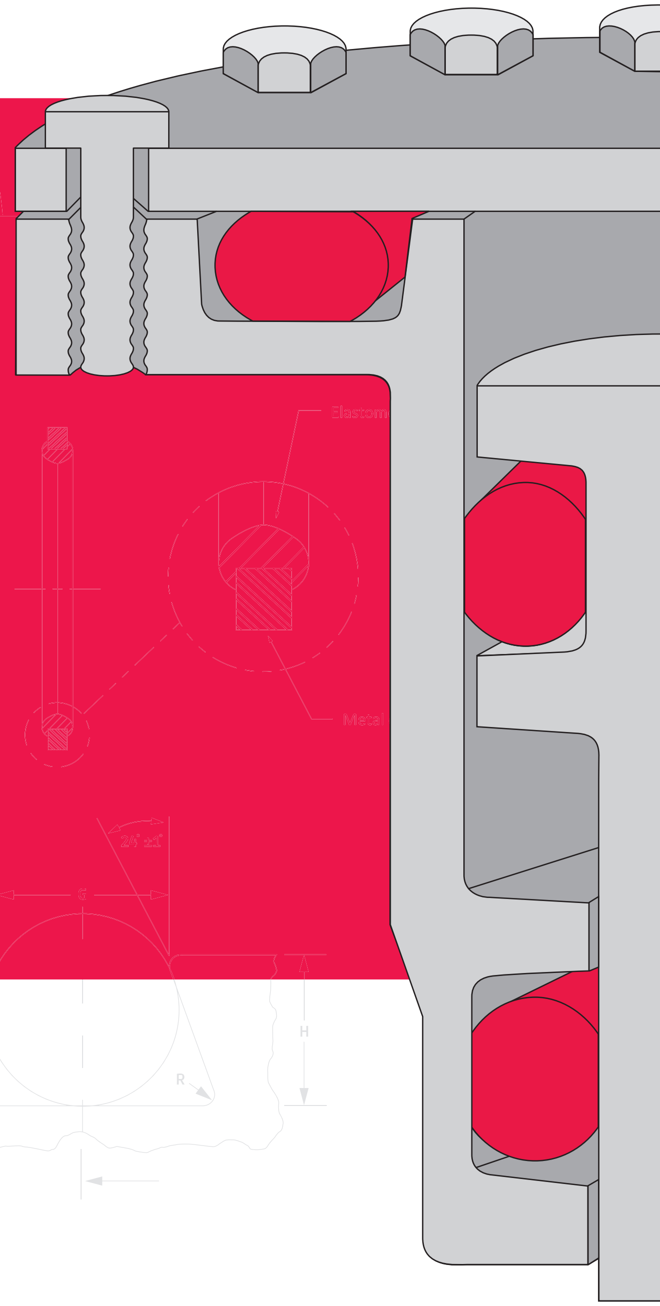
Seal Design Guide



Apple Rubber

applerubber.com

Welcome to Apple Rubber

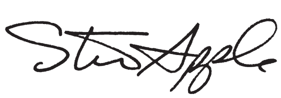
The Apple Rubber Seal Design Guide was first published in 1989 and quickly became more popular and successful than we could have ever hoped, with thousands of copies distributed.

This guide reflects the dynamic growth of Apple Rubber and our commitment to continually bring you new ideas and technologies in seals and other elastomeric products.

So much has happened since our first catalog. In fact, we're not really sure "catalog" is a fitting name for this edition. It will be used in many different ways by many different people – as a design guide, a reference, a handbook, a manual, a textbook, a research tool, and certainly, at times, a catalog.

Whatever you call it, however you may use it, this book is dedicated to helping you design a successful sealing solution. We hope you turn to it often and we thank you for your confidence in Apple Rubber.

Sincerely,



Steven L. Apple
President

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Expanded Seal Design Guide Available Online

We encourage you to visit our expanded online adaptation of the Seal Design Guide. Located at **applerubber.com**, the online version offers exclusive and comprehensive seal content, including all of our standard and non-standard sizes. Let our **online tools and calculators** help you create the exact sealing solution for your needs.

1 Introduction

WHERE TO START

Every day we are partners in seal design and troubleshooting with engineers in industries as diverse as automotive, computer and medical devices. This experience has taught us that most successful seal designs are the result of what we call "Seal Thinking,™" the careful application of sealing concepts that are basic, but not obvious or intuitive.

The Apple Rubber Seal Design Guide makes "Seal Thinking™" even more accessible. The Rules of Thumb feature is the product of hundreds of conversations with engineers about what must be emphasized to achieve a successful design. We have been very fortunate in the many opportunities we have had to work with dedicated and gifted engineers. In a very real sense, they are contributors as well.

THE O-RING EXAMPLE

Throughout this guide, the o-ring is used as an example in our discussion of seal design principles.

We have made this choice for these reasons:

1. It is the most common and most widely known type of seal in use today.
2. It is used in all types of applications and by a broad range of industries.
3. In most new designs, the o-ring is the first type of seal to be considered.

Also, as a practical matter, a discussion of the many types of seals would overwhelm our primary purpose, which is to illustrate the general principles of seal design.

RULES OF THUMB PUT INFORMATION AT YOUR FINGERTIPS

Apple Rubber's Rules of Thumb feature provides basic information anyone working with seals should know and understand. We think you'll find that a small investment of your time in reading these rules will yield a greater understanding and knowledge of sealing principles. These rules are distributed throughout the book and summarized in Section 11.

THE VISUAL SEAL GLOSSARY

Apple Rubber's Visual Seal Glossary is notable for color illustrations that let you see an array of sealing products at a glance. It can help you connect the proper terminology with a variety of sealing devices and related components, which may even spark an idea for your application. The Visual Seal Glossary is included in Section 11.

HOW THIS BOOK WORKS

This edition is organized into 12 sections. You can start wherever you like, but we recommend you at least go over the Rules of Thumb.

In this guide you will find information on basic concepts of o-ring design; seal types and gland design, critical operating environmental factors, a material selection guide, troubleshooting, ordering procedures, o-ring size charts, and much more. Our goal is to offer you the most comprehensive guide in the seal industry today.

BEYOND THESE PAGES

As noted, there are so many types and variations of seals that it is impossible to cover them all in this book. Also, space limitations made it difficult to fully address a number of our many capabilities such as Liquid Silicone Molding (LSR), composite seals, custom engineering, and complete quality assurance. If you don't see what you need here, don't hesitate to contact Apple Rubber, at:

(1-800) 828-7745
P (716) 684-6560
info@applerubber.com

For more information, including our complete list of available products and literature, visit us online at applerubber.com.

ACKNOWLEDGMENTS

As a leading designer and manufacturer of seals and sealing devices, Apple Rubber is in a unique position to bring you this new edition. The information presented comes from our extensive experience with sealing products since our founding in 1971, as well as the most up-to-date sealing industry sources such as:

- Elastomeric material suppliers
- Technical societies and associations
- Technical books, magazines and journals

You'll find a list of these source materials and organizations in the bibliography at the back of this book.

We also wish to extend sincere appreciation to everyone associated with Apple Rubber who made this book possible – our experienced engineers, our technical and manufacturing personnel, our quality control people, our customer service staff, and most importantly, customers like you whose needs for better sealing solutions drive what we do. Specifically, thanks go out to our editorial staff, including:

John Tranquilli, Senior Editor
David Meehan, Associate Editor
Kevin Oberholzer, Associate Editor

FEEDBACK, PLEASE

Apple Rubber created our first catalog and this edition in great part by listening to our customers. We welcome your comments and suggestions on this edition so that future issues meet your changing needs.

To give us your feedback, contact our Marketing Director at:

(1-800) 828-7745
P (716) 684-6560
info@applerubber.com

PLEASE NOTE THE FOLLOWING

The applications, suggestions and recommendations contained in this book are meant to be used as a professional guide only. Because no two situations or installations are the same, these comments, suggestions, and recommendations are necessarily general and should not be relied upon by any purchaser without independent verification based on the particular installation or use. We strongly recommend that the seal you select be rigorously tested in the actual application prior to production use.

2 Products and Services

THE INDUSTRY'S BROADEST RANGE OF PRODUCTS AND SERVICES

As a leading designer and manufacturer of seals and sealing devices, Apple Rubber offers the industry's broadest range of products to meet your seal requirements. We also have an unparalleled range of services and capabilities, and continually implement new technologies to meet the changing needs of our customers. This combination makes Apple Rubber an exceptional resource for your sealing solutions.

An overview of our products and services follows. As always, if you don't see what you need, give us a call at (1-800) 828-7745 or visit our website at applerubber.com. Experienced, knowledgeable sealing professionals are ready to assist you.

PRODUCTS

» O-Rings

The widest size range of o-rings in the seal industry, including standard AS568 and ISO 3601; most metrics; and a wide variety of non-standard sizes. Available in all common and many special materials and durometers.

CUSTOM PRODUCTS

» MicrOring™ Seals

The largest selection of microminiature o-rings anywhere. A MicrOring™ seal is any o-ring that measures less than 1 mm in either inside diameter (I.D.) or cross section (C.S.). Over 2,000 sizes of MicrOring™ seals, from .039" I.D. or C.S. down to .008" I.D. Microminiature composite seals and custom-engineered microminiature seals also available on special order.

» MacrOring™ Seals

MacrOring™ seals are manufactured by proprietary processes for greater strength and tighter tolerances than conventional, large sized bonded o-rings. Available in a broad range of sizes from 5" I.D. to 500" I.D. and in cross sections from .063" to 1". Available in the most popular materials.

» FilterSeals®

Innovative FilterSeals® are custom designed as a combination elastomer and fabric device that operates as both a seal and a filter. A wide variety of elastomers can be bonded to a variety of filter materials (Teflon™ Membrane, Nylon, stainless steel, etc.). Provide cost and time savings- one part to purchase instead of two; one part to install.

» Composite Seals

Custom-engineered composite seals incorporate the seal and another component in one part: increasing performance and reducing assembly costs. Composite seals include complicated parts such as rubber bonded to metal and plastic.

» LSR (Liquid Silicone Rubber) Parts and Seals

LSR parts and seals exhibit a wide temperature range (-85°F to 437°F), low compression set, and resistance to the damaging effects of sunlight and ozone. Available in a durometer range of 10-80 Shore A and custom color for virtually any type seal or part including o-rings, gaskets, face seals, housing seals, FilterSeals® and custom shapes.

» Custom Molded Shapes

Custom designed all-rubber shaped seals to meet exact specifications, including microminiature shapes. Examples include grommets, molded inserts, bushings, poppets, connector seals and piston seals. Custom shapes and seals are available in a wide variety of materials.

» ExpresSeal®

Advanced, computerized manufacturing technology which produces hydraulic and pneumatic seals in minutes for emergency replacements, hard-to-find parts, prototypes and more. U-cups, wipers, piston rings, bushings, back-up rings, wear rings and o-rings also available from inventory.

» Housing Seals

Superior seals custom designed to fit specific housings. Ideal for a variety of applications, they outperform flat gaskets and other gasketing methods. Silicone housing (face) seals are generally reusable after disassembly, unlike RTV gaskets. Available in a range of hardnesses for plastic or metal housing requirements.

» EMI Shielded O-Rings and Seals

Custom designed, EMI-shielded o-rings and seals for a variety of electronic applications provide an alternative to metallic coatings and other methods.

SERVICES

Whether you require design engineering assistance, a fast prototype or a customized quality assurance program, this is where you'll find information on all the services Apple Rubber can provide for your sealing solution.

» Design Engineering

Our engineers have a broad range of experience and knowledge in seal design acquired over

more than 30 years of solving problems for diverse industries and applications. Capabilities include concurrent engineering, complete project management, computer aided design, expertise in polymer technology and other materials and prototyping to drastically reduce development cycle time.

» Research and Development

It is our obligation to provide the best sealing solutions of tomorrow as well as today. Confronted continually by the challenges of new applications from industries as diverse as medical, electronics and automotive, we are always exploring new designs, new materials and new processes.

» Customer Service

With direct access to Apple Rubber's knowledgeable sales team, design engineers and QC staff, you have the "source" working for you. No middlemen – no confusion – no games.

» Comprehensive Manufacturing Technologies

An unparalleled range of capabilities and fully integrated manufacturing facilities including transfer molding, compression molding, liquid silicone molding, plastic injection molding, rubber injection, CNC machining and proprietary bonding processes. Manufacturing is performed in our US plant located in Lancaster, NY.

» Prototyping

We have the experience and advanced processes to respond quickly to prototype requirements, helping you to drastically reduce design and development time.

» ISO 9001 Registration

Apple Rubber earned ISO 9001 Registration. The scope of our ISO 9001 Registration, the most comprehensive standard of the ISO 9000 series, covers the design and manufacture of sealing components for various applications including aerospace, automotive and medical

products. ISO 9001 Registration is testimony to Apple Rubber's commitment to offering the highest quality seals and sealing devices available. Apple Rubber actively participates in ongoing certification updates. Check our website for the most current certification listings and documentation.

» AS9100

Apple Rubber's quality management system meets the requirements of AS9100, Quality Management Systems- Aerospace - Requirements. AS9100 incorporates the requirements of ISO 9001 and adds requirements specific to the aerospace industry.

» Quality Assurance and Testing

Apple Rubber's advanced testing laboratory offers one of the most stringent quality assurance programs in the industry. Material and dimensional certifications are available. We can customize a quality program to meet your specific testing requirements and supply documentation with shipments.

