum Seal Squeeze = 10.3%

   Minimum Seal Squeeze =
   1 - (Maximum Groove Depth / Minimum Ring Cross-Section)
   Maximum Groove Depth = ((Max. Groove Diameter. – Max Bore)/2) + (Max Bore – Min. Rod)
   Maximum Groove Depth = ((.946 - .754)/2) + (.754 - .749)
   Maximum Groove Depth = .096 + .005
   Maximum Groove Depth = .101
   Minimum Seal Squeeze = 1 – (.101 / .100)
   Minimum Seal Squeeze = -1.0%

   In this application if every dimension went to the worst side of the tolerance and the piston was side loaded the seal would leak. To avoid these problems:

   1. *Reduce the clearance between the bore and piston.*
   2. *Reduce the tolerances of the bore and piston.*
   3. *Use a larger cross section Quad-Ring® Brand seal to absorb the extra tolerance.*
   4. *Support the piston so that it can not move off center.*

7. Calculate Maximum Clearance and Evaluate Possible Extrusion Issues

   Maximum Clearance = Maximum Bore – Minimum Rod
   Maximum Clearance = .754 – .749
   Maximum Clearance = .005" (.0025" Radial)

   This application has a max clearance of .0025" and must withstand 150 PSI without extruding the Quad-Ring® Brand seal. Refer to the clearance chart on page 6-9. A 70 Shore A material at 150 PSI can withstand a maximum clearance of .009 so, a 70 Shore A material will work. Making improvements to the Minimum Seal Squeeze issues in Step 6 will also reduce any possible issues with seal extrusion.

8. Select seal size

   For all rotary rod seal applications select a Quad-Ring® Brand seal that has an ID larger than the maximum shaft diameter.
   Part ID >= .751"
   Quad-Ring® Brand Seal Size = 4117

Selection Guide for Standard Size Quad-Ring® Brand Seals and Quad® Brand O-Ring Seals

Our standard Quad-Ring® Brand and O-Ring Seals are available from stock, in compound 366Y, a 70 Shore A nitrile and 514AD, a 70 Shore A fluorocarbon material.

For applications requiring other materials, Minnesota Rubber can recommend one of our existing compounds or customize a special material to meet your needs. These parts are all manufactured in standard tools.

Understanding Our Part Numbers

Seal Configuration Quad-Ring® Brand Seal | Ring Size | Rubber Compound

4 210-366Y

Part Number

Seal Configuration Quad® Brand O-Ring Seal | Ring Size AS-568A Dimensions | Rubber Compound

8 210-366Y

Part Number

Tolerances

Our standard Quad-Ring® Brand and O-Ring seal tooling is designed to the shrinkage characteristics of our popular 366Y, a 70 durometer nitrile formulation. Because every rubber formulation has its own shrinkage characteristics, slight deviations in dimensions will occur when standard seal tooling is used with materials other than our 366Y. The majority of the cases we encounter involve rubber compounds with a higher shrinkage factor, resulting in seals with undersized cross-sections and undersized inside diameters. This increase in shrinkage is most pronounced when using silicone, fluorosilicone and flourocarbon elastomer materials. Because of the decrease in cross-sectional size, groove dimensions may need to decrease to maintain a good seal. Parts produced in materials other than 366Y may not conform to the dimensional specifications as stated in AS-568A or the following table.

Note: The Rod and Bore columns listed in the following table do NOT indicate a rod/bore combination for a specific seal number. To use the table, first determine the proper seal size by locating the rod or the bore size on which you are sealing. The seal groove diameter can then be calculated as indicated, starting on page 6-10.

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
001	.031	.093	$^{1}/_{32}$	$^{1}/_{32}$	.029 ±.004	0.74 ±0.10	.040 ±.003	1.02 ±0.08
002	.046	.125	$^{3}/_{64}$	$^{3}/_{64}$	.042 ±.004	1.07 ±0.10	.050 ±.003	1.27 ±0.08
003	.062	.156	$^{1}/_{16}$	$^{1}/_{16}$	.056 ±.004	1.42 ±0.10	.060 ±.003	1.52 ±0.08
003 $^{1}/_{2}$	.078	.141	$^{1}/_{16}$	$^{1}/_{32}$	.070 ±.004	1.78 ±0.10	.040 ±.003	1.02 ±0.08
004	.078	.203	$^{5}/_{64}$	$^{1}/_{16}$	.070 ±.005	1.78 ±0.13	.070 ±.003	1.78 ±0.08
005	.109	.234	$^{3}/_{32}$	$^{1}/_{16}$	.101 ±.005	2.57 ±0.13	.070 ±.003	1.78 ±0.08
006	.125	.250	$^{1}/_{8}$	$^{1}/_{16}$	.114 ±.005	2.90 ±0.13	.070 ±.003	1.78 ±0.08
007	.156	.281	$^{5}/_{32}$	$^{1}/_{16}$	.145 ±.005	3.68 ±0.13	.070 ±.003	1.78 ±0.08
008	.187	.312	$^{3}/_{16}$	$^{1}/_{16}$	.176 ±.005	4.47 ±0.13	.070 ±.003	1.78 ±0.08
009	.218	.343	$^{7}/_{32}$	$^{1}/_{16}$	.208 ±.005	5.28 ±0.13	.070 ±.003	1.78 ±0.08
010	.250	.375	$^{1}/_{4}$	$^{1}/_{16}$	.239 ±.005	6.07 ±0.13	.070 ±.003	1.78 ±0.08
011	.312	.437	$^{5}/_{16}$	$^{1}/_{16}$	.301 ±.005	7.65 ±0.13	.070 ±.003	1.78 ±0.08
012	.375	.500	$^{3}/_{8}$	$^{1}/_{16}$	.364 ±.005	9.25 ±0.13	.070 ±.003	1.78 ±0.08
013	.437	.562	$^{7}/_{16}$	$^{1}/_{16}$	.426 ±.005	10.82 ±0.13	.070 ±.003	1.78 ±0.08
014	.500	.625	$^{1}/_{2}$	$^{1}/_{16}$	.489 ±.005	12.42 ±0.13	.070 ±.003	1.78 ±0.08
015	.562	.687	$^{9}/_{16}$	$^{1}/_{16}$	.551 ±.007	14.00 ±0.18	.070 ±.003	1.78 ±0.08
016	.625	.750	$^{5}/_{8}$	$^{1}/_{16}$	.614 ±.009	15.60 ±0.23	.070 ±.003	1.78 ±0.08
017	.687	.812	$^{11}/_{16}$	$^{1}/_{16}$	.676 ±.009	17.17 ±0.23	.070 ±.003	1.78 ±0.08

Selection Guide for Standard Size Quad-Ring® Brand Seals and Quad® Brand O-Ring Seals - continued

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
018	.750	.875	3/4	1/16	.739 ±.009	18.77 ±0.23	.070 ±.003	1.78 ±0.08
019	.812	.937	13/16	1/16	.801 ±.009	20.35 ±0.23	.070 ±.003	1.78 ±0.08
020	.875	1.000	7/8	1/16	.864 ±.009	21.95 ±0.23	.070 ±.003	1.78 ±0.08
021	.937	1.062	15/16	1/16	.926 ±.009	23.52 ±0.23	.070 ±.003	1.78 ±0.08
022	1.000	1.125	1	1/16	.989 ±.010	25.12 ±0.25	.070 ±.003	1.78 ±0.08
023	1.062	1.187	1 1/16	1/16	1.051 ±.010	26.70 ±0.25	.070 ±.003	1.78 ±0.08
024	1.125	1.250	1 1/8	1/16	1.114 ±.010	28.30 ±0.25	.070 ±.003	1.78 ±0.08
025	1.187	1.312	1 3/16	1/16	1.176 ±.011	29.87 ±0.28	.070 ±.003	1.78 ±0.08
026	1.250	1.375	1 1/4	1/16	1.239 ±.011	31.47 ±0.28	.070 ±.003	1.78 ±0.08
027	1.312	1.437	1 5/16	1/16	1.301 ±.011	33.05 ±0.28	.070 ±.003	1.78 ±0.08
028	1.375	1.500	1 3/8	1/16	1.364 ±.013	34.65 ±0.33	.070 ±.003	1.78 ±0.08
029	1.500	1.625	1 1/2	1/16	1.489 ±.013	37.82 ±0.33	.070 ±.003	1.78 ±0.08
030	1.625	1.750	1 5/8	1/16	1.614 ±.013	41.00 ±0.33	.070 ±.003	1.78 ±0.08
031	1.750	1.875	1 3/4	1/16	1.739 ±.015	44.17 ±0.38	.070 ±.003	1.78 ±0.08
032	1.875	2.000	1 7/8	1/16	1.864 ±.015	47.35 ±0.38	.070 ±.003	1.78 ±0.08
033	2.000	2.125	2	1/16	1.989 ±.018	50.52 ±0.46	.070 ±.003	1.78 ±0.08
034	2.125	2.250	2 1/8	1/16	2.114 ±.018	53.70 ±0.46	.070 ±.003	1.78 ±0.08
035	2.250	2.375	2 1/4	1/16	2.239 ±.018	56.87 ±0.46	.070 ±.003	1.78 ±0.08
036	2.375	2.500	2 3/8	1/16	2.364 ±.018	60.05 ±0.46	.070 ±.003	1.78 ±0.08
037	2.500	2.625	2 1/2	1/16	2.489 ±.018	63.22 ±0.46	.070 ±.003	1.78 ±0.08
038	2.625	2.750	2 5/8	1/16	2.614 ±.020	66.40 ±0.51	.070 ±.003	1.78 ±0.08
039	2.750	2.875	2 3/4	1/16	2.739 ±.020	69.57 ±0.51	.070 ±.003	1.78 ±0.08
040	2.875	3.000	2 7/8	1/16	2.864 ±.020	72.75 ±0.51	.070 ±.003	1.78 ±0.08
041	3.000	3.125	3	1/16	2.989 ±.024	75.92 ±0.61	.070 ±.003	1.78 ±0.08
042	3.250	3.375	3 1/4	1/16	3.239 ±.024	82.27 ±0.61	.070 ±.003	1.78 ±0.08
043	3.500	3.625	3 1/2	1/16	3.489 ±.024	88.62 ±0.61	.070 ±.003	1.78 ±0.08
044	3.750	3.875	3 3/4	1/16	3.739 ±.027	94.97 ±0.69	.070 ±.003	1.78 ±0.08
045	4.000	4.125	4	1/16	3.989 ±.027	101.32 ±0.69	.070 ±.003	1.78 ±0.08
046	4.250	4.375	4 1/4	1/16	4.239 ±.030	107.67 ±0.76	.070 ±.003	1.78 ±0.08
047	4.500	4.625	4 1/2	1/16	4.489 ±.030	114.02 ±0.76	.070 ±.003	1.78 ±0.08
048	4.750	4.875	4 3/4	1/16	4.739 ±.030	120.37 ±0.76	.070 ±.003	1.78 ±0.08
049	5.000	5.125	5	1/16	4.989 ±.037	126.72 ±0.94	.070 ±.003	1.78 ±0.08
050	5.250	5.375	5 1/4	1/16	5.239 ±.037	133.07 ±0.94	.070 ±.003	1.78 ±0.08
051 THROUGH 101 SIZES NOT ASSIGNED								
102	.062	.250	1/16	3/32	.049 ±.005	1.24 ±0.13	.103 ±.003	2.62 ±0.08
103	.094	.281	3/32	3/32	.081 ±.005	2.06 ±0.13	.103 ±.003	2.62 ±0.08
104	.125	.312	1/8	3/32	.112 ±.005	2.84 ±0.13	.103 ±.003	2.62 ±0.08
105	.156	.343	5/32	3/32	.143 ±.005	3.63 ±0.13	.103 ±.003	2.62 ±0.08
106	.187	.375	3/16	3/32	.174 ±.005	4.42 ±0.13	.103 ±.003	2.62 ±0.08
107	.219	.406	7/32	3/32	.206 ±.005	5.23 ±0.13	.103 ±.003	2.62 ±0.08