3 O-Ring Basics

SEAL THINKING™

Elastomer seals are unlike any other materials that design engineers confront. Metal or plastic parts, for instance, are probably failing if visibly distorted. But, an o-ring must be deformed to function properly. In fact, an o-ring that is not squeezed and stretched in its application is the wrong o-ring.

DEFINITION

An o-ring is a doughnut-shaped object, or torus. The opposite sides of an o-ring are squeezed between the walls of the cavity or "gland" into which the o-ring is installed. The resulting zero clearance within the gland provides an effective seal, blocking the flow of liquids or gases through the gland's internal passage.

An o-ring is defined by its dimensions (based on inside diameter and cross section), durometer (Shore A hardness), and material composition.

Illustration 3.1 demonstrates three applications showing the two basic categories of o-rings: static, contained within a non-moving gland as in a face seal, and dynamice, contained within a moving gland as in a piston or rod seal.

WHY AN O-RING WORKS

As Illustration 3.1 shows, a properly designed sealing system incorporates some degree of initial o-ring compression. At atmospheric pressure, only the resiliency of the compressed o-ring provides the seal. However, as system pressure activates the seal, the o-ring is forced to the low pressure side of the gland.

Designed to deform, the o-ring "flows" to fill the diametrical clearance and blocks any further leakage. Illustration 5.1 in section 5 shows a progressive application of pressure and the effect it has on the seal. Pressure, as well as many other considerations, determine the effectiveness of a seal. These considerations are highlighted throughout this design guide.

DIMENSIONAL CONSIDERATIONS

» Inside Diameter

To provide an effective seal, the o-ring's inside diameter (I.D.) must be smaller than the piston groove diameter, so that the o-ring is slightly stretched, fitting snugly in the groove. This stretch should be between 1%- 5% with 2% as the ideal in most applications. A stretch greater than 5% is not recommended. The resulting stress on the o-ring will cause accelerated aging and cross section reduction.

Exception to this rule is a floating seal. These are o-rings that are allowed to sit in grooves freely or "float". These are typically used in pneumatic piston applications, where some leakage can be tolerated for the benefit of lower friction.

Calculate the o-ring I.D. according to the following formula:

$$\text{O-RING I.D.} = \frac{\text{Groove Diameter}}{\text{\% of stretch desired} + 1}$$

(1% - 5%)

EXAMPLE
If Groove Diameter = .231
Then O-Ring I.D. = $\frac{.231}{1.01 \text{ to } 1.05}$ = .229 to .220
Depending on % of stretch desired

» Cross Section

When calculating the cross section (C.S.) of an o-ring, you need to consider the size of the gland to be filled as well as the amount of squeeze needed to create a good seal. Virtually every gland has a slight gap between the two mating surfaces, termed "diametrical clearance." Therefore, it is important for the o-ring cross-section to be greater than the gland depth. The resulting o-ring squeeze prevents leakage by blocking the diametrical gap.

Illustration 3.1 demonstrates that in "static" face seals or "dynamic" piston and rod seals, the o-ring is being squeezed slightly within the gland. Squeeze may occur in one of two possible ways. If the squeeze occurs on the top and bottom surfaces of the o-ring, as in face seals, it is referred to as axial squeeze. If the squeeze is on the inner and outer surfaces of the o-ring, as in piston or rod seals, it is referred to as radial squeeze.

To obtain the correct amount of squeeze for optimum o-ring sealing, careful consideration must be given to the size of the o-ring in relation to the size of the glandular space into which the o-ring is being installed. The actual calculation for the cross section needed in an o-ring varies depending on whether it will be used in a dynamic or static application. In a dynamic situation, lower squeeze is recommended to reduce friction.

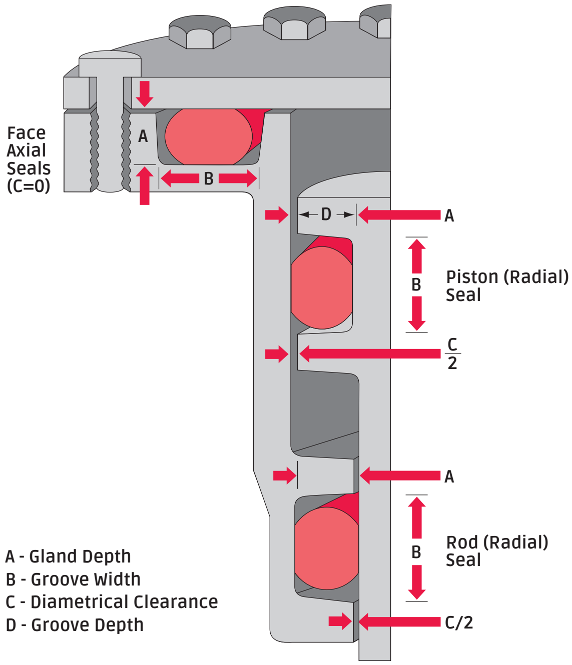


Illustration 3.1, Common Applications

Rule of Thumb | **A stretch greater than 5% on the o-ring I.D. is not recommended because it can lead to a loss of seal compression due to reduced cross-section.**

Rule of Thumb | **A groove depth is the machined depth into one surface, whereas a gland depth consists of the groove depth plus diametrical clearance. The gland depth is used to calculate seal compression.**

» Dynamic (Moving) Radial Seal Cross Section Calculation

Referring to Illustration 3.2 for term definition, and Illustration 3.3 for sample dimensions, calculating the correct o-ring cross section for a specific gland depth is illustrated to the right. In the case of the dynamic piston seal shown, the cross section is calculated as follows:

Calculation of Maximum O-Ring Cross Section

1. Enter the bore diameter
2. Subtract the bore tolerance from the bore diameter
3. Enter the groove diameter
4. Add the groove tolerance to the groove diameter
5. Subtract line 4 from line 2
6. Divide line 5 by 2
7. Enter the maximum % compression
8. Divide line 7 by 100
9. Subtract line 8 from the number 1
10. Divide line 6 by line 9
11. Enter o-ring C.S. tolerance
12. Subtract line 11 from line 10 for the answer

$$\text{Maximum O-RING CS} = \left[\frac{\left(\frac{\text{Min Bore Diameter} - \text{Max Groove Diameter}}{2} \right)}{1 - \left(\frac{\text{Max \% Compression}}{100} \right)} \right] - \text{O-Ring CS Tolerance}$$

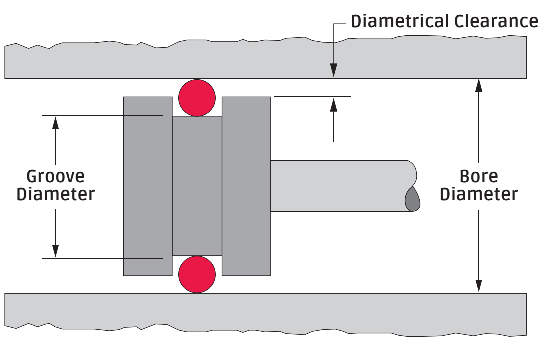


Illustration 3.2, Radial Seal

Rule of Thumb | **To create seal squeeze, the gland depth must be less than the seal cross section.**

Calculation of Minimum O-Ring Cross Section

1. Enter the bore diameter
2. Add the bore tolerance to the bore diameter
3. Enter the groove diameter
4. Subtract the groove tolerance from the groove diameter
5. Subtract line 4 from line 2
6. Divide line 5 by 2
7. Enter the minimum % compression
8. Divide line 7 by 100
9. Subtract line 8 from the number 1
10. Divide line 6 by line 9
11. Enter o-ring C.S. tolerance
12. Add line 11 to line 10 for the answer

Static (Non-moving) Axial Seal Calculation

$$\text{Minimum O-RING CS} = \left[\frac{\left(\frac{\text{Max Bore Diameter} - \text{Min Groove Diameter}}{2} \right)}{1 - \left(\frac{\text{Min \% Compression}}{100} \right)} \right] + \text{O-Ring CS Tolerance}$$

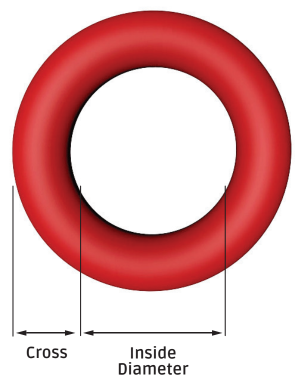


Illustration 3.3, O-ring Profile

To calculate the cross section of an axial seal, determine the gland depth and then multiply by the maximum and minimum squeeze requirements, noting to add 1.00 to the recommended squeeze. For example, a recommended squeeze of 30% would translate to a multiplied factor of 1.3.

The o-ring I.D. is determined by the presence of pressure, whether from the I.D. or the O.D. If pressure forces the o-ring towards the inside, as shown in Illustration 4.2, then the o-ring should be designed with the I.D. close to the groove I.D. However, if pressure forces the seal to the outside, as shown in Illustration 4.1, then the seal should incorporate some inference on the O.D.

MATERIAL CONSIDERATIONS

After you have determined the o-ring size, you will then have to select the appropriate o-ring material. Listed in Section 6, “Material Selection Guide,” are various elastomers including statements of description, key uses, temperature ranges, features and limitations. Prior to seal purchase, make sure to take into account all of the factors discussed below. In addition, you might want to consider availability and cost (see Section 6). If a material is not shown, contact Apple Rubber for availability.

CHEMICAL ATTACK

A major consideration for o-ring material selection is resistance of specific elastomers to degradation by exposure to certain chemicals. Therefore, the first step in material selection is to match your application’s chemicals with the o-ring material that offers the best resistance. To do this, refer to the “Chemical Compatibility” table and the “General Properties” table found on our website or Section 6 of this guide.

TEMPERATURE

The range of temperature experienced during operation is an important factor when considering efficient sealing. It is particularly important to measure temperature in the immediate o-ring environment, not just the system temperature. You must also consider the length of exposure to any high temperature, whether it involves short bursts or long, sustained levels.

The temperature ranges for various o-ring materials are listed in Section 6, “Materials Selection Guide,” as well as graphed in Section 5, “Critical Operating Environmental Factors.” The Material Selection Guide on our website allows users to enter a range to find the correct material.

FRICTION

There are two types of friction, both of which are important considerations in dynamic (moving) applications. When part movement is intermittent, the effects of breakout friction can cause excessively high pressures to develop. This pressure can tear portions of the seal that adhered to the gland wall causing seal failure.

In continuously moving applications, excessive o-ring running friction can cause heat to build up within the o-ring material itself. This causes swelling, which causes more heat to develop, and eventually results in material degradation and failure. For more information, consult Section 5.

DUROMETER

Durometer (Shore A) is a measurement of the hardness of an elastomeric compound. The numerical ratings for hardness run from lower numbered (less than 70) softer materials to higher numbered (greater than 70) harder materials, noting that fluorocarbon has a base rating of 75. This classification system is designed to work within a ±5 point range. All materials are not available in all hardnesses. Please refer to Section 6, “Material Selection Guide,” for the range of individual elastomers.

PRESSURE

The presence of high pressure on an o-ring can jeopardize its ability to seal. For correct o-ring design in high pressure situations, see Section 5, “Extrusion Limit” chart.

However, low pressure can present a problem as well. If the system pressure is below 100 psi, it is classified as low pressure. Because system pressure is not great enough to “activate” the seal, the design must rely solely on the resiliency of the elastomer

Rule of Thumb	**The maximum volume of the o-ring should never surpass the minimum volume of the gland.**

Rule of Thumb	**Static applications are more tolerant of material and design limitations than dynamic applications.**

to retain its original compressive force. Over time, the elastomer may not resist compression as much and take a compression "set," resulting in possible seal failure. However, by proper component design which may include lowering the seal durometer or increasing the o-ring cross section, maximum seal utility is achieved. For an illustration of this relationship, see Section 5.

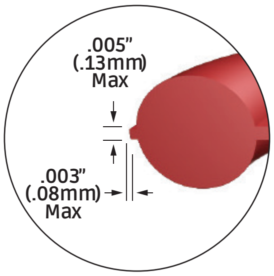


Illustration 3.4, O-ring Profile

PARTING LINE PROJECTION

Parting line projection is a continuous ridge of material located on the parting line at the ID and OD of the o-ring. This is often caused by mold wear creating enlarged radii from the mold cavity to the flat plane of the tool.

EXCESSIVE FLASH

Excessive flash is a thin, film-like layer of material extending from the parting line projection, often caused by mold separation or inadequate de-flashing. The standard acceptable flash shown in Illustration 3.4 is .005" thick and .003" extension.

PLEASE NOTE THE FOLLOWING

The applications, suggestions and recommendations contained in this book are meant to be used as a professional guide only. Because no two situations or installations are the same, these comments, suggestions, and recommendations are necessarily general and should not be relied upon by any purchaser without independent verification based on the particular installation or use. We strongly recommend that the seal you select be rigorously tested in the actual application

SUMMARY

For optimum sealing performance, correct o-ring selection is the direct result of a number of design considerations. These considerations include: size, squeeze, stretch, chemical compatibility and the ability to resist pressure, temperature and friction. All of these points of o-ring design are covered in detail within the sections of this Design Guide. For more information on any of these points, see the appropriate sections. Often, there are a number of materials that are appropriate for a particular application. Consideration should be given to the full range of environmental and cost factors. Your final selection will usually be a compromise in the sense that you have to balance all of these considerations.

4

Seal Types and Gland Design

MAJOR CLASSIFICATIONS

All o-ring seal applications are categorized in terms of relative motion. In situations involving little or no motion relative to the seal, the o-ring application is static. In situations involving reciprocating, rotating,

STATIC SEAL TYPES

Static seals are categorized as either axial or radial, depending upon the direction in which squeeze is applied to the o-ring's cross section.

» Static Axial Seal

A static axial seal acts similar to a gasket in that it is squeezed on both the top and bottom of the o-ring's cross section. This type of seal is typically employed in the face (flange) type applications, depicted in Illustration 4.1.

When used as a face seal involving either internal or external pressure, the o-ring should always be seated against the low pressure side of the groove (as shown in Illustration 4.1 and Illustration 4.2) so the o-ring is already where it needs to be as a result of the pressure.

Static axial seals tend to be easier to design than static radial seals. Since there is no extrusion gap, there are fewer design steps and you can control the tolerances easier.

STATIC AXIAL SEAL GLAND DIMENSIONS

Table B lists SAE recommended dimensions for static axial seal glands by ascending AS568 o-ring numbers.

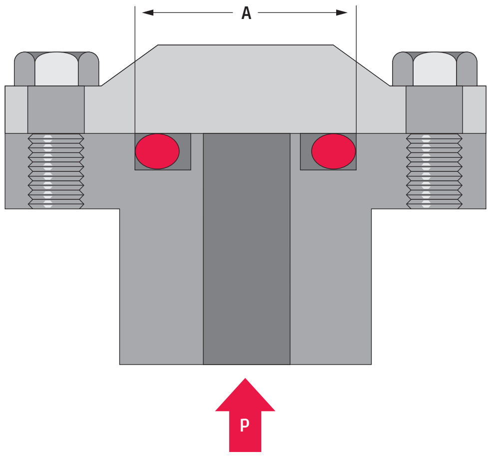


Illustration 4.1, Internal Pressure

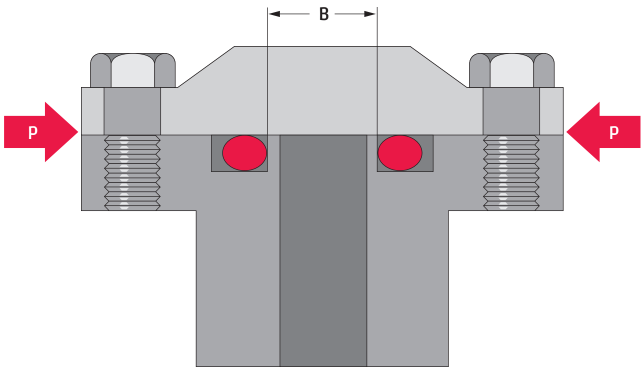


Illustration 4.2, External Pressure

» Static Radial Seals

Static Radial Seals are squeezed between the inner and outer surfaces of the o-ring. They are typically employed in cap and plug type applications, as depicted in Illustration 4.3.

STATIC RADIAL SEAL GLAND DIMENSIONS

Table C (p. 30-44) lists SAE recommended dimensions for static radial seal glands by ascending AS568 numbers.

NOTE: Recommended dimensions for static radial seal glands listed in Table C are based on an application pressure limit of 1500 psi. For higher pressure requirements, reference Section 5, Illustration 5.1 or contact Apple Rubber for technical assistance.

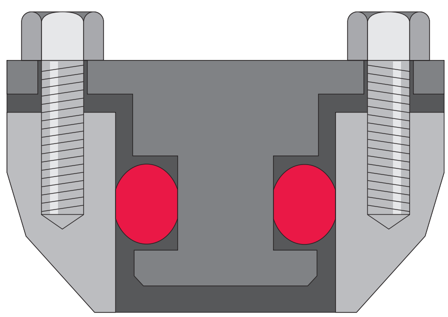


Illustration 4.3, Radial Seal

» Static Crush Seals

In crush seal applications, the o-ring is completely confined and pressure deformed (crushed) within a triangular gland made by machining a 45° angle on the male cover. Squeezed at an angle to the o-ring's axis, crush seals are used in such simple applications as the one depicted in Illustration 4.4.

STATIC CRUSH SEAL GLAND DIMENSION

Table D lists SAE recommended dimensions for static crush seal glands by ascending AS568 numbers.

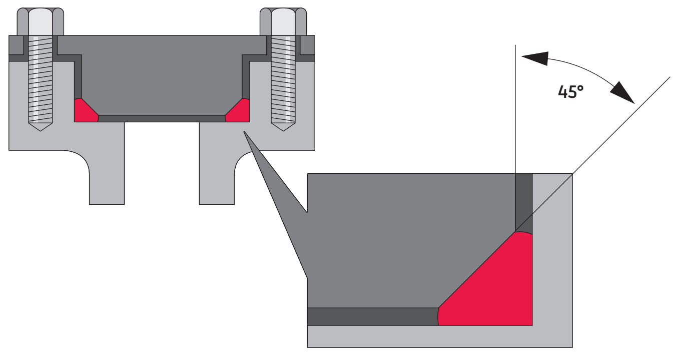


Illustration 4.4, Static Crush Seal

» Static Seals with Dovetail Glands

O-Rings are sometimes employed in static or slow moving dynamic situations calling for specially machined "dovetail" glands. Because of the angles involved, controlling the tolerances in these glands may be difficult. The purpose of these glands is to securely hold the o-ring in place during machine operation and/or maintenance disassembly. A typical valve seat application is shown in Illustration 4.5.

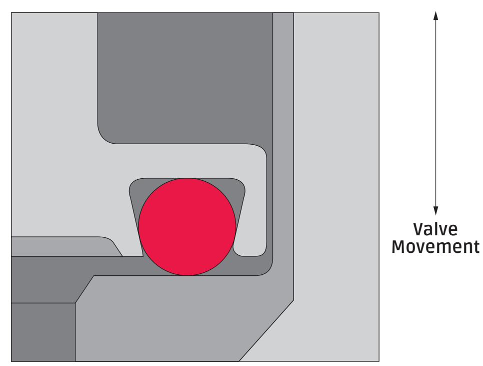


Illustration 4.5, Dovetail Gland

Rule of Thumb | **For a static crush seal application, it is recommended that the o-ring volume does not exceed 95% of the gland void.**

In this application, o-ring squeeze is primarily axial in direction (as valve operation exerts force on top and bottom seal surfaces). To avoid tearing or nicking, the use of o-ring lubrication is recommended while installing the o-ring into the dovetail gland. Because of the difficulty in creating the groove and tight tolerances required, this type of seal application should only be used when necessary.

DOVETAIL GLAND DIMENSIONS

Table E lists SAE recommended dimensions for dovetail glands by ascending AS568 numbers.

DYNAMIC SEAL TYPES

This classification of seals is used in situations involving reciprocating, rotating or oscillating motion. Dynamic seal performance may be substantially affected by a number of operating environmental factors.

Such factors include seal swell in fluids, surface finish of metal parts, lubrication, system pressure, thermal cycling, o-ring squeeze, o-ring stretch and friction. Since many of these factors are interrelated, it is important to consider all of them in dynamic sealing situations.

In discussions of individual dynamic seal types, therefore, mention will be made of the most critical operating environmental factors to consider. More detailed information on "Critical Operating Environmental Factors" is found in Section 5.

» Reciprocating Seals

Reciprocating seals, as depicted in Illustration 4.6, are used in situations involving a moving piston and a rod. These seals constitute the predominant dynamic application for o-rings.

For optimum performance of reciprocating seals, careful consideration of the following factors is required:

1. Compound Selection for Thermal Cycling: Thermal cycling from high (100°F and above) to low (-65°F and below) temperatures may cause o-rings to take compression set at elevated temperatures and fail to rebound enough at low temperatures to provide a leak-proof seal. Such o-ring leaks are especially prone to occur in low pressure, reciprocating applications. Therefore, when extreme operating thermal cycles are anticipated, it is recommended that you specify a seal compound that exceeds, rather than merely meets, desired temperature range, compression set and resilience needs.

2. Control Over Pressure Shocks: With sudden stopping and holding of heavy loads, hydraulic components can create system pressures far in excess of seal extrusion resistance capabilities. To prevent extrusion and eventual o-ring failure, pressure shocks should be anticipated and effectively dealt with in both seal selection and system design. As required, mechanical brakes or pressure relief valves may have to be built into the hydraulic system.

The use of back-up rings or increased seal durometer may also be necessary to prevent o-ring extrusion. For more information on the effects of pressure, see Illustration 5.1 in Section 5 of this guide.

3. Squeeze: Listed in Table A, under "Gland Design" at the end of this section are the recommended squeeze values for o-rings employed in reciprocating applications. Lower squeeze than that shown in Table A will reduce friction, but at a cost of possible leakage in low pressure situations. Greater squeeze than that

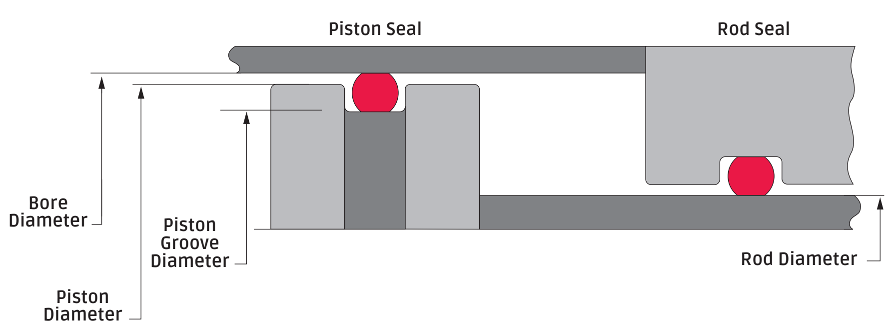


Illustration 4.6, Reciprocating Seals

shown will increase friction and sealing capability, at a cost of difficult assembly, faster seal wear, and the increased potential for spiral failure.

4. Stretch: When the I.D. of an o-ring is stretched, the o-ring's cross section is reduced. In such instances, be sure to consider that the o-ring's reduced cross section maintains the correct percentage of seal squeeze. The percentage of stretch should not exceed 5% in most applications.

$$\%\ STRETCH = \left[\frac{\text{Groove Diameter}}{\text{O-Ring ID}} - 1 \right] \cdot 100$$

ROTARY SEALS

As shown in Illustration 4.7, o-rings may be used as seals for rotating shafts, with the turning shaft protruding through the I.D. of the o-ring.

The most important factors to consider in designing rotary seal glands are application temperature limits, frictional heat buildup, o-ring stretch, squeeze and shaft and glandular machining.

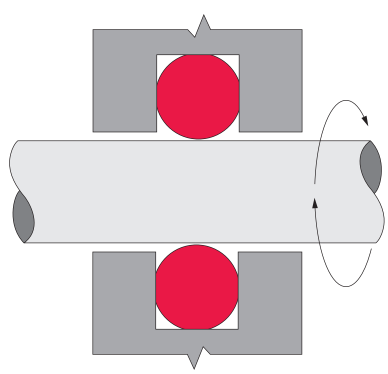


Illustration 4.7, Rotary Seal

1. Application Temperature Limits: Rotary shaft seals are not recommended for applications with operating temperatures lower than-40°F, or higher than +250°F. The closer the application is to room temperature, the longer the o-ring can be expected to effectively seal.

2. Frictional Heat Buildup: As the generation of frictional heat is inevitable with rotary seal applications, it is suggested that o-rings be composed of compounds featuring maximum heat resistance and minimum friction generating properties. Internally lubricated compounds are typically used for rotary applications.

3. Stretch: In this application, I.D. stretch must be eliminated by using shaft diameters no larger than the free state (relaxed) I.D. of the o-ring. Shaft seals for rotary or oscillating applications should be designed with no stretch over the shaft. When an elastomer is stressed in tension and the temperature is increased, it contracts instead of expands which increases the heat and additional contracting until seal failure. This contraction of an elastomer due to increased temperature is known as Joule effect.

4. Squeeze: In most rotational shaft applications, o-ring squeeze should be kept to as little as 0.002" by using an o-ring with an O.D. of about 5% larger than the accompanying gland. Once installed, peripheral compression puts the o-ring's I.D. in light contact with the turning shaft. This design minimizes frictional heat buildup and prolongs seal life.

ROTARY SEAL GLAND DIMENSIONS

Table G lists the recommended dimensions

Rule of Thumb | **The closer the application is to room temperature, the longer an o-ring can be expected to effectively seal.**

Rule of Thumb | **For reciprocating seals – passing o-rings over ports is not recommended. Nibbling and premature wear and seal failure will result.**

OSCILLATING SEALS

In an oscillating o-ring application, the shaft moves in an arc within the gland and in contact with the I.D. of the seal. Because there is a tendency for the shaft to twist, self-lubricated o-rings with a hardness of 80 to 90 durometer are most often employed. Caution should be used, however, with graphite-containing compounds as they tend to pit stainless steel alloys.

OSCILLATING SEAL GLAND DIMENSIONS

Oscillating seal gland dimensions are the same as those used for reciprocating applications (see Table F).

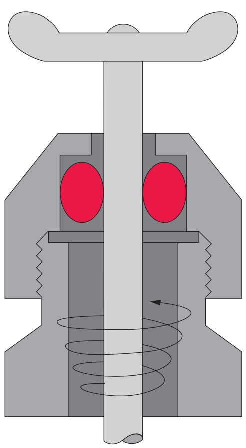


Illustration 4.8, Oscillating Seals

MACHINING

To preclude premature wear and seal failure, the metal surfaces which contact o-rings during installation and system operation must be properly prepared. Preparation consists of appropriate selection of materials, as well as machining for optimum surface finish.