Selection Guide for Standard Size Quad-Ring® Brand Seals and Quad® Brand O-Ring Seals-continued

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
108	.250	.437	1/4	3/32	.237 ±.005	6.02 ±0.13	.103 ±.003	2.62 ±0.08
109	.312	.500	5/16	3/32	.299 ±.005	7.59 ±0.13	.103 ±.003	2.62 ±0.08
110	.375	.562	3/8	3/32	.362 ±.005	9.19 ±0.13	.103 ±.003	2.62 ±0.08
111	.437	.625	7/16	3/32	.424 ±.005	10.77 ±0.13	.103 ±.003	2.62 ±0.08
112	.500	.687	1/2	3/32	.487 ±.005	12.37 ±0.13	.103 ±.003	2.62 ±0.08
113	.562	.750	9/16	3/32	.549 ±.007	13.94 ±0.18	.103 ±.003	2.62 ±0.08
114	.625	.812	5/8	3/32	.612 ±.009	15.54 ±0.23	.103 ±.003	2.62 ±0.08
115	.687	.875	11/16	3/32	.674 ±.009	17.12 ±0.23	.103 ±.003	2.62 ±0.08
116	.750	.937	3/4	3/32	.737 ±.009	18.72 ±0.23	.103 ±.003	2.62 ±0.08
117	.812	1.000	13/16	3/32	.799 ±.010	20.29 ±0.25	.103 ±.003	2.62 ±0.08
118	.875	1.062	7/8	3/32	.862 ±.010	21.89 ±0.25	.103 ±.003	2.62 ±0.08
119	.937	1.125	15/16	3/32	.924 ±.010	23.47 ±0.25	.103 ±.003	2.62 ±0.08
120	1.000	1.187	1	3/32	.987 ±.010	25.07 ±0.25	.103 ±.003	2.62 ±0.08
121	1.062	1.250	1 1/16	3/32	1.049 ±.010	26.64 ±0.25	.103 ±.003	2.62 ±0.08
122	1.125	1.312	1 1/8	3/32	1.112 ±.010	28.24 ±0.25	.103 ±.003	2.62 ±0.08
123	1.187	1.375	1 3/16	3/32	1.174 ±.012	29.82 ±0.30	.103 ±.003	2.62 ±0.08
124	1.250	1.437	1 1/4	3/32	1.237 ±.012	31.42 ±0.30	.103 ±.003	2.62 ±0.08
125	1.312	1.500	1 5/16	3/32	1.299 ±.012	32.99 ±0.30	.103 ±.003	2.62 ±0.08
126	1.375	1.562	1 3/8	3/32	1.362 ±.012	34.59 ±0.30	.103 ±.003	2.62 ±0.08
127	1.437	1.625	1 7/16	3/32	1.424 ±.012	36.17 ±0.30	.103 ±.003	2.62 ±0.08
128	1.500	1.687	1 1/2	3/32	1.487 ±.012	37.77 ±0.30	.103 ±.003	2.62 ±0.08
129	1.562	1.750	1 9/16	3/32	1.549 ±.015	39.34 ±0.38	.103 ±.003	2.62 ±0.08
130	1.625	1.812	1 5/8	3/32	1.612 ±.015	40.94 ±0.38	.103 ±.003	2.62 ±0.08
131	1.687	1.875	1 11/16	3/32	1.674 ±.015	42.52 ±0.38	.103 ±.003	2.62 ±0.08
132	1.750	1.937	1 3/4	3/32	1.737 ±.015	44.12 ±0.38	.103 ±.003	2.62 ±0.08
133	1.812	2.000	1 13/16	3/32	1.799 ±.015	45.69 ±0.38	.103 ±.003	2.62 ±0.08
134	1.875	2.062	1 7/8	3/32	1.862 ±.015	47.29 ±0.38	.103 ±.003	2.62 ±0.08
135	1.938	2.125	1 15/16	3/32	1.925 ±.017	48.90 ±0.43	.103 ±.003	2.62 ±0.08
136	2.000	2.187	2	3/32	1.987 ±.017	50.47 ±0.43	.103 ±.003	2.62 ±0.08
137	2.063	2.250	2 1/16	3/32	2.050 ±.017	52.07 ±0.43	.103 ±.003	2.62 ±0.08
138	2.125	2.312	2 1/8	3/32	2.112 ±.017	53.64 ±0.43	.103 ±.003	2.62 ±0.08
139	2.188	2.375	2 3/16	3/32	2.175 ±.017	55.25 ±0.43	.103 ±.003	2.62 ±0.08
140	2.250	2.437	2 1/4	3/32	2.237 ±.017	56.82 ±0.43	.103 ±.003	2.62 ±0.08
141	2.313	2.500	2 5/16	3/32	2.300 ±.020	58.42 ±0.51	.103 ±.003	2.62 ±0.08
142	2.375	2.562	2 3/8	3/32	2.362 ±.020	59.99 ±0.51	.103 ±.003	2.62 ±0.08
143	2.438	2.625	2 7/16	3/32	2.425 ±.020	61.60 ±0.51	.103 ±.003	2.62 ±0.08
144	2.500	2.687	2 1/2	3/32	2.487 ±.020	63.17 ±0.51	.103 ±.003	2.62 ±0.08
145	2.563	2.750	2 9/16	3/32	2.550 ±.020	64.77 ±0.51	.103 ±.003	2.62 ±0.08
146	2.625	2.812	2 5/8	3/32	2.612 ±.020	66.34 ±0.51	.103 ±.003	2.62 ±0.08
147	2.688	2.875	2 11/16	3/32	2.675 ±.022	67.95 ±0.56	.103 ±.003	2.62 ±0.08

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
148	2.750	2.937	2 3/4	3/32	2.737 ±.022	69.52 ±0.56	.103 ±.003	2.62 ±0.08
149	2.813	3.000	2 13/16	3/32	2.800 ±.022	71.12 ±0.56	.103 ±.003	2.62 ±0.08
150	2.875	3.062	2 7/8	3/32	2.862 ±.022	72.69 ±0.56	.103 ±.003	2.62 ±0.08
151	3.000	3.187	3	3/32	2.987 ±.024	75.87 ±0.61	.103 ±.003	2.62 ±0.08
152	3.250	3.437	3 1/4	3/32	3.237 ±.024	82.22 ±0.61	.103 ±.003	2.62 ±0.08
153	3.500	3.687	3 1/2	3/32	3.487 ±.024	88.57 ±0.61	.103 ±.003	2.62 ±0.08
154	3.750	3.937	3 3/4	3/32	3.737 ±.028	94.92 ±0.71	.103 ±.003	2.62 ±0.08
155	4.000	4.187	4	3/32	3.987 ±.028	101.27 ±0.71	.103 ±.003	2.62 ±0.08
156	4.250	4.437	4 1/4	3/32	4.237 ±.030	107.62 ±0.76	.103 ±.003	2.62 ±0.08
157	4.500	4.687	4 1/2	3/32	4.487 ±.030	113.97 ±0.76	.103 ±.003	2.62 ±0.08
158	4.750	4.937	4 3/4	3/32	4.737 ±.030	120.32 ±0.76	.103 ±.003	2.62 ±0.08
159	5.000	5.187	5	3/32	4.987 ±.035	126.67 ±0.89	.103 ±.003	2.62 ±0.08
160	5.250	5.437	5 1/4	3/32	5.237 ±.035	133.02 ±0.89	.103 ±.003	2.62 ±0.08
161	5.500	5.687	5 1/2	3/32	5.487 ±.035	139.37 ±0.89	.103 ±.003	2.62 ±0.08
162	5.750	5.937	5 3/4	3/32	5.737 ±.035	145.72 ±0.89	.103 ±.003	2.62 ±0.08
163	6.000	6.187	6	3/32	5.987 ±.035	152.07 ±0.89	.103 ±.003	2.62 ±0.08
164	6.250	6.437	6 1/4	3/32	6.237 ±.040	158.42 ±1.02	.103 ±.003	2.62 ±0.08
165	6.500	6.687	6 1/2	3/32	6.487 ±.040	164.77 ±1.02	.103 ±.003	2.62 ±0.08
166	6.750	6.937	6 3/4	3/32	6.737 ±.040	171.12 ±1.02	.103 ±.003	2.62 ±0.08
167	7.000	7.187	7	3/32	6.987 ±.040	177.47 ±1.02	.103 ±.003	2.62 ±0.08
168	7.250	7.437	7 1/4	3/32	7.237 ±.045	183.82 ±1.14	.103 ±.003	2.62 ±0.08
169	7.500	7.687	7 1/2	3/32	7.487 ±.045	190.17 ±1.14	.103 ±.003	2.62 ±0.08
170	7.750	7.937	7 3/4	3/32	7.737 ±.045	196.52 ±1.14	.103 ±.003	2.62 ±0.08
171	8.000	8.187	8	3/32	7.987 ±.045	202.87 ±1.14	.103 ±.003	2.62 ±0.08
172	8.250	8.437	8 1/4	3/32	8.237 ±.050	209.22 ±1.27	.103 ±.003	2.62 ±0.08
173	8.500	8.687	8 1/2	3/32	8.487 ±.050	215.57 ±1.27	.103 ±.003	2.62 ±0.08
174	8.750	8.937	8 3/4	3/32	8.737 ±.050	221.92 ±1.27	.103 ±.003	2.62 ±0.08
175	9.000	9.187	9	3/32	8.987 ±.050	228.27 ±1.27	.103 ±.003	2.62 ±0.08
176	9.250	9.437	9 1/4	3/32	9.237 ±.055	234.62 ±1.40	.103 ±.003	2.62 ±0.08
177	9.500	9.687	9 1/2	3/32	9.487 ±.055	240.97 ±1.40	.103 ±.003	2.62 ±0.08
178	9.750	9.937	9 3/4	3/32	9.737 ±.055	247.32 ±1.40	.103 ±.003	2.62 ±0.08
179 THROUGH 201 SIZES NOT ASSIGNED								
201	.187	.437	3/16	1/8	.171 ±.005	4.34 ±0.13	.139 ±.004	3.53 ±0.10
202	.250	.500	1/4	1/8	.234 ±.005	5.94 ±0.13	.139 ±.004	3.53 ±0.10
203	.312	.562	5/16	1/8	.296 ±.005	7.52 ±0.13	.139 ±.004	3.53 ±0.10
204	.375	.625	3/8	1/8	.359 ±.005	9.12 ±0.13	.139 ±.004	3.53 ±0.10
205	.437	.687	7/16	1/8	.421 ±.005	10.69 ±0.13	.139 ±.004	3.53 ±0.10
206	.500	.750	1/2	1/8	.484 ±.005	12.29 ±0.13	.139 ±.004	3.53 ±0.10
207	.562	.812	9/16	1/8	.546 ±.007	13.87 ±0.18	.139 ±.004	3.53 ±0.10
208	.625	.875	5/8	1/8	.609 ±.009	15.47 ±0.23	.139 ±.004	3.53 ±0.10

Selection Guide for Standard Size Quad-Ring® Brand Seals and Quad® Brand O-Ring Seals - continued