To prevent o-ring extrusion or nibbling, rectangular, straight-sided, glandular grooves are best. For pressures up to 1,500 psi, 5° sloping sides are acceptable and easier to machine. Break all sharp corners by at least 0.005" to avoid unnecessary cutting or nicking of o-rings during assembly and operation.

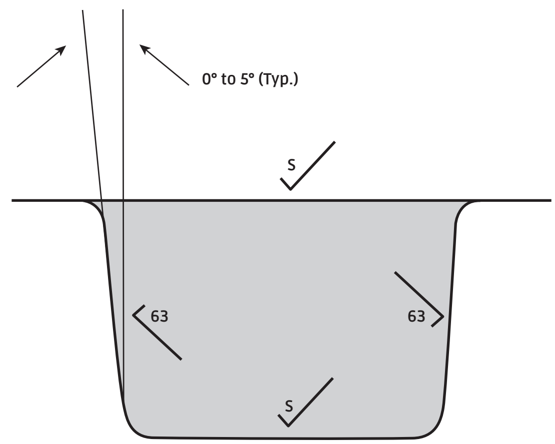
SURFACE FINISHES

» Static Glands

Surface finishes as rough as 64 to 128 micro-inches RMS can be tolerated. However, a finish of 32 micro-inches RMS is preferred.

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases



Finishes are RMS values

Illustration 4.9, Static Gland Detail

DYNAMIC GLANDS

» Reciprocating Seals

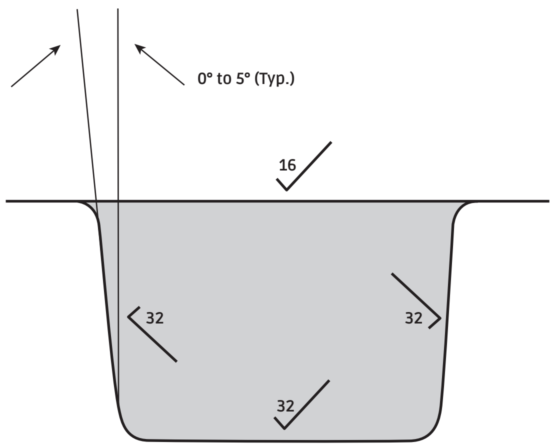
A highly polished surface is not desirable because it will not hold lubricant. The most desirable metal surface roughness value for dynamic seal applications is from 10 to 20 micro-inches. A shot-peened or electro-polished surface is ideal, because it provides many small pockets in the metal for entrapment of lubricants. The best surfaces are honed, burnished or hard chrome plated. Softer metallic surfaces, such as aluminum or brass, should generally not be used for dynamic applications.

Rule of Thumb

Avoid using graphite-loaded compounds with stainless steel, as they tend to pit the stainless steel surface over time.

» Rotary Seals

Shaft composition should be of a relatively hard metal and be within 0.0005" TIR. Additionally, it is recommended that shaft surfaces be finished to 16 RMS (for smooth, non-abrasive running), with gland surfaces finished to a rougher 32 RMS (to discourage o-ring movement within the gland).



Finishes are RMS values

Illustration 4.10, Dynamic Gland Detail

O-RING INSTALLATION

An o-ring may be easily damaged by improper handling and may fail for this reason alone. Prior to o-ring installation, make sure that all glandular surfaces are free of all debris. If necessary, clean these surfaces with an appropriate solvent that is compatible with the o-ring being installed.

Before installation, make sure to lightly coat the o-ring with a lubricant that is compatible with the o-ring being installed, as well as compatible with system chemicals.

In piston applications, avoid stretching the o-ring more than 100% during installation (stretch should not exceed 5% in the application). Also, be sure to stretch it uniformly. Cones, or mandrels, are often used to assist in these installations. Once the o-ring has been installed, make certain to remove any twists.

When the piston is pushed into the cylinder, push it straight in. Do not turn or twist pistons into cylinders as this may bunch or cut o-rings.

In installations where the o-ring must pass over threads or other sharp edges, cover these edges with tape or a plastic thimble prior to o-ring installation.

As necessary, o-rings may be folded into internal grooves, but excessive twisting should again be avoided.

In hydraulic systems, it is recommended that glandular surfaces be washed with hydraulic fluid, then cleaned with a lint-free cloth.

In all cases of o-ring installation, try to avoid excessive twisting, turning, rotating, or oscillating of glandular components relative to the o-ring. Also try to avoid o-ring contact with any sharp surfaces, including fingernails.

NOTE

The tables that follow represent a compilation of data from various sources to aid in the design of an effective seal. Because each sealing application is unique, the presented data should be referred to as a proper initial step, with

Rule of Thumb | **Before installation, make sure to lightly coat the o-ring with a lubricant that is compatible with the o-ring material, as well as with system chemicals.**

PLEASE NOTE THE FOLLOWING

The applications, suggestions and recommendations contained in this book are meant to be used as a professional guide only. Because no two situations or installations are the same, these comments, suggestions, and recommendations are necessarily general and should not be relied upon by any purchaser without independent verification based on the particular installation or use. We strongly recommend that the seal you select be rigorously tested in the actual application

One general guideline to consider when designing a seal is to maintain a range of % squeeze on the o-ring (~10-40% for static and no more than 30% for dynamic).

No less than 75% of the seal cross-section should be contained within the groove to ensure the seal doesn't "roll" or extrude out of the groove. See Section 5 for more detail on determining the allowable clearance gap.

Finally, be sure to consider the void/volume relationship in worst case tolerance conditions. The maximum o-ring volume should not exceed 90% of the minimum gland void. The groove width may be increased to provide additional void.

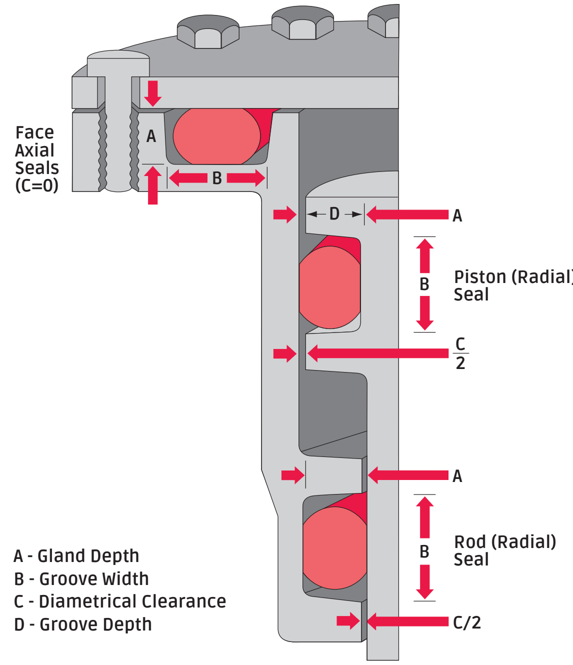


Illustration 4.11

TABLE A O-Ring Gland Design for Dynamic Seals

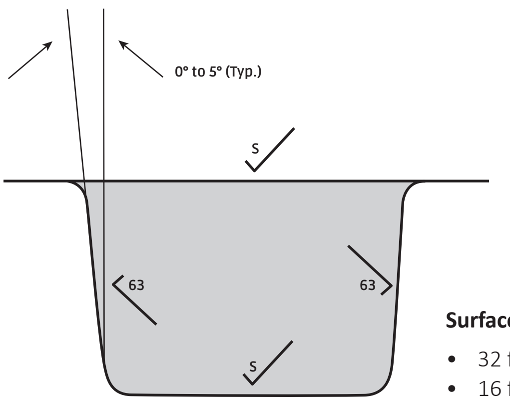
O-Ring Cross Section	Gland Depth	Squeeze		Diametrical Clearance Max.	Groove Width. ±.005			Groove Radius	Eccentricity Max.
		Inches	%		No Backup Rings	One Backup Ring	Two Backup Rings		
.040	.031/.033	.004/.012	11-28	.004	.063	–	–	.005-.008	.002
.050	.039/.041	.006/.014	13-26	.004	.073	–	–	.005-.008	.002
.060	.047/.049	.008/.016	14-25	.004	.084	–	–	.005-.008	.002
.070	.055/.057	.010/.018	15-25	.004	.095	.150	.208	.005-.015	.002
.103	.087/.090	.010/.019	10-18	.005	.145	.187	.249	.005-.020	.003
.139	.119/.123	.012/.024	9-17	.006	.185	.222	.301	.005-.030	.004
.210	.183/.188	.017/.032	8.5-15	.006	.285	.338	.428	.005-.050	.006
.275	.234/.240	.029/.047	10.5-17	.007	.375	.440	.579	.005-.060	.008

NOTE: Table A contains general sealing guidelines. More specific information is available throughout this guide.

O-Ring Gland Design for Static Seals

O-Ring Cross Section	Gland Depth		Squeeze				Diametrical Clearance Max.	Groove Width. ±.005			Groove Radius	Eccen-tricity Max.
			Radial		Axial							
	Radial	Axial	Inches	%	Inches	%		No Backup Rings	One Backup Ring	Two Backup Rings		
.020*	.013-.014	.013-.014	.004-.009	22-41	.004-.009	22-41	.002	.035	–	–	–	.0015
.030	.020-.022	.020-.022	.005-.013	19-39	.005-.013	19-39	.003	.045	–	–	–	.0015
.040	.027-.030	.027-.030	.007-.016	19-37	.007-.016	19-37	.003	.060	–	–	.005-.008	.002
.050	.035-.039	.034-.038	.008-.018	17-34	.009-.019	19-36	.004	.075	–	–	.005-.008	.002
.060	.042-.047	.042-.046	.010-.021	18-33	.011-.021	19-33	.004	.090	–	–	.005-.008	.002
.070	.050-.055	.049-.054	.012-.023	18-32	.013-.024	19-33	.004	.105	.150	.208	.005-.015	.002
.103	.080-.086	.075-.081	.014-.026	14-25	.019-.031	19-29	.005	.146	.182	.244	.005-.020	.003
.139	.110-.116	.100-.108	.019-.033	14-23	.027-.043	20-30	.006	.195	.217	.296	.005-.030	.004
.210	.170-.176	.155-.165	.029-.045	14-21	.040-.060	20-28	.006	.280	.333	.423	.005-.050	.006
.275	.225-.235	.205-.215	.034-.056	13-20	.054-.076	20-27	.007	.350	.435	.574	.005-.060	.008

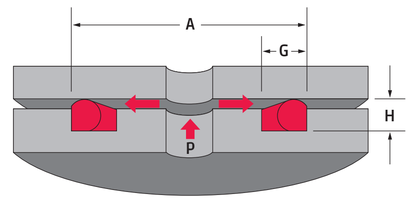
***NOTE:** It is recommended that an o-ring with tighter CS tolerance (±.002) be requested.



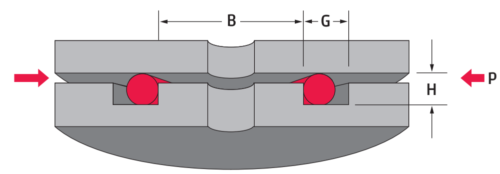
Finishes are RMS values

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases



Internal Pressure



External Pressure

TABLE B Static Axial Seal Gland Dimensions

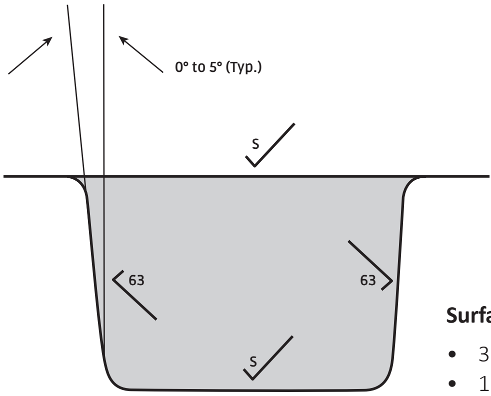
AS568 Number	O-Ring Dimensions			Internal Pressure Diameter A	External Pressure Diameter B	Groove Width G	Gland Depth H
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.005 -.000**	**+.000 -.005**	**+.010 -.000**	**+.005 -.000**
-004	.070 ± .005	.070 ± .003	.210	**	.075	.125	.049
-005	.101 ± .005		.241	**	.106	.125	.049
-006	.114 ± .005		.254	**	.119	.125	.049
-007	.145 ± .005		.285	**	.150	.125	.049
-008	.176 ± .005		.316	**	.181	.125	.049
-009	.208 ± .005		.348	**	.213	.125	.049
-010	.239 ± .005		.379	**	.244	.125	.049
-011	.301 ± .005		.441	.436	.306	.125	.049
-012	.364 ± .005		.504	.499	.369	.125	.049
-013	.426 ± .005		.566	.561	.431	.125	.049
-014	.489 ± .005		.629	.624	.494	.125	.049
-015	.551 ± .007		.691	.686	.556	.125	.049
-016	.614 ± .009		.754	.749	.619	.125	.049
-017	.676 ± .009		.816	.811	.681	.125	.049
-018	.739 ± .009		.879	.874	.744	.125	.049
-019	.801 ± .009		.941	.936	.806	.125	.049
-020	.864 ± .009		1.004	.999	.869	.125	.049
-021	.926 ± .009		1.066	1.061	.931	.125	.049
-022	.989 ± .009		1.129	1.124	.994	.125	.049
-023	1.051 ± .010		1.191	1.186	1.056	.125	.049

****NOTE:** O-Ring seal sizes not listed are not recommended for axial seals because the seal ID after installation becomes too small for practical use.

TABLE B Static Axial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions			Internal Pressure Diameter A	External Pressure Diameter B	Groove Width G	Gland Depth H
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.005 -.000**	**+.000 -.005**	**+.010 -.000**	**+.005 -.000**
-024	1.114 ± .010	.070 ± .003	1.254	1.249	1.119	.125	.049
-025	1.176 ± .011		1.316	1.311	1.181	.125	.049
-026	1.239 ± .011		1.379	1.374	1.244	.125	.049
-027	1.301 ± .011		1.441	1.436	1.306	.125	.049
-028	1.364 ± .013		1.504	1.499	1.368	.125	.049
-029	1.489 ± .013		1.629	1.624	1.494	.125	.049
-030	1.614 ± .013		1.754	1.749	1.619	.125	.049
-031	1.739 ± .015		1.879	1.874	1.744	.125	.049
-032	1.864 ± .015		2.004	1.999	1.869	.125	.049
-033	1.989 ± .018		2.129	2.124	1.994	.125	.049
-034	2.114 ± .018		2.254	2.249	2.119	.125	.049
-035	2.239 ± .018		2.379	2.374	2.244	.125	.049
-036	2.364 ± .018		2.504	2.499	2.369	.125	.049
-037	2.489 ± .018		2.629	2.624	2.494	.125	.049
-038	2.614 ± .020		2.754	2.749	2.619	.125	.049
-039	2.739 ± .020		2.879	2.874	2.744	.125	.049
-040	2.864 ± .020		3.004	2.999	2.869	.125	.049
-041	2.989 ± .024		3.129	3.124	2.994	.125	.049
-042	3.239 ± .024		3.379	3.374	3.244	.125	.049
-043	3.489 ± .024		3.629	3.624	3.494	.125	.049
-044	3.739 ± .027		3.879	3.874	3.744	.125	.049
-045	3.989 ± .027		4.129	4.124	3.994	.125	.049
-046	4.239 ± .030		4.379	4.374	4.244	.125	.049
-047	4.489 ± .030		4.629	4.624	4.494	.125	.049
-048	4.739 ± .030		4.879	4.874	4.744	.125	.049
-049	4.989 ± .037		5.129	5.124	4.994	.125	.049
-050	5.239 ± .037		5.379	5.374	5.244	.125	.049
-102	.049 ± .005	.103 ± .003	0.255	**	.054	.170	.075
-103	.081 ± .005		0.287	**	.086	.170	.075
-104	.112 ± .005		0.318	**	.117	.170	.075

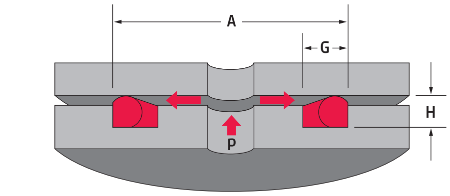
****NOTE:** O-Ring seal sizes not listed are not recommended for axial seals because the seal ID after installation becomes too small for practical use.



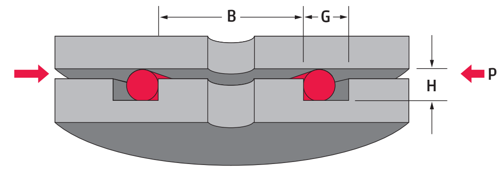
Finishes are RMS values

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases



Internal Pressure



External Pressure

TABLE B Static Axial Seal Gland Dimensions

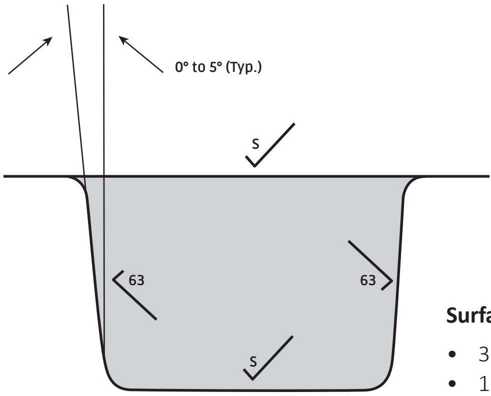
AS568 Number	O-Ring Dimensions			Internal Pressure Diameter A	External Pressure Diameter B	Groove Width G	Gland Depth H
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.005 -.000**	**+.000 -.005**	**+.010 -.000**	**+.005 -.000**
-105	.143 ± .005	.103 ± .003	0.349	**	.148	.170	.075
-106	.174 ± .005		0.380	**	.179	.170	.075
-107	.206 ± .005		0.412	**	.211	.170	.075
-108	.237 ± .005		0.443	**	.242	.170	.075
-109	.299 ± .005		0.505	**	.304	.170	.075
-110	.362 ± .005		0.568	.563	.367	.170	.075
-111	.424 ± .005		0.630	.625	.429	.170	.075
-112	.487 ± .005		0.693	.688	.492	.170	.075
-113	.549 ± .005		0.755	.750	.554	.170	.075
-114	.612 ± .009		0.818	.813	.617	.170	.075
-115	.674 ± .009		0.880	.875	.679	.170	.075
-116	.737 ± .009		0.943	.938	.742	.170	.075
-117	.799 ± .010		1.005	1.000	.804	.170	.075
-118	.862 ± .010		1.068	1.063	.867	.170	.075
-119	.924 ± .010		1.130	1.125	.929	.170	.075
-120	.987 ± .010		1.193	1.188	.992	.170	.075
-121	1.049 ± .010		1.255	1.250	1.054	.170	.075
-122	1.112 ± .010		1.318	1.313	1.117	.170	.075
-123	1.174 ± .012		1.380	1.375	1.179	.170	.075
-124	1.237 ± .012		1.443	1.438	1.242	.170	.075
-125	1.299 ± .012		1.505	1.500	1.304	.170	.075
-126	1.362 ± .012		1.568	1.563	1.367	.170	.075
-127	1.424 ± .012		1.630	1.625	1.429	.170	.075
-128	1.487 ± .012		1.693	1.688	1.492	.170	.075
-129	1.549 ± .015		1.755	1.750	1.554	.170	.075
-130	1.612 ± .015		1.818	1.813	1.617	.170	.075
-131	1.674 ± .015		1.880	1.875	1.679	.170	.075
-132	1.737 ± .015		1.943	1.938	1.742	.170	.075
-133	1.799 ± .015		2.005	2.000	1.804	.170	.075
-134	1.862 ± .015		2.068	2.063	1.867	.170	.075

****NOTE:** O-Ring seal sizes not listed are not recommended for axial seals because the seal ID after installation becomes too small for practical use.

TABLE B Static Axial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions			Internal Pressure Diameter A	External Pressure Diameter B	Groove Width G	Gland Depth H
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.005 -.000**	**+.000 -.005**	**+.010 -.000**	**+.005 -.000**
-135	1.925 ± .017	.103 ± .003	2.131	2.126	1.930	.170	.075
-136	1.987 ± .017		2.193	2.188	1.992	.170	.075
-137	2.050 ± .017		2.256	2.251	2.055	.170	.075
-138	2.112 ± .017		2.318	2.313	2.117	.170	.075
-139	2.175 ± .017		2.381	2.376	2.180	.170	.075
-140	2.237 ± .017		2.443	2.438	2.242	.170	.075
-141	2.300 ± .020		2.506	2.501	2.305	.170	.075
-142	2.362 ± .020		2.568	2.563	2.367	.170	.075
-143	2.425 ± .020		2.631	2.626	2.430	.170	.075
-144	2.487 ± .020		2.693	2.688	2.492	.170	.075
-145	2.550 ± .020		2.756	2.751	2.555	.170	.075
-146	2.612 ± .020		2.818	2.813	2.617	.170	.075
-147	2.675 ± .022		2.881	2.876	2.680	.170	.075
-148	2.737 ± .022		2.943	2.938	2.742	.170	.075
-149	2.800 ± .022		3.006	3.001	2.805	.170	.075
-150	2.862 ± .022		3.068	3.063	2.867	.170	.075
-151	2.987 ± .024		3.193	3.188	2.992	.170	.075
-152	3.237 ± .024		3.443	3.438	3.242	.170	.075
-153	3.487 ± .024		3.693	3.688	3.492	.170	.075
-154	3.737 ± .028		3.943	3.938	3.742	.170	.075
-155	3.987 ± .028		4.193	4.188	3.992	.170	.075
-156	4.237 ± .030		4.443	4.438	4.242	.170	.075
-157	4.487 ± .030		4.693	4.688	4.492	.170	.075
-158	4.737 ± .030		4.943	4.938	4.742	.170	.075
-159	4.987 ± .035		5.193	5.188	4.992	.170	.075
-160	5.237 ± .035		5.443	5.438	5.242	.170	.075
-161	5.487 ± .035		5.693	5.688	5.492	.170	.075
-162	5.737 ± .035		5.943	5.938	5.742	.170	.075
-163	5.987 ± .035		6.193	6.188	5.992	.170	.075
-164	6.237 ± .040		6.443	6.438	6.242	.170	.075

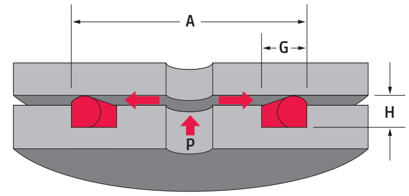
NOTE: O-Ring seal sizes not listed are not recommended for axial seals because the seal ID after installation becomes too small for practical use.



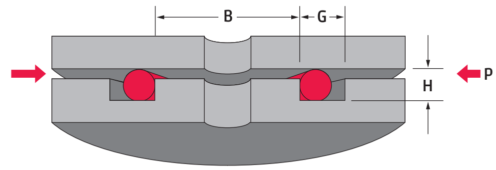
Finishes are RMS values

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases



Internal Pressure



External Pressure

TABLE B Static Axial Seal Gland Dimensions

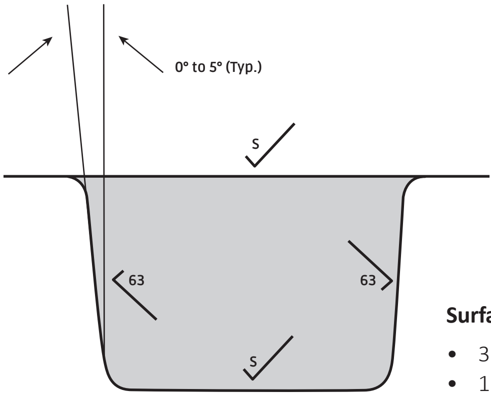
AS568 Number	O-Ring Dimensions			Internal Pressure Diameter A	External Pressure Diameter B	Groove Width G	Gland Depth H
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.005 -.000**	**+.000 -.005**	**+.010 -.000**	**+.005 -.000**
-165	6.487 ± .040	.103 ± .003	6.693	6.688	6.492	.170	.075
-166	6.737 ± .040		6.943	6.938	6.742	.170	.075
-167	6.987 ± .040		7.193	7.188	6.992	.170	.075
-168	7.237 ± .045		7.443	7.438	7.242	.170	.075
-169	7.487 ± .045		7.693	7.688	7.492	.170	.075
-170	7.737 ± .045		7.943	7.938	7.742	.170	.075
-171	7.987 ± .045		8.193	8.188	7.992	.170	.075
-172	8.237 ± .050		8.443	8.438	8.242	.170	.075
-173	8.487 ± .050		8.693	8.688	8.492	.170	.075
-174	8.737 ± .050		8.943	8.938	8.742	.170	.075
-175	8.987 ± .050		9.193	9.188	8.992	.170	.075
-176	9.237 ± .055		9.443	9.438	9.242	.170	.075
-177	9.487 ± .055		9.693	9.688	9.492	.170	.075
-178	9.737 ± .055		9.943	9.939	9.742	.170	.075
-201	.171 ± .005	.139 ± .004	0.449	**	.176	.210	.107
-202	.234 ± .005		0.512	**	.239	.210	.107
-203	.296 ± .005		0.574	**	.301	.210	.107
-204	.359 ± .005		0.637	**	.364	.210	.107
-205	.421 ± .005		0.699	.694	.426	.210	.107
-206	.484 ± .005		0.762	.757	.489	.210	.107
-207	.546 ± .007		0.824	.819	.551	.210	.107
-208	.609 ± .009		0.887	.882	.614	.210	.107
-209	.671 ± .009		0.949	.944	.676	.210	.107
-210	.734 ± .010		1.012	1.007	.739	.210	.107
-211	.796 ± .010		1.074	1.069	.801	.210	.107
-212	.859 ± .010		1.137	1.132	.864	.210	.107
-213	.921 ± .010		1.199	1.194	.926	.210	.107
-214	.984 ± .010		1.262	1.257	.989	.210	.107
-215	1.046 ± .010		1.324	1.319	1.051	.210	.107
-216	1.109 ± .012		1.387	1.382	1.114	.210	.107

NOTE: O-Ring seal sizes not listed are not recommended for axial seals because the seal ID after installation becomes too small for practical use.