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
209	.687	.937	11/16	1/8	.671 ±.009	17.04 ±0.23	.139 ±.004	3.53 ±0.10
210	.750	1.000	3/4	1/8	.734 ±.010	18.64 ±0.25	.139 ±.004	3.53 ±0.10
211	.812	1.062	13/16	1/8	.796 ±.010	20.22 ±0.25	.139 ±.004	3.53 ±0.10
212	.875	1.125	7/8	1/8	.859 ±.010	21.82 ±0.25	.139 ±.004	3.53 ±0.10
213	.937	1.187	15/16	1/8	.921 ±.010	23.39 ±0.25	.139 ±.004	3.53 ±0.10
214	1.000	1.250	1	1/8	.984 ±.010	24.99 ±0.25	.139 ±.004	3.53 ±0.10
215	1.062	1.312	1 1/16	1/8	1.046 ±.010	26.57 ±0.25	.139 ±.004	3.53 ±0.10
216	1.125	1.375	1 1/8	1/8	1.109 ±.012	28.17 ±0.30	.139 ±.004	3.53 ±0.10
217	1.187	1.437	1 3/16	1/8	1.171 ±.012	29.74 ±0.30	.139 ±.004	3.53 ±0.10
218	1.250	1.500	1 1/4	1/8	1.234 ±.012	31.34 ±0.30	.139 ±.004	3.53 ±0.10
219	1.312	1.562	1 5/16	1/8	1.296 ±.012	32.92 ±0.30	.139 ±.004	3.53 ±0.10
220	1.375	1.625	1 3/8	1/8	1.359 ±.012	34.52 ±0.30	.139 ±.004	3.53 ±0.10
221	1.437	1.687	1 7/16	1/8	1.421 ±.012	36.09 ±0.30	.139 ±.004	3.53 ±0.10
222	1.500	1.750	1 1/2	1/8	1.484 ±.015	37.69 ±0.38	.139 ±.004	3.53 ±0.10
223	1.625	1.875	1 5/8	1/8	1.609 ±.015	40.87 ±0.38	.139 ±.004	3.53 ±0.10
224	1.750	2.000	1 3/4	1/8	1.734 ±.015	44.04 ±0.38	.139 ±.004	3.53 ±0.10
225	1.875	2.125	1 7/8	1/8	1.859 ±.018	47.22 ±0.46	.139 ±.004	3.53 ±0.10
226	2.000	2.250	2	1/8	1.984 ±.018	50.39 ±0.46	.139 ±.004	3.53 ±0.10
227	2.125	2.375	2 1/8	1/8	2.109 ±.018	53.57 ±0.46	.139 ±.004	3.53 ±0.10
228	2.250	2.500	2 1/4	1/8	2.234 ±.020	56.74 ±0.51	.139 ±.004	3.53 ±0.10
229	2.375	2.625	2 3/8	1/8	2.359 ±.020	59.92 ±0.51	.139 ±.004	3.53 ±0.10
230	2.500	2.750	2 1/2	1/8	2.484 ±.020	63.09 ±0.51	.139 ±.004	3.53 ±0.10
231	2.625	2.875	2 5/8	1/8	2.609 ±.020	66.27 ±0.51	.139 ±.004	3.53 ±0.10
232	2.750	3.000	2 3/4	1/8	2.734 ±.024	69.44 ±0.61	.139 ±.004	3.53 ±0.10
233	2.875	3.125	2 7/8	1/8	2.859 ±.024	72.62 ±0.61	.139 ±.004	3.53 ±0.10
234	3.000	3.250	3	1/8	2.984 ±.024	75.79 ±0.61	.139 ±.004	3.53 ±0.10
235	3.125	3.375	3 1/8	1/8	3.109 ±.024	78.97 ±0.61	.139 ±.004	3.53 ±0.10
236	3.250	3.500	3 1/4	1/8	3.234 ±.024	82.14 ±0.61	.139 ±.004	3.53 ±0.10
237	3.375	3.625	3 3/8	1/8	3.359 ±.024	85.32 ±0.61	.139 ±.004	3.53 ±0.10
238	3.500	3.750	3 1/2	1/8	3.484 ±.024	88.49 ±0.61	.139 ±.004	3.53 ±0.10
239	3.625	3.875	3 5/8	1/8	3.609 ±.028	91.67 ±0.71	.139 ±.004	3.53 ±0.10
240	3.750	4.000	3 3/4	1/8	3.734 ±.028	94.84 ±0.71	.139 ±.004	3.53 ±0.10
241	3.875	4.125	3 7/8	1/8	3.859 ±.028	98.02 ±0.71	.139 ±.004	3.53 ±0.10
242	4.000	4.250	4	1/8	3.984 ±.028	101.19 ±0.71	.139 ±.004	3.53 ±0.10
243	4.125	4.375	4 1/8	1/8	4.109 ±.028	104.37 ±0.71	.139 ±.004	3.53 ±0.10
244	4.250	4.500	4 1/4	1/8	4.234 ±.030	107.54 ±0.76	.139 ±.004	3.53 ±0.10
245	4.375	4.625	4 3/8	1/8	4.359 ±.030	110.72 ±0.76	.139 ±.004	3.53 ±0.10
246	4.500	4.750	4 1/2	1/8	4.484 ±.030	113.89 ±0.76	.139 ±.004	3.53 ±0.10
247	4.625	4.875	4 5/8	1/8	4.609 ±.030	117.07 ±0.76	.139 ±.004	3.53 ±0.10
248	4.750	5.000	4 3/4	1/8	4.734 ±.030	120.24 ±0.76	.139 ±.004	3.53 ±0.10

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
249	4.875	5.125	4 7/8	1/8	4.859 ±.035	123.42 ±0.89	.139 ±.004	3.53 ±0.10
250	5.000	5.250	5	1/8	4.984 ±.035	126.59 ±0.89	.139 ±.004	3.53 ±0.10
251	5.125	5.375	5 1/8	1/8	5.109 ±.035	129.77 ±0.89	.139 ±.004	3.53 ±0.10
252	5.250	5.500	5 1/4	1/8	5.234 ±.035	132.94 ±0.89	.139 ±.004	3.53 ±0.10
253	5.375	5.625	5 3/8	1/8	5.359 ±.035	136.12 ±0.89	.139 ±.004	3.53 ±0.10
254	5.500	5.750	5 1/2	1/8	5.484 ±.035	139.29 ±0.89	.139 ±.004	3.53 ±0.10
255	5.625	5.875	5 5/8	1/8	5.609 ±.035	142.47 ±0.89	.139 ±.004	3.53 ±0.10
256	5.750	6.000	5 3/4	1/8	5.734 ±.035	145.64 ±0.89	.139 ±.004	3.53 ±0.10
257	5.875	6.125	5 7/8	1/8	5.859 ±.035	148.82 ±0.89	.139 ±.004	3.53 ±0.10
258	6.000	6.250	6	1/8	5.984 ±.035	151.99 ±0.89	.139 ±.004	3.53 ±0.10
259	6.250	6.500	6 1/4	1/8	6.234 ±.040	158.34 ±1.02	.139 ±.004	3.53 ±0.10
260	6.500	6.750	6 1/2	1/8	6.484 ±.040	164.69 ±1.02	.139 ±.004	3.53 ±0.10
261	6.750	7.000	6 3/4	1/8	6.734 ±.040	171.04 ±1.02	.139 ±.004	3.53 ±0.10
262	7.000	7.250	7	1/8	6.984 ±.040	177.39 ±1.02	.139 ±.004	3.53 ±0.10
263	7.250	7.500	7 1/4	1/8	7.234 ±.045	183.74 ±1.14	.139 ±.004	3.53 ±0.10
264	7.500	7.750	7 1/2	1/8	7.484 ±.045	190.09 ±1.14	.139 ±.004	3.53 ±0.10
265	7.750	8.000	7 3/4	1/8	7.734 ±.045	196.44 ±1.14	.139 ±.004	3.53 ±0.10
266	8.000	8.250	8	1/8	7.984 ±.045	202.79 ±1.14	.139 ±.004	3.53 ±0.10
267	8.250	8.500	8 1/4	1/8	8.234 ±.050	209.14 ±1.27	.139 ±.004	3.53 ±0.10
268	8.500	8.750	8 1/2	1/8	8.484 ±.050	215.49 ±1.27	.139 ±.004	3.53 ±0.10
269	8.750	9.000	8 3/4	1/8	8.734 ±.050	221.84 ±1.27	.139 ±.004	3.53 ±0.10
270	9.000	9.250	9	1/8	8.984 ±.050	228.19 ±1.27	.139 ±.004	3.53 ±0.10
271	9.250	9.500	9 1/4	1/8	9.234 ±.055	234.54 ±1.40	.139 ±.004	3.53 ±0.10
272	9.500	9.750	9 1/2	1/8	9.484 ±.055	240.89 ±1.40	.139 ±.004	3.53 ±0.10
273	9.750	10.000	9 3/4	1/8	9.734 ±.055	247.24 ±1.40	.139 ±.004	3.53 ±0.10
274	10.000	10.250	10	1/8	9.984 ±.055	253.59 ±1.40	.139 ±.004	3.53 ±0.10
275	10.500	10.750	10 1/2	1/8	10.484 ±.055	266.29 ±1.40	.139 ±.004	3.53 ±0.10
276	11.000	11.250	11	1/8	10.984 ±.065	278.99 ±1.65	.139 ±.004	3.53 ±0.10
277	11.500	11.750	11 1/2	1/8	11.484 ±.065	291.69 ±1.65	.139 ±.004	3.53 ±0.10
278	12.000	12.250	12	1/8	11.984 ±.065	304.39 ±1.65	.139 ±.004	3.53 ±0.10
279	13.000	13.250	13	1/8	12.984 ±.065	329.79 ±1.65	.139 ±.004	3.53 ±0.10
280	14.000	14.250	14	1/8	13.984 ±.065	355.19 ±1.65	.139 ±.004	3.53 ±0.10
281	15.000	15.250	15	1/8	14.984 ±.065	380.59 ±1.65	.139 ±.004	3.53 ±0.10
282	16.000	16.250	16	1/8	15.955 ±.075	405.26 ±1.91	.139 ±.004	3.53 ±0.10
283	17.000	17.250	17	1/8	16.955 ±.080	430.66 ±2.03	.139 ±.004	3.53 ±0.10
284	18.000	18.250	18	1/8	17.955 ±.085	456.06 ±2.16	.139 ±.004	3.53 ±0.10
285 THROUGH 308 SIZES NOT ASSIGNED								
309	.437	.812	7/16	3/16	.412 ±.005	10.46 ±0.13	.210 ±.005	5.33 ±0.13
310	.500	.875	1/2	3/16	.475 ±.005	12.07 ±0.13	.210 ±.005	5.33 ±0.13
311	.562	.937	9/16	3/16	.537 ±.007	13.64 ±0.18	.210 ±.005	5.33 ±0.13

Selection Guide for Standard Size Quad-Ring® Brand Seals and Quad® Brand O-Ring Seals - continued

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
312	.625	1.000	5/8	3/16	.600 ±.009	15.24 ±0.23	.210 ±.005	5.33 ±0.13
313	.687	1.062	11/16	3/16	.662 ±.009	16.81 ±0.23	.210 ±.005	5.33 ±0.13
314	.750	1.125	3/4	3/16	.725 ±.010	18.42 ±0.25	.210 ±.005	5.33 ±0.13
315	.812	1.187	13/16	3/16	.787 ±.010	19.99 ±0.25	.210 ±.005	5.33 ±0.13
316	.875	1.250	7/8	3/16	.850 ±.010	21.59 ±0.25	.210 ±.005	5.33 ±0.13
317	.937	1.312	15/16	3/16	.912 ±.010	23.16 ±0.25	.210 ±.005	5.33 ±0.13
318	1.000	1.375	1	3/16	.975 ±.010	24.77 ±0.25	.210 ±.005	5.33 ±0.13
319	1.062	1.437	1 1/16	3/16	1.037 ±.010	26.34 ±0.25	.210 ±.005	5.33 ±0.13
320	1.125	1.500	1 1/8	3/16	1.100 ±.012	27.94 ±0.30	.210 ±.005	5.33 ±0.13
321	1.187	1.562	1 3/16	3/16	1.162 ±.012	29.51 ±0.30	.210 ±.005	5.33 ±0.13
322	1.250	1.625	1 1/4	3/16	1.225 ±.012	31.12 ±0.30	.210 ±.005	5.33 ±0.13
323	1.312	1.687	1 5/16	3/16	1.287 ±.012	32.69 ±0.30	.210 ±.005	5.33 ±0.13
324	1.375	1.750	1 3/8	3/16	1.350 ±.012	34.29 ±0.30	.210 ±.005	5.33 ±0.13
325	1.500	1.875	1 1/2	3/16	1.475 ±.015	37.47 ±0.38	.210 ±.005	5.33 ±0.13
326	1.625	2.000	1 5/8	3/16	1.600 ±.015	40.64 ±0.38	.210 ±.005	5.33 ±0.13
327	1.750	2.125	1 3/4	3/16	1.725 ±.015	43.82 ±0.38	.210 ±.005	5.33 ±0.13
328	1.875	2.250	1 7/8	3/16	1.850 ±.015	46.99 ±0.38	.210 ±.005	5.33 ±0.13
329	2.000	2.375	2	3/16	1.975 ±.018	50.17 ±0.46	.210 ±.005	5.33 ±0.13
330	2.125	2.500	2 1/8	3/16	2.100 ±.018	53.34 ±0.46	.210 ±.005	5.33 ±0.13
331	2.250	2.625	2 1/4	3/16	2.225 ±.018	56.52 ±0.46	.210 ±.005	5.33 ±0.13
332	2.375	2.750	2 3/8	3/16	2.350 ±.018	59.69 ±0.46	.210 ±.005	5.33 ±0.13
333	2.500	2.875	2 1/2	3/16	2.475 ±.020	62.87 ±0.51	.210 ±.005	5.33 ±0.13
334	2.625	3.000	2 5/8	3/16	2.600 ±.020	66.04 ±0.51	.210 ±.005	5.33 ±0.13
335	2.750	3.125	2 3/4	3/16	2.725 ±.020	69.22 ±0.51	.210 ±.005	5.33 ±0.13
336	2.875	3.250	2 7/8	3/16	2.850 ±.020	72.39 ±0.51	.210 ±.005	5.33 ±0.13
337	3.000	3.375	3	3/16	2.975 ±.024	75.57 ±0.61	.210 ±.005	5.33 ±0.13
338	3.125	3.500	3 1/8	3/16	3.100 ±.024	78.74 ±0.61	.210 ±.005	5.33 ±0.13
339	3.250	3.625	3 1/4	3/16	3.225 ±.024	81.92 ±0.61	.210 ±.005	5.33 ±0.13
340	3.375	3.750	3 3/8	3/16	3.350 ±.024	85.09 ±0.61	.210 ±.005	5.33 ±0.13
341	3.500	3.875	3 1/2	3/16	3.475 ±.024	88.27 ±0.61	.210 ±.005	5.33 ±0.13
342	3.625	4.000	3 5/8	3/16	3.600 ±.028	91.44 ±0.71	.210 ±.005	5.33 ±0.13
343	3.750	4.125	3 3/4	3/16	3.725 ±.028	94.62 ±0.71	.210 ±.005	5.33 ±0.13
344	3.875	4.250	3 7/8	3/16	3.850 ±.028	97.79 ±0.71	.210 ±.005	5.33 ±0.13
345	4.000	4.375	4	3/16	3.975 ±.028	100.97 ±0.71	.210 ±.005	5.33 ±0.13
346	4.125	4.500	4 1/8	3/16	4.100 ±.028	104.14 ±0.71	.210 ±.005	5.33 ±0.13
347	4.250	4.625	4 1/4	3/16	4.225 ±.030	107.32 ±0.76	.210 ±.005	5.33 ±0.13
348	4.375	4.750	4 3/8	3/16	4.350 ±.030	110.49 ±0.76	.210 ±.005	5.33 ±0.13
349	4.500	4.875	4 1/2	3/16	4.475 ±.030	113.67 ±0.76	.210 ±.005	5.33 ±0.13
350	4.625	5.000	4 5/8	3/16	4.600 ±.030	116.84 ±0.76	.210 ±.005	5.33 ±0.13
351	4.750	5.125	4 3/4	3/16	4.725 ±.030	120.02 ±0.76	.210 ±.005	5.33 ±0.13

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
352	4.875	5.250	$4\frac{7}{8}$	$\frac{3}{16}$	4.850 ±.030	123.19 ±0.76	.210 ±.005	5.33 ±0.13
353	5.000	5.375	5	$\frac{3}{16}$	4.975 ±.037	126.37 ±0.94	.210 ±.005	5.33 ±0.13
354	5.125	5.500	$5\frac{1}{8}$	$\frac{3}{16}$	5.100 ±.037	129.54 ±0.94	.210 ±.005	5.33 ±0.13
355	5.250	5.625	$5\frac{1}{4}$	$\frac{3}{16}$	5.225 ±.037	132.72 ±0.94	.210 ±.005	5.33 ±0.13
356	5.375	5.750	$5\frac{3}{8}$	$\frac{3}{16}$	5.350 ±.037	135.89 ±0.94	.210 ±.005	5.33 ±0.13
357	5.500	5.875	$5\frac{1}{2}$	$\frac{3}{16}$	5.475 ±.037	139.07 ±0.94	.210 ±.005	5.33 ±0.13
358	5.625	6.000	$5\frac{5}{8}$	$\frac{3}{16}$	5.600 ±.037	142.24 ±0.94	.210 ±.005	5.33 ±0.13
359	5.750	6.125	$5\frac{3}{4}$	$\frac{3}{16}$	5.725 ±.037	145.42 ±0.94	.210 ±.005	5.33 ±0.13
360	5.875	6.250	$5\frac{7}{8}$	$\frac{3}{16}$	5.850 ±.037	148.59 ±0.94	.210 ±.005	5.33 ±0.13
361	6.000	6.375	6	$\frac{3}{16}$	5.975 ±.037	151.77 ±0.94	.210 ±.005	5.33 ±0.13
362	6.250	6.625	$6\frac{1}{4}$	$\frac{3}{16}$	6.225 ±.040	158.12 ±1.02	.210 ±.005	5.33 ±0.13
363	6.500	6.875	$6\frac{1}{2}$	$\frac{3}{16}$	6.475 ±.040	164.47 ±1.02	.210 ±.005	5.33 ±0.13
364	6.750	7.125	$6\frac{3}{4}$	$\frac{3}{16}$	6.725 ±.040	170.82 ±1.02	.210 ±.005	5.33 ±0.13
365	7.000	7.375	7	$\frac{3}{16}$	6.975 ±.040	177.17 ±1.02	.210 ±.005	5.33 ±0.13
366	7.250	7.625	$7\frac{1}{4}$	$\frac{3}{16}$	7.225 ±.045	183.52 ±1.14	.210 ±.005	5.33 ±0.13
367	7.500	7.875	$7\frac{1}{2}$	$\frac{3}{16}$	7.475 ±.045	189.87 ±1.14	.210 ±.005	5.33 ±0.13
368	7.750	8.125	$7\frac{3}{4}$	$\frac{3}{16}$	7.725 ±.045	196.22 ±1.14	.210 ±.005	5.33 ±0.13
369	8.000	8.375	8	$\frac{3}{16}$	7.975 ±.045	202.57 ±1.14	.210 ±.005	5.33 ±0.13
370	8.250	8.625	$8\frac{1}{4}$	$\frac{3}{16}$	8.225 ±.050	208.92 ±1.27	.210 ±.005	5.33 ±0.13
371	8.500	8.875	$8\frac{1}{2}$	$\frac{3}{16}$	8.475 ±.050	215.27 ±1.27	.210 ±.005	5.33 ±0.13
372	8.750	9.125	$8\frac{3}{4}$	$\frac{3}{16}$	8.725 ±.050	221.62 ±1.27	.210 ±.005	5.33 ±0.13
373	9.000	9.375	9	$\frac{3}{16}$	8.975 ±.050	227.97 ±1.27	.210 ±.005	5.33 ±0.13
374	9.250	9.625	$9\frac{1}{4}$	$\frac{3}{16}$	9.225 ±.055	234.32 ±1.40	.210 ±.005	5.33 ±0.13
375	9.500	9.875	$9\frac{1}{2}$	$\frac{3}{16}$	9.475 ±.055	240.67 ±1.40	.210 ±.005	5.33 ±0.13
376	9.750	10.125	$9\frac{3}{4}$	$\frac{3}{16}$	9.725 ±.055	247.02 ±1.40	.210 ±.005	5.33 ±0.13
377	10.000	10.375	10	$\frac{3}{16}$	9.975 ±.055	253.37 ±1.40	.210 ±.005	5.33 ±0.13
378	10.500	10.875	$10\frac{1}{2}$	$\frac{3}{16}$	10.475 ±.060	266.07 ±1.52	.210 ±.005	5.33 ±0.13
379	11.000	11.375	11	$\frac{3}{16}$	10.975 ±.060	278.77 ±1.52	.210 ±.005	5.33 ±0.13
380	11.500	11.875	$11\frac{1}{2}$	$\frac{3}{16}$	11.475 ±.065	291.47 ±1.65	.210 ±.005	5.33 ±0.13
381	12.000	12.375	12	$\frac{3}{16}$	11.975 ±.065	304.17 ±1.65	.210 ±.005	5.33 ±0.13
382	13.000	13.375	13	$\frac{3}{16}$	12.975 ±.065	329.57 ±1.65	.210 ±.005	5.33 ±0.13
383	14.000	14.375	14	$\frac{3}{16}$	13.975 ±.070	354.97 ±1.78	.210 ±.005	5.33 ±0.13
384	15.000	15.375	15	$\frac{3}{16}$	14.975 ±.070	380.37 ±1.78	.210 ±.005	5.33 ±0.13
385	16.000	16.375	16	$\frac{3}{16}$	15.955 ±.075	405.26 ±1.91	.210 ±.005	5.33 ±0.13
386	17.000	17.375	17	$\frac{3}{16}$	16.955 ±.080	430.66 ±2.03	.210 ±.005	5.33 ±0.13
387	18.000	18.375	18	$\frac{3}{16}$	17.955 ±.085	456.06 ±2.16	.210 ±.005	5.33 ±0.13
388	19.000	19.375	19	$\frac{3}{16}$	18.955 ±.090	481.46 ±2.29	.210 ±.005	5.33 ±0.13
389	20.000	20.375	20	$\frac{3}{16}$	19.955 ±.095	506.86 ±2.41	.210 ±.005	5.33 ±0.13
390	21.000	21.375	21	$\frac{3}{16}$	20.955 ±.095	532.26 ±2.41	.210 ±.005	5.33 ±0.13
391	22.000	22.375	22	$\frac{3}{16}$	21.955 ±.100	557.66 ±2.54	.210 ±.005	5.33 ±0.13