TABLE B Static Axial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions			Internal Pressure Diameter A	External Pressure Diameter B	Groove Width G	Gland Depth H
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.005 -.000**	**+.000 -.005**	**+.010 -.000**	**+.005 -.000**
-217	1.171 ± .012	.139 ± .004	1.449	1.444	1.176	.210	.107
-218	1.234 ± .012		1.512	1.507	1.239	.210	.107
-219	1.296 ± .012		1.574	1.569	1.301	.210	.107
-220	1.359 ± .012		1.637	1.632	1.364	.210	.107
-221	1.421 ± .012		1.699	1.694	1.426	.210	.107
-222	1.484 ± .015		1.762	1.757	1.489	.210	.107
-223	1.609 ± .015		1.887	1.882	1.614	.210	.107
-224	1.734 ± .015		2.012	2.007	1.739	.210	.107
-225	1.859 ± .018		2.137	2.132	1.864	.210	.107
-226	1.984 ± .018		2.262	2.257	1.989	.210	.107
-227	2.109 ± .018		2.387	2.382	2.114	.210	.107
-228	2.234 ± .020		2.512	2.507	2.239	.210	.107
-229	2.359 ± .020		2.637	2.632	2.364	.210	.107
-230	2.484 ± .020		2.762	2.757	2.489	.210	.107
-231	2.609 ± .020		2.887	2.882	2.614	.210	.107
-232	2.734 ± .024		3.012	3.007	2.739	.210	.107
-233	2.859 ± .024		3.137	3.132	2.864	.210	.107
-234	2.984 ± .024		3.262	3.257	2.989	.210	.107
-235	3.109 ± .024		3.387	3.382	3.114	.210	.107
-236	3.234 ± .024		3.512	3.507	3.239	.210	.107
-237	3.359 ± .024		3.637	3.632	3.364	.210	.107
-238	3.484 ± .024		3.762	3.757	3.489	.210	.107
-239	3.609 ± .028		3.887	3.882	3.614	.210	.107
-240	3.734 ± .028		4.012	4.007	3.739	.210	.107
-241	3.859 ± .028		4.137	4.132	3.864	.210	.107
-242	3.984 ± .028		4.262	4.257	3.989	.210	.107
-243	4.109 ± .028		4.387	4.382	4.114	.210	.107
-244	4.234 ± .030		4.512	4.507	4.239	.210	.107
-245	4.359 ± .030		4.637	4.632	4.364	.210	.107
-246	4.484 ± .030	▼	4.762	4.757	4.489	.210	.107

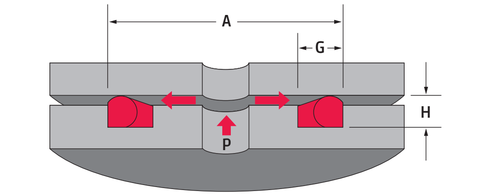
NOTE: O-Ring seal sizes not listed are not recommended for axial seals because the seal ID after installation becomes too small for practical use.



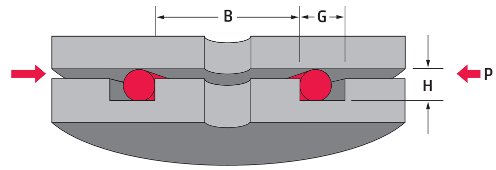
Finishes are RMS values

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases



Internal Pressure



External Pressure

TABLE B Static Axial Seal Gland Dimensions

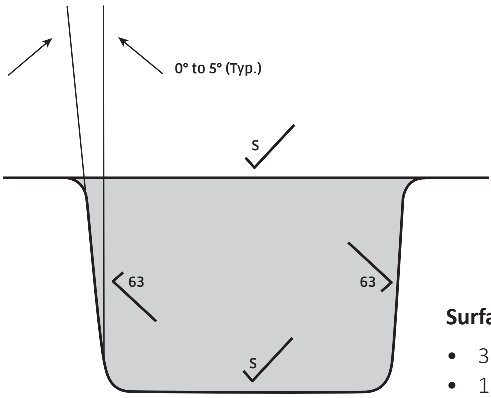
AS568 Number	O-Ring Dimensions			Internal Pressure Diameter A	External Pressure Diameter B	Groove Width G	Gland Depth H
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.005 -.000**	**+.000 -.005**	**+.010 -.000**	**+.005 -.000**
-247	4.609 ± .030	.139 ± .004	4.887	4.882	4.614	.210	.107
-248	4.734 ± .030		5.012	5.007	4.739	.210	.107
-249	4.859 ± .035		5.137	5.132	4.864	.210	.107
-250	4.984 ± .035		5.262	5.257	4.989	.210	.107
-251	5.109 ± .035		5.387	5.382	5.114	.210	.107
-252	5.234 ± .035		5.512	5.507	5.239	.210	.107
-253	5.359 ± .035		5.637	5.632	5.359	.210	.107
-254	5.484 ± .035		5.762	5.757	5.489	.210	.107
-255	5.609 ± .035		5.887	5.882	5.614	.210	.107
-256	5.734 ± .035		6.012	6.007	5.739	.210	.107
-257	5.859 ± .035		6.137	6.132	5.864	.210	.107
-258	5.984 ± .035		6.262	6.257	5.989	.210	.107
-259	6.234 ± .040		6.512	6.507	6.239	.210	.107
-260	6.484 ± .040		6.762	6.757	6.489	.210	.107
-261	6.734 ± .040		7.012	7.007	6.739	.210	.107
-262	6.984 ± .040		7.262	7.257	6.989	.210	.107
-263	7.234 ± .045		7.512	7.507	7.239	.210	.107
-264	7.484 ± .045		7.762	7.757	7.489	.210	.107
-265	7.734 ± .045		8.012	8.007	7.739	.210	.107
-266	7.984 ± .045		8.262	8.257	7.989	.210	.107
-267	8.234 ± .050		8.512	8.507	8.239	.210	.107
-268	8.484 ± .050		8.762	8.757	8.489	.210	.107
-269	8.734 ± .050		9.012	9.007	8.739	.210	.107
-270	8.984 ± .050		9.262	9.257	8.989	.210	.107
-271	9.234 ± .055		9.512	9.507	9.239	.210	.107
-272	9.484 ± .055		9.762	9.757	9.489	.210	.107
-273	9.734 ± .055		10.012	10.007	9.739	.210	.107
-274	9.984 ± .055		10.262	10.257	9.989	.210	.107
-275	10.484 ± .055		10.762	10.757	10.489	.210	.107
-276	10.984 ± .065		11.262	11.257	10.989	.210	.107

NOTE: O-Ring seal sizes not listed are not recommended for axial seals because the seal ID after installation becomes too small for practical use.

TABLE B Static Axial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions I.D. ± Tol.	W. ± Tol.	O.D. (ref)	Internal Pressure Diameter A	External Pressure Diameter B	Groove Width G	Gland Depth H
Tolerance				+.005 -.000	+.000 -.005	+.010 -.000	+.005 -.000
-277	11.484 ± .065	.139 ± .004	11.762	11.757	11.489	.210	.107
-278	11.984 ± .065		12.262	12.257	11.989	.210	.107
-279	12.984 ± .065		13.262	13.257	12.989	.210	.107
-280	13.984 ± .065		14.262	14.257	13.989	.210	.107
-281	14.984 ± .065		15.262	15.257	14.989	.210	.107
-282	15.955 ± .075		16.233	16.228	15.960	.210	.107
-283	16.955 ± .080		17.233	17.228	16.960	.210	.107
-284	17.955 ± .085		18.233	18.228	17.960	.210	.107
-309	.412 ± .005	.210 ± .005	0.832	**	.417	.300	.169
-310	.475 ± .005		0.895	.890	.480	.300	.169
-311	.537 ± .007		0.957	.952	.542	.300	.169
-312	.600 ± .009		1.020	1.015	.605	.300	.169
-313	.662 ± .009		1.082	1.077	.667	.300	.169
-314	.725 ± .010		1.145	1.140	.730	.300	.169
-315	.787 ± .010		1.207	1.202	.792	.300	.169
-316	.850 ± .010		1.270	1.265	.855	.300	.169
-317	.912 ± .010		1.332	1.327	.917	.300	.169
-318	.975 ± .010		1.395	1.390	.980	.300	.169
-319	1.037 ± .010		1.457	1.452	1.042	.300	.169
-320	1.100 ± .012		1.520	1.515	1.105	.300	.169
-321	1.162 ± .012		1.582	1.577	1.167	.300	.169
-322	1.225 ± .012		1.645	1.640	1.230	.300	.169
-323	1.287 ± .012		1.707	1.702	1.292	.300	.169
-324	1.350 ± .012		1.770	1.765	1.355	.300	.169
-325	1.475 ± .015		1.895	1.890	1.480	.300	.169
-326	1.600 ± .015		2.020	2.015	1.605	.300	.169
-327	1.725 ± .015		2.145	2.140	1.730	.300	.169
-328	1.850 ± .015		2.270	2.265	1.855	.300	.169
-329	1.975 ± .018		2.395	2.390	1.980	.300	.169
-330	2.100 ± .018		2.520	2.515	2.105	.300	.169

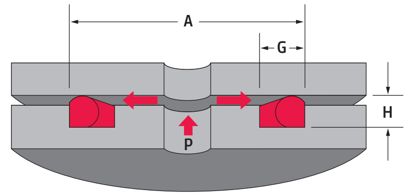
****NOTE:** O-Ring seal sizes not listed are not recommended for axial seals because the seal ID after installation becomes too small for practical use.



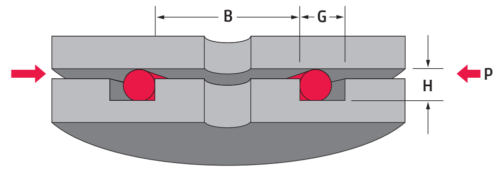
Finishes are RMS values

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases



Internal Pressure



External Pressure

TABLE B Static Axial Seal Gland Dimensions

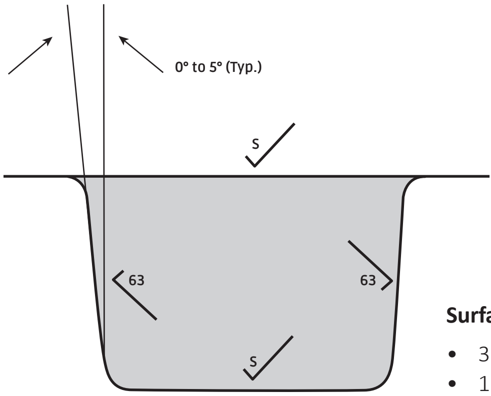
AS568 Number	O-Ring Dimensions			Internal Pressure Diameter A	External Pressure Diameter B	Groove Width G	Gland Depth H
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.005 -.000**	**+.000 -.005**	**+.010 -.000**	**+.005 -.000**
-331	2.225 ± .018	.210 ± .005	2.645	2.640	2.230	.300	.169
-332	2.350 ± .018		2.770	2.765	2.355	.300	.169
-333	2.475 ± .020		2.895	2.890	2.480	.300	.169
-334	2.600 ± .020		3.020	3.015	2.605	.300	.169
-335	2.725 ± .020		3.145	3.140	2.730	.300	.169
-336	2.850 ± .020		3.270	3.265	2.855	.300	.169
-337	2.975 ± .024		3.395	3.390	2.980	.300	.169
-338	3.100 ± .024		3.520	3.515	3.105	.300	.169
-339	3.225 ± .024		3.645	3.640	3.230	.300	.169
-340	3.350 ± .024		3.770	3.765	3.355	.300	.169
-341	3.475 ± .024		3.895	3.890	3.480	.300	.169
-342	3.600 ± .028		4.020	4.015	3.605	.300	.169
-343	3.725 ± .028		4.145	4.140	3.730	.300	.169
-344	3.850 ± .028		4.270	4.265	3.855	.300	.169
-345	3.975 ± .028		4.395	4.390	3.980	.300	.169
-346	4.100 ± .028		4.520	4.515	4.105	.300	.169
-347	4.225 ± .030		4.645	4.640	4.230	.300	.169
-348	4.350 ± .030		4.770	4.765	4.355	.300	.169
-349	4.475 ± .030		4.895	4.890	4.480	.300	.169
-350	4.600 ± .030		5.020	5.015	4.605	.300	.169
-351	4.725 ± .030		5.145	5.140	4.730	.300	.169
-352	4.850 ± .030		5.270	5.265	4.855	.300	.169
-353	4.975 ± .037		5.395	5.390	4.980	.300	.169
-354	5.100 ± .037		5.520	5.515	5.105	.300	.169
-355	5.225 ± .037		5.645	5.640	5.230	.300	.169
-356	5.350 ± .037		5.770	5.765	5.355	.300	.169
-357	5.475 ± .037		5.895	5.890	5.480	.300	.169
-358	5.600 ± .037		6.020	6.015	5.605	.300	.169
-359	5.725 ± .037		6.145	6.140	5.730	.300	.169
-360	5.850 ± .037		6.270	6.265	5.855	.300	.169

NOTE: O-Ring seal sizes not listed are not recommended for axial seals because the seal ID after installation becomes too small for practical use.