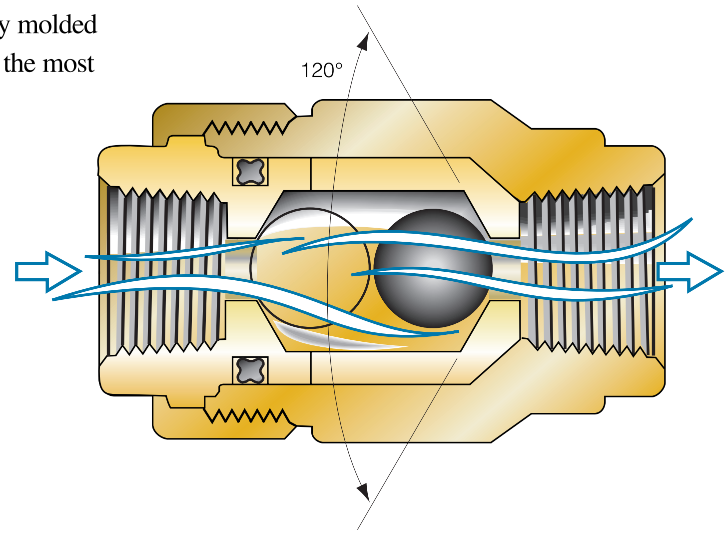
Selection Guide for Standard Size Quad-Ring® Brand Seals and Quad® Brand O-Ring Seals - continued

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
392	23.000	23.375	23	3/16	22.940 ±.105	582.68 ±2.67	.210 ±.005	5.33 ±0.13
393	24.000	24.375	24	3/16	23.940 ±.110	608.08 ±2.79	.210 ±.005	5.33 ±0.13
394	25.000	25.375	25	3/16	24.940 ±.115	633.48 ±2.92	.210 ±.005	5.33 ±0.13
395	26.000	26.375	26	3/16	25.940 ±.120	658.88 ±3.05	.210 ±.005	5.33 ±0.13
396 THROUGH 424 SIZES NOT ASSIGNED								
425	4.500	5.000	4 1/2	1/4	4.475 ±.033	113.67 ±0.84	.275 ±.006	6.99 ±0.15
426	4.625	5.125	4 5/8	1/4	4.600 ±.033	116.84 ±0.84	.275 ±.006	6.99 ±0.15
427	4.750	5.250	4 3/4	1/4	4.725 ±.033	120.02 ±0.84	.275 ±.006	6.99 ±0.15
428	4.875	5.375	4 7/8	1/4	4.850 ±.033	123.19 ±0.84	.275 ±.006	6.99 ±0.15
429	5.000	5.500	5	1/4	4.975 ±.037	126.37 ±0.94	.275 ±.006	6.99 ±0.15
430	5.125	5.625	5 1/8	1/4	5.100 ±.037	129.54 ±0.94	.275 ±.006	6.99 ±0.15
431	5.250	5.750	5 1/4	1/4	5.225 ±.037	132.72 ±0.94	.275 ±.006	6.99 ±0.15
432	5.375	5.875	5 3/8	1/4	5.350 ±.037	135.89 ±0.94	.275 ±.006	6.99 ±0.15
433	5.500	6.000	5 1/2	1/4	5.475 ±.037	139.07 ±0.94	.275 ±.006	6.99 ±0.15
434	5.625	6.125	5 5/8	1/4	5.600 ±.037	142.24 ±0.94	.275 ±.006	6.99 ±0.15
435	5.750	6.250	5 3/4	1/4	5.725 ±.037	145.42 ±0.94	.275 ±.006	6.99 ±0.15
436	5.875	6.375	5 7/8	1/4	5.850 ±.037	148.59 ±0.94	.275 ±.006	6.99 ±0.15
437	6.000	6.500	6	1/4	5.975 ±.037	151.77 ±0.94	.275 ±.006	6.99 ±0.15
438	6.250	6.750	6 1/4	1/4	6.225 ±.040	158.12 ±1.02	.275 ±.006	6.99 ±0.15
439	6.500	7.000	6 1/2	1/4	6.475 ±.040	164.47 ±1.02	.275 ±.006	6.99 ±0.15
440	6.750	7.250	6 3/4	1/4	6.725 ±.040	170.82 ±1.02	.275 ±.006	6.99 ±0.15
441	7.000	7.500	7	1/4	6.975 ±.040	177.17 ±1.02	.275 ±.006	6.99 ±0.15
442	7.250	7.750	7 1/4	1/4	7.225 ±.045	183.52 ±1.14	.275 ±.006	6.99 ±0.15
443	7.500	8.000	7 1/2	1/4	7.475 ±.045	189.87 ±1.14	.275 ±.006	6.99 ±0.15
444	7.750	8.250	7 3/4	1/4	7.725 ±.045	196.22 ±1.14	.275 ±.006	6.99 ±0.15
445	8.000	8.500	8	1/4	7.975 ±.045	202.57 ±1.14	.275 ±.006	6.99 ±0.15
446	8.500	9.000	8 1/2	1/4	8.475 ±.055	215.27 ±1.40	.275 ±.006	6.99 ±0.15
447	9.000	9.500	9	1/4	8.975 ±.055	227.97 ±1.40	.275 ±.006	6.99 ±0.15
448	9.500	10.000	9 1/2	1/4	9.475 ±.055	240.67 ±1.40	.275 ±.006	6.99 ±0.15
449	10.000	10.500	10	1/4	9.975 ±.055	253.37 ±1.40	.275 ±.006	6.99 ±0.15
450	10.500	11.000	10 1/2	1/4	10.475 ±.060	266.07 ±1.52	.275 ±.006	6.99 ±0.15
451	11.000	11.500	11	1/4	10.975 ±.060	278.77 ±1.52	.275 ±.006	6.99 ±0.15
452	11.500	12.000	11 1/2	1/4	11.475 ±.060	291.47 ±1.52	.275 ±.006	6.99 ±0.15
453	12.000	12.500	12	1/4	11.975 ±.060	304.17 ±1.52	.275 ±.006	6.99 ±0.15
454	12.500	13.000	12 1/2	1/4	12.475 ±.060	316.87 ±1.52	.275 ±.006	6.99 ±0.15
455	13.000	13.500	13	1/4	12.975 ±.060	329.57 ±1.52	.275 ±.006	6.99 ±0.15
456	13.500	14.000	13 1/2	1/4	13.475 ±.070	342.27 ±1.78	.275 ±.006	6.99 ±0.15
457	14.000	14.500	14	1/4	13.975 ±.070	354.97 ±1.78	.275 ±.006	6.99 ±0.15
458	14.500	15.000	14 1/2	1/4	14.475 ±.070	367.67 ±1.78	.275 ±.006	6.99 ±0.15
459	15.000	15.500	15	1/4	14.975 ±.070	380.37 ±1.78	.275 ±.006	6.99 ±0.15

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
460	15.500	16.000	15 1/2	1/4	15.475 ±.070	393.07 ±1.78	.275 ±.006	6.99 ±0.15
461	16.000	16.500	16	1/4	15.955 ±.075	405.26 ±1.91	.275 ±.006	6.99 ±0.15
462	16.500	17.000	16 1/2	1/4	16.455 ±.075	417.96 ±1.91	.275 ±.006	6.99 ±0.15
463	17.000	17.500	17	1/4	16.955 ±.080	430.66 ±2.03	.275 ±.006	6.99 ±0.15
464	17.500	18.000	17 1/2	1/4	17.455 ±.085	443.36 ±2.16	.275 ±.006	6.99 ±0.15
465	18.000	18.500	18	1/4	17.955 ±.085	456.06 ±2.16	.275 ±.006	6.99 ±0.15
466	18.500	19.000	18 1/2	1/4	18.455 ±.085	468.76 ±2.16	.275 ±.006	6.99 ±0.15
467	19.000	19.500	19	1/4	18.955 ±.090	481.46 ±2.29	.275 ±.006	6.99 ±0.15
468	19.500	20.000	19 1/2	1/4	19.455 ±.090	494.16 ±2.29	.275 ±.006	6.99 ±0.15
469	20.000	20.500	20	1/4	19.955 ±.095	506.86 ±2.41	.275 ±.006	6.99 ±0.15
470	21.000	21.500	21	1/4	20.955 ±.095	532.26 ±2.41	.275 ±.006	6.99 ±0.15
471	22.000	22.500	22	1/4	21.955 ±.100	557.66 ±2.54	.275 ±.006	6.99 ±0.15
472	23.000	23.500	23	1/4	22.940 ±.105	582.68 ±2.67	.275 ±.006	6.99 ±0.15
473	24.000	24.500	24	1/4	23.940 ±.110	608.08 ±2.79	.275 ±.006	6.99 ±0.15
474	25.00	25.500	25	1/4	24.940 ±.115	633.48 ±2.92	.275 ±.006	6.99 ±0.15
475	26.000	26.500	26	1/4	25.940 ±.120	658.88 ±3.05	.275 ±.006	6.99 ±0.15

Quad® Brand Ground Rubber Balls

Rubber balls from Minnesota Rubber are carefully molded and precision ground for superior performance in the most critical applications.



Material

Our standard rubber balls are molded from a 70 Shore A nitrile compound specially formulated for grinding. Our compound 525K is recommended for most typical pneumatic, hydraulic or water applications.

Other elastomeric compounds are also available for more demanding situations such as steam, high temperatures or corrosive fluids. Compounds with a hardness lower than 70 Shore A are difficult to grind. Harder materials are also available.

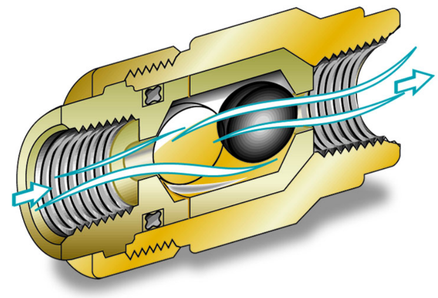
Sphericity

High speed centerless grinding combined with automatic gauging/measuring equipment assures you of a consistent, close tolerance on both spherical and diametric dimensions. The resulting uniform finish also ensures consistent sealing performance regardless of how the ball seats.

Variety of Sizes

Select from our standard sizes below, or take advantage of our custom molding facilities for your specialized ball applications.