TABLE B Static Axial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions			Internal Pressure Diameter A	External Pressure Diameter B	Groove Width G	Gland Depth H
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.005 -.000**	**+.000 -.005**	**+.010 -.000**	**+.005 -.000**
-361	5.975 ± .037	.210 ± .005	6.395	6.390	5.980	.300	.169
-362	6.225 ± .040		6.645	6.640	6.230	.300	.169
-363	6.475 ± .040		6.895	6.890	6.480	.300	.169
-364	6.725 ± .040		7.145	7.140	6.730	.300	.169
-365	6.975 ± .040		7.395	7.390	6.980	.300	.169
-366	7.225 ± .045		7.645	7.640	7.230	.300	.169
-367	7.475 ± .045		7.895	7.890	7.480	.300	.169
-368	7.725 ± .045		8.145	8.140	7.730	.300	.169
-369	7.975 ± .045		8.395	8.390	7.980	.300	.169
-370	8.225 ± .050		8.645	8.640	8.230	.300	.169
-371	8.475 ± .050		8.895	8.890	8.480	.300	.169
-372	8.725 ± .050		9.145	9.140	8.730	.300	.169
-373	8.975 ± .050		9.395	9.390	8.980	.300	.169
-374	9.225 ± .055		9.645	9.640	9.230	.300	.169
-375	9.475 ± .055		9.895	9.890	9.480	.300	.169
-376	9.725 ± .055		10.145	10.140	9.730	.300	.169
-377	9.975 ± .055		10.395	10.390	9.980	.300	.169
-378	10.475 ± .060		10.895	10.890	10.480	.300	.169
-379	10.975 ± .060		11.395	11.390	10.980	.300	.169
-380	11.475 ± .065		11.895	11.890	11.480	.300	.169
-381	11.975 ± .065		12.395	12.390	11.980	.300	.169
-382	12.975 ± .065		13.395	13.390	12.980	.300	.169
-383	13.975 ± .070		14.395	14.390	13.980	.300	.169
-384	14.975 ± .070		15.395	15.390	14.980	.300	.169
-385	15.955 ± .075		16.375	16.370	15.960	.300	.169
-386	16.955 ± .080		17.375	17.370	16.960	.300	.169
-387	17.955 ± .085		18.375	18.370	17.960	.300	.169
-388	18.955 ± .090		19.375	19.370	18.960	.300	.169
-389	19.955 ± .095		20.375	20.370	19.960	.300	.169
-390	20.955 ± .095		21.375	21.370	20.960	.300	.169

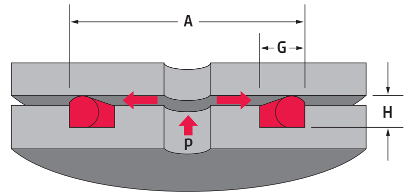
NOTE: O-Ring seal sizes not listed are not recommended for axial seals because the seal ID after installation becomes too small for practical use.



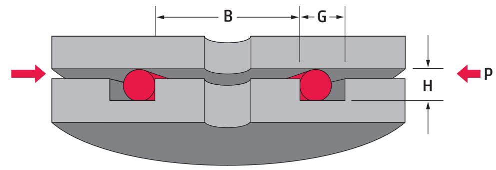
Finishes are RMS values

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases



Internal Pressure

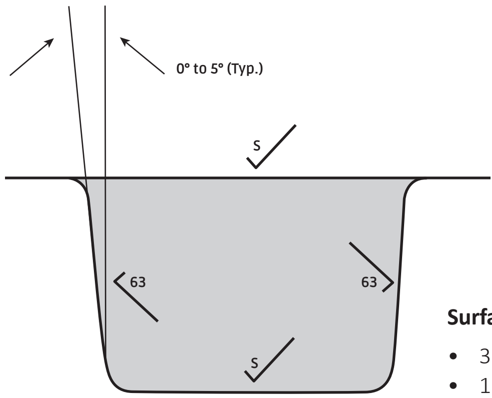


External Pressure

TABLE B Static Axial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions			Internal Pressure Diameter A	External Pressure Diameter B	Groove Width G	Gland Depth H
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.005 -.000**	**+.000 -.005**	**+.010 -.000**	**+.005 -.000**
-391	21.955 ± .100	.210 ± .005	22.375	22.370	21.960	.300	.169
-392	22.940 ± .105	↓	23.360	23.355	22.945	.300	.169
-393	23.940 ± .110	↓	24.360	24.355	23.945	.300	.169
-394	24.940 ± .115	↓	25.360	25.355	24.945	.300	.169
-395	25.940 ± .120	↓	26.360	26.355	25.945	.300	.169
-425	4.475 ± .033	.275 ± .006	5.025	5.020	4.480	.355	.231
-426	4.600 ± .033	↓	5.150	5.145	4.605	.355	.231
-427	4.725 ± .033	↓	5.275	5.270	4.730	.355	.231
-428	4.850 ± .033	↓	5.400	5.395	4.855	.355	.231
-429	4.975 ± .037	↓	5.525	5.520	4.980	.355	.231
-430	5.100 ± .037	↓	5.650	5.645	5.105	.355	.231
-431	5.225 ± .037	↓	5.775	5.770	5.230	.355	.231
-432	5.350 ± .037	↓	5.900	5.895	5.355	.355	.231
-433	5.475 ± .037	↓	6.025	6.020	5.480	.355	.231
-434	5.600 ± .037	↓	6.150	6.145	5.605	.355	.231
-435	5.725 ± .037	↓	6.275	6.270	5.730	.355	.231
-436	5.850 ± .037	↓	6.400	6.395	5.855	.355	.231
-437	5.975 ± .037	↓	6.525	6.520	5.980	.355	.231
-438	6.225 ± .040	↓	6.775	6.770	6.230	.355	.231
-439	6.475 ± .040	↓	7.025	7.020	6.480	.355	.231
-440	6.725 ± .040	↓	7.275	7.270	6.730	.355	.231
-441	6.975 ± .040	↓	7.525	7.520	6.980	.355	.231
-442	7.225 ± .045	↓	7.775	7.770	7.230	.355	.231
-443	7.475 ± .045	↓	8.025	8.020	7.480	.355	.231
-444	7.725 ± .045	↓	8.275	8.270	7.730	.355	.231
-445	7.975 ± .045	↓	8.525	8.520	7.980	.355	.231
-446	8.475 ± .055	↓	9.025	9.020	8.480	.355	.231
-447	8.975 ± .055	↓	9.525	9.520	8.980	.355	.231
-448	9.475 ± .055	↓	10.025	10.020	9.480	.355	.231
-449	9.975 ± .055	↓	10.525	10.520	9.980	.355	.231

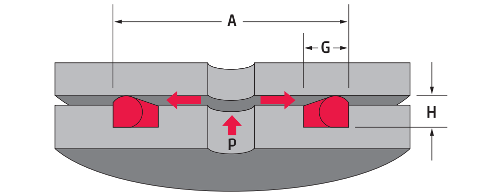
NOTE: O-Ring seal sizes not listed are not recommended for axial seals because the seal ID after installation becomes too small for practical use.



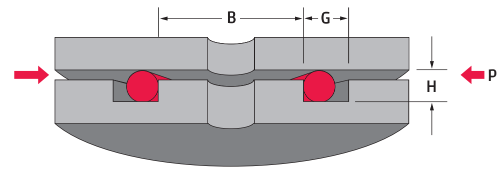
Finishes are RMS values

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases



Internal Pressure

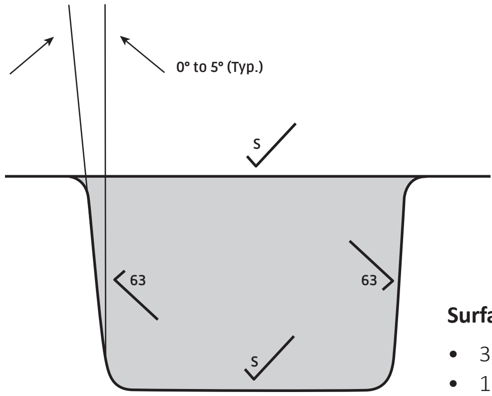


External Pressure

TABLE B Static Axial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions			Internal Pressure Diameter A	External Pressure Diameter B	Groove Width G	Gland Depth H
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.005 -.000**	**+.000 -.005**	**+.010 -.000**	**+.005 -.000**
-450	10.475 ± .060	.275 ± .006	11.025	11.020	10.480	.355	.231
-451	10.975 ± .060		11.525	11.520	10.980	.355	.231
-452	11.475 ± .060		12.025	12.020	11.480	.355	.231
-453	11.975 ± .060		12.525	12.520	11.980	.355	.231
-454	12.475 ± .060		13.025	13.020	12.480	.355	.231
-455	12.975 ± .060		13.525	13.520	12.980	.355	.231
-456	13.475 ± .070		14.025	14.020	13.480	.355	.231
-457	13.975 ± .070		14.525	14.520	13.980	.355	.231
-458	14.475 ± .070		15.025	15.020	14.480	.355	.231
-459	14.975 ± .070		15.525	15.520	14.980	.355	.231
-460	15.475 ± .070		16.025	16.020	15.480	.355	.231
-461	15.955 ± .075		16.505	16.500	15.960	.355	.231
-462	16.455 ± .075		17.005	17.000	16.460	.355	.231
-463	16.955 ± .080		17.505	17.500	16.960	.355	.231
-464	17.455 ± .085		18.005	18.000	17.460	.355	.231
-465	17.955 ± .085		18.505	18.500	17.960	.355	.231
-466	18.455 ± .085		19.005	19.000	18.460	.355	.231
-467	18.955 ± .090		19.505	19.500	18.960	.355	.231
-468	19.455 ± .090		20.005	20.000	19.460	.355	.231
-469	19.955 ± .090		20.505	20.500	19.960	.355	.231
-470	20.955 ± .090		21.505	21.500	20.960	.355	.231
-471	21.955 ± .100		22.505	22.500	21.960	.355	.231
-472	22.940 ± .105		23.490	23.485	22.945	.355	.231
-473	23.940 ± .110		24.490	24.485	23.945	.355	.231
-474	24.940 ± .115		25.490	25.485	24.945	.355	.231
-475	25.940 ± .120		26.490	26.485	25.945	.355	.231

NOTE: O-Ring seal sizes not listed are not recommended for axial seals because the seal ID after installation becomes too small for practical use.



Finishes are RMS values

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases

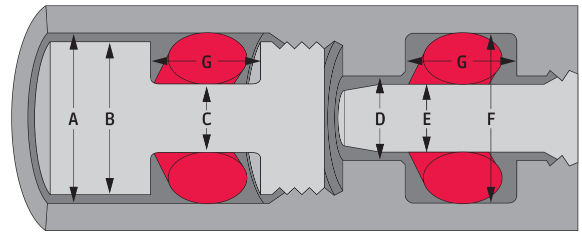


TABLE C Static Radial Seal Gland Dimensions

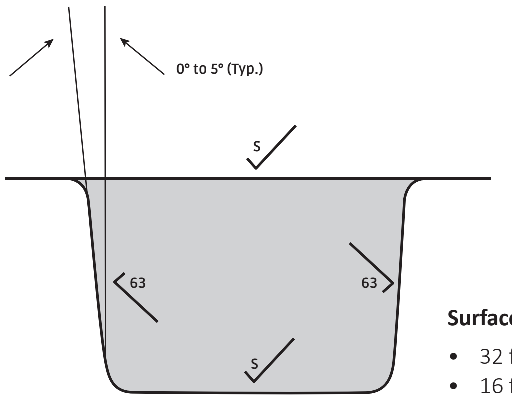
AS568 Number	O-Ring Dimensions				Cylinder Bore Diameter A	Piston Diameter B	Piston Groove Diameter C	Rod Bore Diameter D	Rod Diameter E	Rod Gland Diameter F	Gland Width G
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.003**		**+.002 -.000**	**+.000 -.001**	**+.000 -.001**	**+.002 -.000**	**+.000 -.001**	**+.001 -.000**	**+.010 -.000**
-001	.029	.004	0.040	0.109	.082	.081	.035	.036	.035	.083	.101
-002	.042	.004	0.050	0.142	.115	.114	.048	.049	.048	.116	.101
-003	.056	.004	0.060	0.176	.148	.147	.062	.063	.062	.149	.101
-004	.070	.005	0.070	0.210	.181	.180	.077	.078	.077	.182	.105
-005	.101	.005		0.241	.215	.214	.109	.110	.109	.216	.105
-006	.114	.005		0.254	.229	.228	.122	.123	.122	.230	.105
-007	.145	.005		0.285	.262	.261	.154	.155	.154	.263	.105
-008	.176	.005		0.316	.295	.294	.186	.187	.186	.296	.105
-009	.208	.005		0.348	.326	.325	.218	.219	.218	.327	.105
-010	.239	.005		0.379	.359	.358	.250	.251	.250	.360	.105
-011	.301	.005		0.441	.421	.420	.313	.314	.313	.422	.105
-012	.364	.005		0.504	.486	.485	.377	.378	.377	.487	.105
-013	.426	.005		0.566	.550	.549	.441	.442	.442	.551	.105
-014	.489	.005		0.629	.614	.613	.505	.506	.505	.615	.105
Tolerance			**±0.003**		**+.002 -.000**	**+.000 -.002**	**+.000 -.003**	**+.002 -.000**	**+.000 -.002**	**+.003 -.000**	**+.010 -.000**
-015	.551	.007	0.070	0.691	.680	.679	.572	.572	.571	.679	.105
-016	.614	.009		0.754	.746	.745	.638	.638	.637	.745	.105
-017	.676	.009		0.816	.810	.809	.702	.702	.701	.809	.105
-018	.739	.009		0.879	.874	.873	.766	.766	.765	.873	.105
-019	.801	.009		0.941	.937	.936	.829	.829	.828	.936	.105
-020	.864	.009		1.004	1.000	.999	.893	.893	.892	.999	.105
-021	.926	.009		1.066	1.064	1.063	.957	.957	.956	1.063	.105
-022	.989	.010		1.129	1.129	1.128	1.022	1.022	1.021	1.128	.105
-023	1.051	.010		1.191	1.192	1.191	1.085	1.085	1.084	1.191	.105
-024	1.114	.010		1.254	1.257	1.256	1.149	1.149	1.148	1.256	.105

NOTE: Standard glands are not provided for the larger diameter bore-mounted applications because Diameter F becomes larger than the outside diameter of the O-Ring seal, making the installation of the seal impractical.