PART NO.	COMPOUND	DIAMETER Nominal	DIAMETER (in)	DIAMETER (mm)
B130093	525K	3/32	.093 ±.003 dia., .003sph. Total	2.36 ±0.08 dia., 0.08sph. Total
B130125	525K	1/8	.125 ±.003 dia., .003sph. Total	3.18 ±0.08 dia., 0.08sph. Total
B130156	525K	5/32	.156 ±.003 dia., .003sph. Total	3.96 ±0.08 dia., 0.08sph. Total
B130187	525K	3/16	.187 ±.003 dia., .003sph. Total	4.75 ±0.08 dia., 0.08sph. Total
B130218	525K	7/32	.218 ±.003 dia., .003sph. Total	5.54 ±0.08 dia., 0.08sph. Total
B130250	525K	1/4	.250 ±.003 dia., .003sph. Total	6.35 ±0.08 dia., 0.08sph. Total
B130312	525K	5/16	.312 ±.003 dia., .003sph. Total	7.93 ±0.08 dia., 0.08sph. Total
B130375	525K	3/8	.375 ±.003 dia., .003sph. Total	9.53 ±0.08 dia., 0.08sph. Total
B130437	525K	7/16	.437 ±.004 dia., .005sph. Total	11.10 ±0.10 dia., 0.13sph. Total
B130500	525K	1/2	.500 ±.004 dia., .005sph. Total	12.70 ±0.10 dia., 0.13sph. Total
B130562	525K	9/16	.562 ±.004 dia., .005sph. Total	14.28 ±0.10 dia., 0.13sph. Total
B130625	525K	5/8	.625 ±.004 dia., .005sph. Total	15.88 ±0.10 dia., 0.13sph. Total
B130750	525K	3/4	.750 ±.004 dia., .005sph. Total	19.05 ±0.10 dia., 0.13sph. Total
B131000	525K	1	1.000 ±.004 dia., .005sph. Total	25.40 ±0.10 dia., 0.13sph. Total

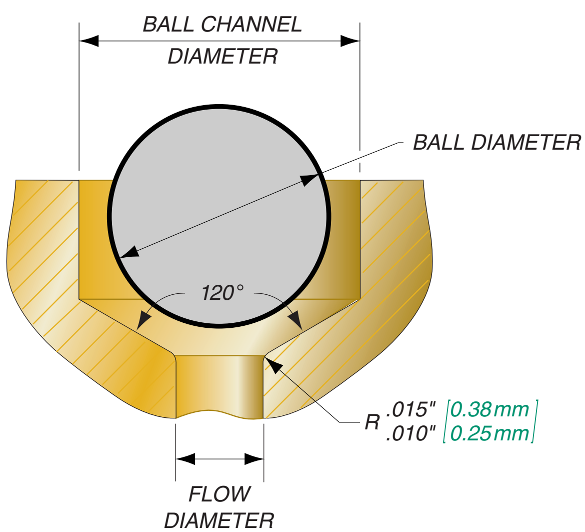


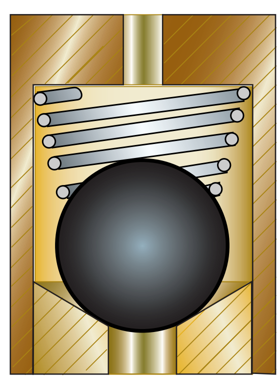
Ground Ball Tip Sheet

- Solid, non-reinforced core ground balls are generally used as check devices for pressures less than 120 psi.
- When designing an application to incorporate a check ball, the differential area between the projected ball area and the area of the ball channel should be slightly greater than that of the main flow area. This will minimize flow disruption due to the presence of the ball in the flow stream.
- The ball seat should have an included angle of 120° and have a .010"-.015" radius where the seat and the flow channel meet. For liquids, the ball seat should have a surface finish of 20µin RMS or better. For air or vacuum applications, the ball seat should have a surface finish of 10µin RMS or better.
- At pressures greater than 120 psi, there is a tendency for ground balls to become stuck in the ball seat (checking orifice). If this occurs often, it can damage the ball eventually causing the ball to extrude through the orifice.
- As a “rule-of-thumb,” the diameter of a check ball should be at least three times the diameter of the flow orifice. The larger the ball-to-orifice ratio, the lower the likelihood of ball extrusion.
- Standard tolerances for ground balls are indicated in the following table:

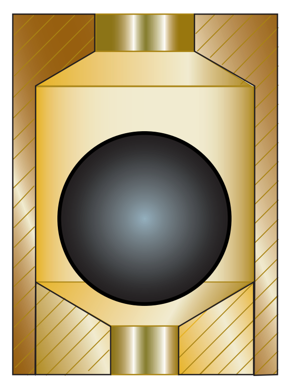
BALL DIAMETER	DIAMETER TOLERANCE	SPHERICITY
<= .375"	±.003	.003 Total
>.375”	±.004	.005 Total

Typical Applications



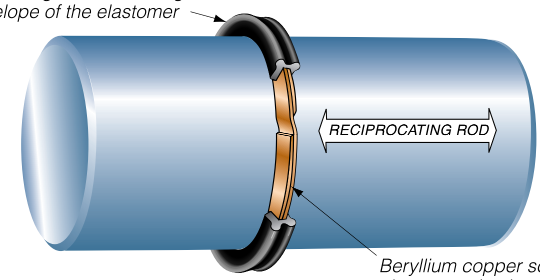


Spring Loaded



Double Seat

Equi-Flex™ Rod Wiper/Scraper



What is Equi-Flex™?

Equi-Flex™ rod wiper/scrapers effectively wipe and scrape the full 360º circumference of a reciprocating rod. They are designed to remove road dust, dirt, ice, mud, weld flash, paint and many other particulates from the rod surface. They prevent damage to bearings, seals, packings, and rods, thereby reducing or eliminating contamination of fluids in hydraulic systems.

Equi-Flex™ rod wiper/scrapers consist of a honed, double-spiral wiping element of age-hardened beryllium copper (Rockwell C 40 hardness) surrounded by a synthetic rubber elastomer. It is designed so that the beryllium copper element is distended from the final rod diameter. It is precision honed to an inner-diameter tolerance of +/- 0.0005". The honing process guarantees a true circle on the ring inside diameter and provides a highly polished and knife-sharp edge. In operation, the beryllium copper ring polishes the rod without damage to the rod's finish. It is self-sharpening and does not oval, curve, or feather.

Equi-Flex™ rod wiper/scrapers are found wherever hydraulic or pneumatic cylinders are used. They have demonstrated their effectiveness on fork lifts, resistance welders, off-road machinery, farm equipment, hydraulic presses, foundry machines, and aircraft landing gear.

Why Use Equi-Flex™?

Equi-Flex™ rod wiper/scrapers provide the following benefits:

Feature	Advantage	Benefit
360° contact	No gap eliminates clogging and bypass contamination	Longer primary seal life means more up-time
Spring action scraper	Greater rod tolerance	No precision machining of rods
Low friction/low wear	Longer scraper life	More up-time & lower equipment maintenance cost
Self-sharpening	Continuous and consistent performance	More up-time & lower equipment maintenance cost
Occupies a minimum amount of space	Greater design freedom	Smaller package
MS28776-R2 compatible gland	Use existing components	No modification required
Product availability	Readily available from stock	Reduces design cycle time. Shortens leadtimes resulting in less purchasing and planning
Large selection of sizes	Greater design freedom	No non-recurring engineering charges. No custom tooling

Selecting Equi-Flex™ Rod Wiper/ Scraper Elastomeric Compounds.

Standard Equi-Flex™ rod wiper/scraper elastomers are compounded of a nitrile material which is compatible with most mineral-based oils and other commercial hydraulic fluids within a temperature range of -65°F to 212°F (-54°C to 100°C). However, a wide variety of other elastomers are available to meet special application requirements.

LetterSuffix	MN Rubber Compound	Shore A Hardness	Compatible With:	Temperature Range
A	Nitrile 523EU Date Coded	70	MIL-H-5606 Petroleum Fluids Auto Transmission Fluids Water	-65°F to 212°F (-54°C to 100°C)
I	FKM 514AD	70	Fuel Oil, Chemicals Petroleum Fluids Other Corrosive Fluids	-25°F to 400°F (-32°C to 204°C)
P	Ethylene Propylene 559N	70	Ozone Aqueous Chemicals Acid or Alkali Phosphate Esters (Skydrol) Auto Brake Fluids	-70°F to 300°F (-57°C to 149°C)
None	Nitrile 523EU	70	Petroleum Hydraulic Fluids Auto Transmission Fluids Water	-65°F to 212°F (-54°C to 100°C)

Mounting Principle and Methods

When distended around a rod and mounted in an appropriate recess of proper diameter and depth (Figure A, confined view), the elastomer deforms, surrounds and seals the beryllium copper element in a cushioned suspension. The elastomer prevents solids from migrating through the sealing cavity and reaching the rod bearing or primary seal. It exerts a uniform peripheral squeeze on the wiping element to provide 360° contact with the rod. This squeeze, and the spring characteristics of the beryllium copper element, provide exceptionally good wear resistance for both the scraper element and the reciprocating rod. The elastomer also allows a cushioned float of the scraper element to compensate for normal misalignments.

To obtain the best performance, Equi-Flex™ rod wiper/scrapers should be installed with consideration of the following:

1. Equi-Flex™ rod wiper/scrapers should be assembled on the rod in a free state and then confined (Figure A) using gland dimensions from the Housing Recesses Tables on the following pages.
2. To prevent damage to the honed inner-diameter of the Equi-Flex™ scraper ring; A) chamfer the rod ends a minimum of 5° and a maximum of 20°, or B) use a distention sleeve to insert the rod into the Equi-Flex™ scraper. A properly inserted Equi-Flex™ scraper can then be mounted in the housing using any of several mounting methods (including those shown in Figure B).
3. Refer to the selection criteria listed on the opposite page to assure compatibility of the elastomer with the fluids used in your application.

Figure A

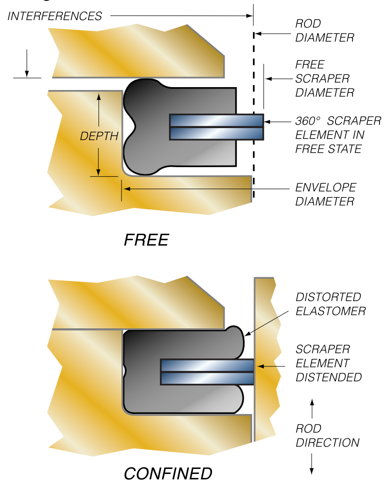
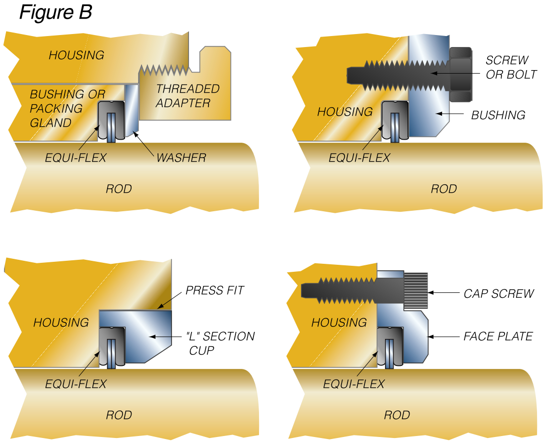


Figure B



Note: Always use a rigid metallic adapter or washer between Equi-Flex and packing or seal.

Application Specifications

To assist you in selecting the right materials and part size for your application, include the following information:

1. A description of the application including rod length, speed of travel, and materials to be wiped from the rod.
2. The type, brand name, product number, etc. for any liquids that may contact the Equi-Flex™ rod wiper/scraper.
3. The exact decimal rod size.
4. The rod finish and hardness (Rockwell C scale).
5. The operational temperature range.
6. The service requirements (number of cycles per minute, hour, day, etc.)

Rod Diameters

Equi-Flex™ rod wiper/scrapers are distended on an arbor and honed to .005" under the normal rod diameter. They may be applied without modification to rods that are .003" larger or smaller than their nominal diameter. If a rod diameter exceeds the honed diameter of an Equi-Flex™ wiper by more than +/-.003", special honing may be required to ensure effective 360º wiping performance.

Friction

The friction experienced by an Equi-Flex™ rod wiper/scraper is primarily determined by the diameter and depth of the elastomer retaining cavity. Standard cavity dimensions ensure tight wiper contact with the rod while maintaining relatively low friction. If an application demands a minimum of drag force, the cavity dimensions can be modified and we can add a special polishing procedure.

Rod Finish and Hardness

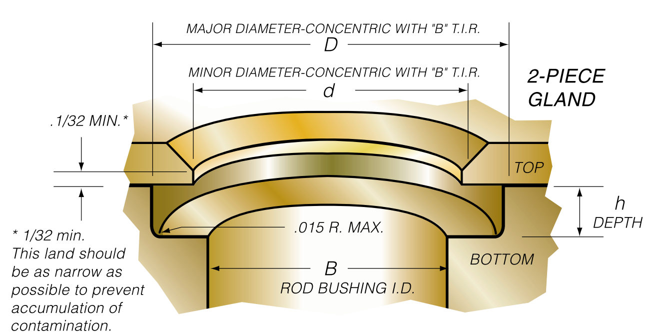
Standard Equi-Flex™ rod wiper/scrapers function best on rods having a surface finish of 25 micro inches RMS or better. The rod should be chrome-plated or hardened to Rockwell C 45 or harder.

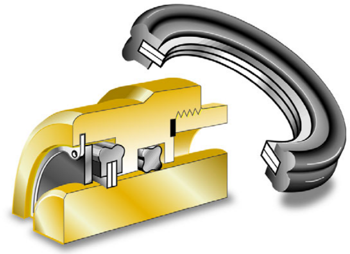
Elastomer Compounds

Standard Equi-Flex™ rod wiper/scrapers consist of elastomers made from a 70 Shore A nitrile material. This material is compatible with most mineral-based oils and other commercial hydraulic fluids. A wide variety of custom elastomer materials is available to meet special application requirements. Commonly used materials and associated physical properties are shown in the table on the proceeding page.

Housing Recess Specifications - Standard Industrial

E/F NUMBER (See Note 1)	ROD DIAMETER NOMINAL	ROD DIAMETER ACTUAL +/-.003 (See Note 2)	ROD BORE ID "B" MAXIMUM	GROOVE DIMENSIONS MAJOR DIA."D" +.005/-.000 (See Note 3)	GROOVE DIMENSIONS DEPTH "h" +.003/-.000 (See Note 3)	GROOVE DIMENSIONS MINOR DIA."d" +.005/-.000 (See Note 3)
109000	1/4	.245	.254	.498	.100	.280
110000	5/16	.307	.316	.562	.100	.342
120000	3/8	.370	.379	.624	.100	.405
130000	7/16	.432	.441	.686	.104	.467
201000	1/2	.495	.504	.769	.104	.530
202000	9/16	.557	.566	.831	.104	.592
203000	5/8	.620	.629	.894	.104	.655
204000	11/16	.682	.691	.956	.104	.717
205000	3/4	.745	.754	1.019	.104	.780
306000	13/16	.807	.820	1.095	.104	.843
307000	7/8	.870	.879	1.157	.104	.905
308000	15/16	.932	.941	1.219	.104	.967
309000	1	.995	1.004	1.282	.104	1.030
310000	1 1/16	1.057	1.066	1.344	.104	1.092
311000	1 1/8	1.120	1.129	1.407	.104	1.155
312000	1 3/16	1.182	1.191	1.469	.104	1.217
313000	1 1/4	1.245	1.254	1.532	.104	1.208
414000	1 5/16	1.307	1.316	1.623	.104	1.342
415000	1 3/8	1.370	1.379	1.686	.104	1.405
417000	1 1/2	1.495	1.504	1.811	.104	1.530
418000	1 5/8	1.620	1.629	1.934	.104	1.655
419000	1 3/4	1.745	1.754	2.061	.104	1.780
420000	1 7/8	1.870	1.879	2.186	.104	1.905
421000	2	1.995	2.004	2.311	.104	2.030
422000	2 1/8	2.120	2.129	2.436	.104	2.155
423000	2 1/4	2.245	2.254	2.561	.104	2.280
424000	2 3/8	2.370	2.379	2.686	.104	2.405
425000	2 1/2	2.495	2.504	2.811	.104	2.530
526000	2 5/8	2.620	2.629	3.000	.119	2.675
527000	2 3/4	2.745	2.754	3.125	.119	2.800
528000	2 7/8	2.870	2.879	3.250	.119	2.925
529000	3	2.995	3.004	3.375	.119	3.050
530000	3 1/8	3.120	3.129	3.500	.119	3.175
531000	3 1/4	3.245	3.254	3.625	.119	3.300
532000	3 3/8	3.370	3.379	3.750	.119	3.425





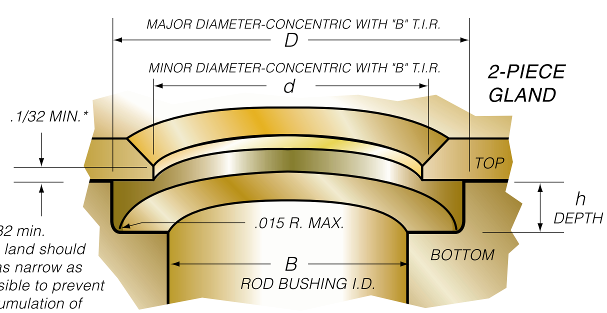
E/F NUMBER (See Note 1)	ROD DIAMETER NOMINAL	ROD DIAMETER ACTUAL +/-.003 (See Note 2)	ROD BORE ID "B" MAXIMUM	GROOVE DIMENSIONS MAJOR DIA."D" +.005/-.000 (See Note 3)	GROOVE DIMENSIONS DEPTH "h" +.003/-.000 (See Note 3)	GROOVE DIMENSIONS MINOR DIA."d" +.005/-.000 (See Note 3)
533000	$3^{1}/_{2}$	3.495	3.504	3.875	.119	3.550
534000	$3^{5}/_{8}$	3.620	3.629	4.000	.119	3.675
535000	$3^{3}/_{4}$	3.745	3.754	4.125	.119	3.800
536000	$3^{7}/_{8}$	3.870	3.879	4.250	.119	3.925
637000	4	3.995	4.006	4.439	.135	4.060
638000	$4^{1}/_{8}$	4.120	4.018	4.564	.135	4.180
639000	$4^{1}/_{4}$	4.245	4.256	4.689	.135	4.310
640000	$4^{3}/_{8}$	4.370	4.381	4.814	.135	4.440
641000	$4^{1}/_{2}$	4.495	4.506	4.939	.135	4.560
642000	$4^{5}/_{8}$	4.920	4.631	5.064	.135	4.680
643000	$4^{3}/_{4}$	4.745	4.756	5.189	.135	4.810
644000	$4^{7}/_{8}$	4.870	4.881	5.314	.135	4.940
645000	5	4.995	5.006	5.439	.135	5.060
646000	$5^{1}/_{8}$	5.120	5.131	5.564	.135	5.185
647000	$5^{1}/_{4}$	5.245	5.256	5.689	.135	5.310
648000	$5^{3}/_{8}$	5.370	5.381	5.814	.135	5.440
649000	$5^{1}/_{2}$	5.495	5.506	5.939	.135	5.560
751000	$5^{3}/_{4}$	5.745	5.756	6.251	.151	5.810
753000	6	5.995	6.006	6.501	.151	6.060
754000	$6^{1}/_{4}$	6.245	6.256	6.751	.151	6.310
755000	$6^{1}/_{2}$	6.495	6.506	7.000	.151	6.560
756000	$6^{3}/_{4}$	6.745	6.756	7.250	.151	6.810
757000	7	6.995	7.008	7.500	.151	7.060
758000	$7^{1}/_{4}$	7.245	7.258	7.750	.151	7.310
759000	$7^{1}/_{2}$	7.495	7.508	8.00	.151	7.560
760000	$7^{3}/_{4}$	7.745	7.758	8.250	.151	7.810
761000	8	7.995	8.008	8.500	.151	8.060
762000	$8^{1}/_{2}$	8.495	8.508	9.000	.151	8.560
763000	9	8.995	9.008	9.500	.151	9.060
764000	$9^{1}/_{2}$	9.495	9.508	10.000	.151	9.560
765000	10	9.995	10.008	10.500	.151	10.060
766000	$10^{1}/_{2}$	10.495	10.508	11.000	.151	10.560
767000	11	10.995	11.008	11.500	.166	11.060
869000	12	11.995	12.008	12.500	.166	12.060

Notes:

1. Equi-Flex™ numbers without a letter suffix indicate the standard 70 Shore A nitrile elastomer. It is suitable for most industrial applications. This material is compatible with most mineral-based fluids when used within a temperature range of -65°F to 212°F (-54°C to 100°C).
2. Rod diameters beyond listed dimensions and tolerances may require special honing of the beryllium copper component in the Equi-Flex™ rod wiper/scraper.
3. Any mounting method can be employed, provided the major diameter D, minor diameter d, and depth h, are maintained within specified tolerances. Examples of recommended mounting methods are shown in section 6-35.

Housing Recess Specifications - Aircraft

E/F NUMBER (See Note 1)	ROD DIAMETER NOMINAL	ROD DIAMETER ACTUAL +/-.003 (See Note 2)	ROD BORE ID "B" MAXIMUM	GROOVE DIMENSIONS MAJOR DIA."D" +.005/-.000 (See Note 3 & 4)	GROOVE DIMENSIONS DEPTH "h" +.003/-.000 (See Note 3 & 4)	GROOVE DIMENSIONS MINOR DIA."d" +.005/-.000 (See Note 3 & 4)
109000-A	1/4	.245	.254	.498	.100	.280
110000-A	5/16	.307	.316	.562	.100	.342
120000-A	3/8	.370	.379	.624	.100	.405
130000-A	7/16	.432	.441	.686	.104	.467
201000-A	1/2	.495	.504	.760	.104	.548
202000-A	9/16	.557	.566	.823	.104	.610
203000-A	5/8	.620	.629	.885	.104	.673
204000-A	11/16	.682	.691	.948	.104	.735
205000-A	3/4	.745	.754	1.010	.104	.798
306000-A	13/16	.807	.820	1.086	.104	.866
307000-A	7/8	.870	.879	1.148	.104	.930
308000-A	15/16	.932	.941	1.210	.104	.991
309000-A	1	.995	1.004	1.273	.104	1.054
310000-A	1 1/16	1.057	1.066	1.335	.104	1.116
311000-A	1 1/8	1.120	1.129	1.398	.104	1.179
312000-A	1 3/16	1.182	1.191	1.460	.104	1.241
313000-A	1 1/4	1.245	1.254	1.523	.104	1.304
414000-A	1 5/16	1.307	1.316	1.614	.104	1.375
415000-A	1 3/8	1.370	1.379	1.677	.104	1.438
417000-A	1 1/2	1.495	1.504	1.802	.104	1.563
418000-A	1 5/8	1.620	1.629	1.927	.104	1.688
419000-A	1 3/4	1.745	1.754	2.052	.104	1.813
420000-A	1 7/8	1.870	1.879	2.177	.104	1.938
421000-A	2	1.995	2.004	2.302	.104	2.063
422000-A	2 1/8	2.120	2.129	2.427	.104	2.188
423000-A	2 1/4	2.245	2.254	2.552	.104	2.313
424000-A	2 3/8	2.370	2.379	2.677	.104	2.438
425000-A	2 1/2	2.495	2.504	2.802	.104	2.563
526000-A	2 5/8	2.620	2.629	2.989	.119	2.703
527000-A	2 3/4	2.745	2.754	3.114	.119	2.828
528000-A	2 7/8	2.870	2.879	3.239	.119	2.953
529000-A	3	2.995	3.004	3.364	.119	3.077
530000-A	3 1/8	3.120	3.129	3.489	.119	3.202
531000-A	3 1/4	3.245	3.254	3.614	.119	3.327
532000-A	3 3/8	3.370	3.379	3.739	.119	3.452



* 1/32 min. This land should be as narrow as possible to prevent accumulation of contamination.

E/F NUMBER (See Note 1)	ROD DIAMETER		ROD BORE	GROOVE DIMENSIONS		
	NOMINAL	ACTUAL +/-.003 (See Note 2)	ID "B" MAXIMUM	MAJOR DIA."D" +.005/-.000 (See Note 3 & 4)	DEPTH "h" +.003/-.000 (See Note 3 & 4)	MINOR DIA."d" +.005/-.000 (See Note 3 & 4)
533000-A	$3^1/_2$	3.495	3.504	3.864	.119	3.577
534000-A	$3^5/_8$	3.620	3.629	3.989	.119	3.702
535000-A	$3^3/_4$	3.745	3.754	4.114	.119	3.827
536000-A	$3^7/_8$	3.870	3.879	4.239	.119	3.952
637000-A	4	3.995	4.006	4.427	.135	4.092
638000-A	$4^1/_8$	4.120	4.018	4.552	.135	4.217
639000-A	$4^1/_4$	4.245	4.256	4.677	.135	4.342
640000-A	$4^3/_8$	4.370	4.381	4.802	.135	4.467
641000-A	$4^1/_2$	4.495	4.506	4.927	.135	4.592
642000-A	$4^5/_8$	4.920	4.631	5.052	.135	4.717
643000-A	$4^3/_4$	4.745	4.756	5.177	.135	4.842
644000-A	$4^7/_8$	4.870	4.881	5.302	.135	4.967
645000-A	5	4.995	5.006	5.427	.135	5.092
646000-A	$5^1/_8$	5.120	5.131	5.552	.135	5.217
647000-A	$5^1/_4$	5.245	5.256	5.677	.135	5.342
648000-A	$5^3/_8$	5.370	5.381	5.802	.135	5.467
649000-A	$5^1/_2$	5.495	5.506	5.927	.135	5.592
751000-A	$5^3/_4$	5.745	5.756	6.239	.151	5.858
753000-A	6	5.995	6.006	6.489	.151	6.108
754000-A	$6^1/_4$	6.245	6.256	6.739	.151	6.358
755000-A	$6^1/_2$	6.495	6.506	6.989	.151	6.608
756000-A	$6\ ^3/_4$	6.745	6.756	7.239	.151	6.858
757000-A	7	6.995	7.008	7.489	.151	7.108
758000-A	$7^1/_4$	7.245	7.258	7.739	.151	7.354
759000-A	$7^1/_2$	7.495	7.508	7.989	.151	7.608
760000-A	$7^3/_4$	7.745	7.758	8.239	.151	7.858
761000-A	8	7.995	8.008	8.489	.151	8.117
762000-A	$8^1/_2$	8.495	8.508	8.989	.151	8.617
763000-A	9	8.995	9.008	9.489	.151	9.117
764000-A	$9^1/_2$	9.495	9.508	9.989	.151	9.617
765000-A	10	9.995	10.008	10.489	.151	10.117
766000-A	$10^1/_2$	10.495	10.508	10.989	.151	10.617
767000-A	11	10.995	11.008	11.489	.166	11.117
869000-A	12	11.995	12.008	12.489	.166	12.117

Notes:

1. Equi-Flex™ numbers with the letter "A" suffix indicate a date coded 70 Shore A nitrile elastomer suitable for aircraft applications. This material is compatible with MIL-H-5606 petroleum-based fluids when used within a temperature range of -65°F to 212°F (-54°C to 100°C).
2. Rod diameters beyond listed dimensions and tolerances may require special honing of the beryllium copper component in the Equi-Flex™ rod wiper/scraper.
3. Listed housing recesses will accommodate MS-28776 of corresponding nominal sizes with modification of only minor diameter d.
4. Second and third digits of Equi-Flex™ numbers, 201000 and up, conform to MS-28776 dash numbers of corresponding sizes.
5. Major diameter D and depth h must be held strictly within indicated dimensions and tolerances.

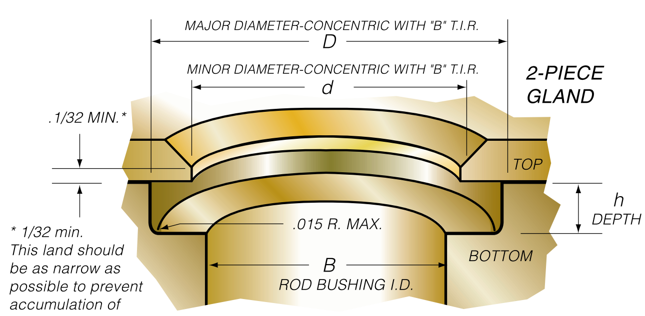
Housing Recess Specifications - Metric

E/F NUMBER (See Note 1 & 2)	ROD DIAMETER +0.00/-0.15mm (See Note 3)	ROD BORE ID "B" MAXIMUM	GROOVE DIMENSIONS MAJOR DIA."D" +0.10/-0.15mm (See Note 4)	DEPTH "h" +0.08mm/-0.00mm (See Note 4)	MINOR DIA."d" +0.13/-0.00mm (See Note 4)
60080	8.00	8.10	14.30	2.54	8.90
60120	12.00	12.10	18.20	2.54	12.90
60160	16.00	16.10	22.70	2.64	16.90
60200	20.00	20.10	26.80	2.64	20.90
60220	22.00	22.10	29.20	2.64	22.90
60250	25.00	25.10	32.00	2.64	25.90
60280	28.00	28.10	35.00	2.64	28.90
60300	30.00	30.10	37.20	2.64	30.90
60320	32.00	32.10	39.00	2.64	32.90
60350	35.00	35.10	42.80	2.64	35.90
60360	36.00	36.10	43.90	2.64	36.90
60400	40.00	40.10	47.90	2.64	40.90
60450	45.00	45.10	53.00	2.64	45.90
60500	50.00	50.10	58.10	2.64	50.90
60550	55.00	55.10	62.80	2.64	55.90
60560	56.00	56.10	63.80	2.64	56.90
60620	62.00	62.10	70.10	2.64	62.90
60630	63.00	63.00	71.10	3.02	63.90
60700	70.00	70.00	79.20	3.02	71.40
60800	80.00	80.00	89.60	3.02	81.40
60900	90.00	90.00	99.70	3.02	91.40
61000	100.00	100.15	109.60	3.43	101.40
61100	110.00	110.15	119.80	3.43	111.40
61250	125.00	125.15	134.80	3.43	126.40
61400	140.00	140.15	150.00	3.83	141.40
61600	160.00	160.15	172.80	3.83	161.60
61800	180.00	180.20	192.80	3.83	181.60
62000	200.00	200.20	212.90	3.83	201.60
62240	224.00	224.20	236.80	3.83	225.60

Notes:

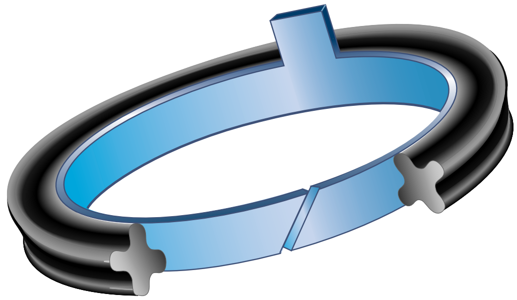
1. Equi-Flex™ numbers without a letter "A" suffix indicate a standard 70 Shore A nitrile elastomer suitable for industrial applications. The 523EU material is compatible with most mineral-based fluids when used within a temperature range of -65°F to 212°F (-54°C to 100°C).
2. Not shown in the table, but also available, are metric Equi-Flex™ rod wiper/scrapers with the letter "A" suffix. The suffix indicates a date coded 70 Shore A nitrile elastomer suitable for industrial applications.

   The date coded 523EU material is compatible with MIL-H-5606 petroleum-based fluids when used within a temperature range of -65°F to 212°F (-54°C to 100°C).



3. Rod diameters beyond listed dimensions and tolerances may require special honing of the beryllium copper component in the Equi-Flex™ rod wiper/scraper.
4. Any mounting method can be employed, providing the major diameter D, minor diameter d, and depth h, are maintained within the specified tolerances. Examples of recommended mounting methods are shown on page 6-35.

Quad® P.E. Plus Brand Plastic Exclusion Seals



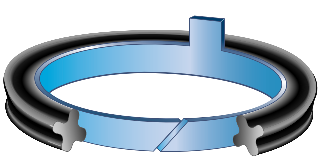
The Quad® P.E. Plus Brand is a patented seal design that combines an injection-molded thermoplastic bearing material with a Quad-Ring® Brand seal, O-ring, or custom seal to form a self-lubricating seal for both rotary and reciprocating seal applications. This seal can be used in applications where some leakage is permissible.

A tab on the thermoplastic ring locks it into the housing or shaft to prevent independent movement of the seal assembly. The ring is split to allow for thermal expansion of the shaft or cylinder.

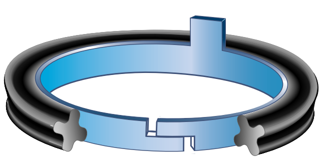
Materials used for the custom-molded Quad® P.E. Plus Brand seal can be specified from a wide range of rubber compounds and high performance thermoplastics.

The characteristically high pressure-velocity values and low coefficients of friction of thermoplastic bearing materials make them ideal for high velocity applications. These thermoplastics are also self-lubricating, which means that a Quad® P.E. Plus Brand seal can be used in continuous applications without external lubrication, a condition that would cause other seals to either burn up quickly, or destroy the surface of the cylinder or shaft it was meant to protect. Versions of the Quad® P.E. Plus Brand seal can be designed to operate in:

- Nonlubricated rotary applications with up to 1200 fpm (457.2 M/min) surface speeds
- Pressure lubricated rotary applications with up to 6500 fpm (1981.2 M/min) surface speeds
- Continuous temperature up to 450°F (232°C)
- Nonlubricated reciprocating applications with an operating life of more than 15 million cycles.



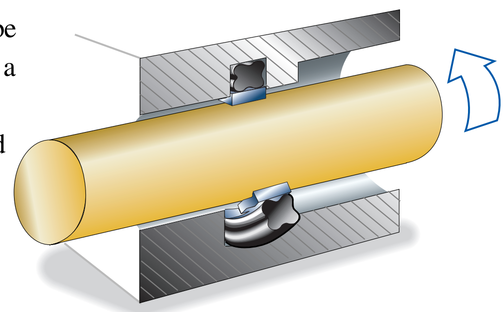
Angle Cut
For thermal expansion



Step-Cut
Minimizes fluid bypass

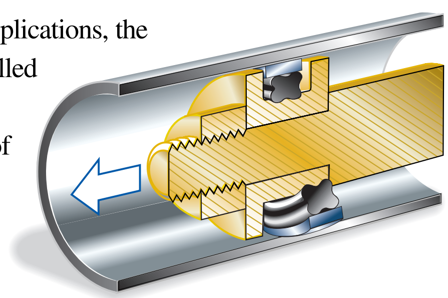
For rotating shafts

For rotary applications, the thermoplastic ring is split at an angle to allow for thermo-expansion of the metal surface. The thermoplastic ring can also be designed with a step-cut to minimize fluid bypass.



Placed in the housing or on the shaft, the rubber seal squeezes the thermoplastic ring snugly against the sealing surface. The tab on the thermoplastic ring fits into a slot in the groove and prevents the seal from rotating.

Reciprocating Applications



In reciprocating applications, the rubber seal is installed in a groove on the piston (on the ID of the thermoplastic ring) and presses the thermoplastic ring firmly against the cylinder wall. The ring is split to compensate for thermal expansion.