TABLE C Static Radial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions				Cylinder Bore Diameter A	Piston Diameter B	Piston Groove Diameter C	Rod Bore Diameter D	Rod Diameter E	Rod Gland Diameter F	Gland Width G
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.003**		**+.002 -.000**	**+.000 -.002**	**+.000 -.003**	**+.002 -.000**	**+.000 -.002**	**+.003 -.000**	**+.010 -.000**
-025	1.176	.011	0.070	1.316	1.321	1.320	1.214	1.214	1.213	1.320	.105
-026	1.239	.011		1.379	1.386	1.385	1.278	1.278	1.277	1.385	.105
-027	1.301	.011		1.441	1.449	1.448	1.341	1.341	1.340	1.448	.105
-028	1.364	.013		1.504	1.515	1.514	1.408	1.408	1.407	1.514	.105
-029	1.489	.013		1.629	1.643	1.642	1.535	1.535	1.534	1.642	.105
-030	1.614	.013		1.754	1.771	1.770	1.663	1.663	1.662	1.770	.105
-031	1.739	.015		1.879	1.900	1.899	1.792	1.791	1.792	1.899	.105
-032	1.864	.015		2.004	2.028	2.027	1.920	1.920	1.919	2.027	.105
-033	1.989	.018		2.129	2.158	2.157	2.050	**	**	**	.105
-034	2.114	.018		2.254	2.286	2.285	2.178	**	**	**	.105
-035	2.239	.018		2.379	2.413	2.412	2.305	**	**	**	.105
-036	2.364	.018		2.504	2.541	2.540	2.433	**	**	**	.105
-037	2.489	.018		2.629	2.668	2.667	2.560	**	**	**	.105
-038	2.614	.020		2.754	2.798	2.797	2.690	**	**	**	.105
-039	2.739	.020		2.879	2.925	2.924	2.817	**	**	**	.105
-040	2.864	.020		3.004	3.053	3.052	2.945	**	**	**	.105
-041	2.989	.024		3.129	3.184	3.183	3.076	**	**	**	.105
-042	3.239	.024		3.379	3.439	3.438	3.331	**	**	**	.105
-043	3.489	.024		3.629	3.694	3.693	3.586	**	**	**	.105
-044	3.739	.027		3.879	3.952	3.951	3.844	**	**	**	.105
-045	3.989	.027		4.129	4.207	4.206	4.099	**	**	**	.105
-046	4.239	.030		4.379	4.465	4.464	4.357	**	**	**	.105
-047	4.489	.030		4.629	4.720	4.719	4.612	**	**	**	.105
-048	4.739	.030		4.879	4.975	4.974	4.867	**	**	**	.105
-049	4.989	.037		5.129	5.238	5.237	5.130	**	**	**	.105
-050	5.239	.037		5.379	5.493	5.492	5.385	**	**	**	.105
Tolerance			**±0.003**		**+.003 -.000**	**+.000 -.002**	**+.000 -.004**	**+.003 -.000**	**+.000 -.002**	**+.003 -.000**	**+.010 -.000**
-102	.049	.005	0.103	0.255	.213	.212	.059	.058	.057	.212	.146
-103	.081	.005		0.287	.251	.250	.092	.091	.090	.250	.146
-104	.112	.005		0.318	.285	.284	.123	.122	.121	.284	.146
-105	.143	.005		0.349	.318	.317	.155	.154	.153	.317	.146
-106	.174	.005		0.380	.350	.349	.187	.186	.185	.349	.146

NOTE: Standard glands are not provided for the larger diameter bore-mounted applications because Diameter F becomes larger than the outside diameter of the O-Ring seal, making the installation of the seal impractical.



Finishes are RMS values

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases

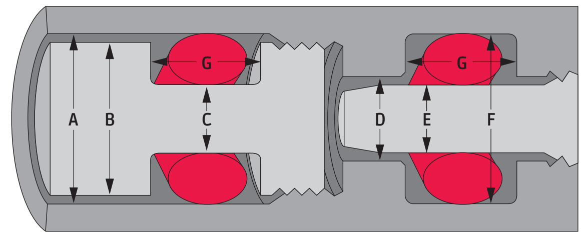


TABLE C Static Radial Seal Gland Dimensions

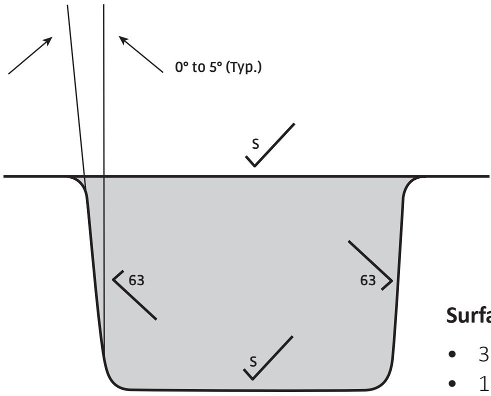
AS568 Number	O-Ring Dimensions				Cylinder Bore Diameter A	Piston Diameter B	Piston Groove Diameter C	Rod Bore Diameter D	Rod Diameter E	Rod Gland Diameter F	Gland Width G
	I.D.	± Tol.	W	(O.D.)							
Tolerance			±0.003		+.003 -.000	+.000 -.002	+.000 -.004	+.003 -.000	+.000 -.002	+.003 -.000	+.010 -.000
-107	.206	.005	0.103	0.412	.382	.381	.219	.218	.217	.381	.146
-108	.237	.005		0.443	.415	.414	.251	.250	.249	.414	.146
-109	.299	.005		0.505	.478	.477	.314	.313	.312	.477	.146
-110	.362	.005		0.568	.541	.540	.378	.377	.376	.540	.146
-111	.424	.005		0.630	.606	.605	.442	.441	.440	.605	.146
-112	.487	.005		0.693	.669	.668	.506	.505	.504	.668	.146
-113	.549	.005		0.755	.734	.733	.571	.570	.569	.733	.146
-114	.612	.009		0.818	.800	.799	.637	.636	.635	.799	.146
-115	.674	.009		0.880	.864	.863	.701	.700	.699	.863	.146
-116	.737	.009		0.943	.929	.928	.765	.764	.763	.928	.146
-117	.799	.010		1.005	.993	.992	.829	.828	.827	.992	.146
-118	.862	.010		1.068	1.056	1.055	.893	.892	.891	1.055	.146
-119	.924	.010		1.130	1.120	1.119	.957	.958	.955	1.119	.146
-120	.987	.010		1.193	1.184	1.183	1.021	1.020	1.019	1.183	.146
-121	1.049	.010		1.255	1.247	1.246	1.084	1.083	1.082	1.246	.146
-122	1.112	.010		1.318	1.311	1.310	1.148	1.147	1.146	1.310	.146
-123	1.174	.012		1.380	1.377	1.376	1.214	1.213	1.212	1.376	.146
-124	1.237	.012		1.443	1.441	1.440	1.278	1.277	1.276	1.440	.146
-125	1.299	.012		1.505	1.504	1.503	1.341	1.340	1.339	1.503	.146
-126	1.362	.012		1.568	1.568	1.567	1.405	1.404	1.403	1.567	.146
-127	1.424	.012		1.630	1.633	1.632	1.469	1.468	1.467	1.632	.146
-128	1.487	.012		1.693	1.696	1.695	1.533	1.532	1.531	1.695	.146
-129	1.549	.015		1.755	1.762	1.761	1.599	1.598	1.597	1.761	.146
-130	1.612	.015		1.818	1.827	1.826	1.664	1.663	1.662	1.826	.146
-131	1.674	.015		1.880	1.890	1.889	1.727	1.726	1.725	1.889	.146
-132	1.737	.015		1.943	1.954	1.953	1.791	1.790	1.789	1.953	.146
-133	1.799	.015		2.005	2.018	2.017	1.854	1.853	1.852	2.017	.146
-134	1.862	.015		2.068	2.083	2.082	1.919	1.918	1.917	2.082	.146
-135	1.925	.017		2.131	2.148	2.147	1.985	1.984	1.983	2.147	.146
-136	1.987	.017		2.193	2.211	2.210	2.048	2.047	2.046	2.210	.146
-137	2.050	.017		2.256	2.276	2.275	2.112	2.111	2.110	2.275	.146

NOTE: Standard glands are not provided for the larger diameter bore-mounted applications because Diameter F becomes larger than the outside diameter of the O-Ring seal, making the installation of the seal impractical.

TABLE C Static Radial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions				Cylinder Bore Diameter A	Piston Diameter B	Piston Groove Diameter C	Rod Bore Diameter D	Rod Diameter E	Rod Gland Diameter F	Gland Width G
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.003**		**+.003 -.000**	**+.000 -.002**	**+.000 -.004**	**+.003 -.000**	**+.000 -.002**	**+.004 -.000**	**+.010 -.000**
-138	2.112	.017	0.103	2.318	2.340	2.339	2.176	2.175	2.174	2.339	.146
-139	2.175	.017		2.381	2.403	2.402	2.240	2.239	2.238	2.402	.146
-140	2.237	.017		2.443	2.466	2.465	2.303	2.302	2.301	2.465	.146
-141	2.300	.020		2.506	2.533	2.532	2.370	2.369	2.368	2.532	.146
-142	2.362	.020		2.568	2.597	2.596	2.434	2.433	2.432	2.596	.146
-143	2.425	.020		2.631	2.662	2.661	2.498	2.497	2.496	2.661	.146
-144	2.487	.020		2.693	2.724	2.723	2.561	2.560	2.559	2.723	.146
-145	2.550	.020		2.756	2.788	2.787	2.625	2.624	2.623	2.787	.146
-146	2.612	.020		2.818	2.852	2.851	2.689	2.688	2.687	2.851	.146
-147	2.675	.022		2.881	2.919	2.918	2.755	2.754	2.753	2.918	.146
-148	2.737	.022		2.943	2.981	2.980	2.818	2.817	2.816	2.980	.146
-149	2.800	.022		3.006	3.045	3.044	2.882	2.881	2.880	3.044	.146
-150	2.862	.022		3.068	3.109	3.108	2.946	2.945	2.944	3.108	.146
-151	2.987	.024		3.193	3.238	3.237	3.075	3.074	3.073	3.237	.146
-152	3.237	.024		3.443	3.493	3.492	3.330	**	**	**	.146
-153	3.487	.024		3.693	3.748	3.747	3.585	**	**	**	.146
-154	3.737	.028		3.943	4.007	4.006	3.844	**	**	**	.146
-155	3.987	.028		4.193	4.262	4.261	4.099	**	**	**	.146
-156	4.237	.030		4.443	4.519	4.518	4.356	**	**	**	.146
-157	4.487	.030		4.693	4.774	4.773	4.611	**	**	**	.146
-158	4.737	.030		4.943	5.029	5.028	4.866	**	**	**	.146
-159	4.987	.035		5.193	5.289	5.288	5.126	**	**	**	.146
-160	5.237	.035		5.443	5.544	5.543	5.381	**	**	**	.146
-161	5.487	.035		5.693	5.799	5.798	5.636	**	**	**	.146
-162	5.737	.035		5.943	6.054	6.053	5.891	**	**	**	.146
-163	5.987	.035		6.193	6.309	6.308	6.146	**	**	**	.146
-164	6.237	.040		6.443	6.570	6.569	6.407	**	**	**	.146
-165	6.487	.040		6.693	6.825	6.824	6.662	**	**	**	.146
-166	6.737	.040		6.943	7.080	7.079	6.917	**	**	**	.146
-167	6.987	.040	▼	7.193	7.335	7.334	7.172	**	**	**	.146

****NOTE:** Standard glands are not provided for the larger diameter bore-mounted applications because Diameter F becomes larger than the outside diameter of the O-Ring seal, making the installation of the seal impractical.



Finishes are RMS values

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases

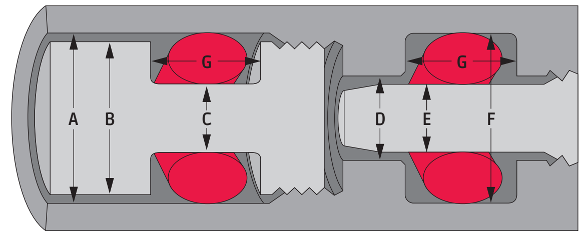


TABLE C Static Radial Seal Gland Dimensions

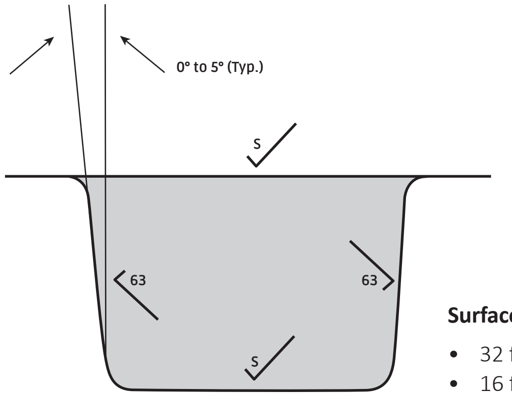
AS568 Number	O-Ring Dimensions				Cylinder Bore Diameter A	Piston Diameter B	Piston Groove Diameter C	Rod Bore Diameter D	Rod Diameter E	Rod Gland Diameter F	Gland Width G
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.003**		**+.003 -.000**	**+.000 -.002**	**+.000 -.004**	**+.003 -.000**	**+.000 -.002**	**+.004 -.000**	**+.010 -.000**
-168	7.237	.045	0.103	7.443	7.596	7.594	7.432	**	**	**	.146
-169	7.487	.045		6.693	7.850	7.849	7.687	**	**	**	.146
-170	7.737	.045		7.943	8.105	8.104	7.942	**	**	**	.146
-171	7.987	.045		8.193	8.360	8.359	8.197	**	**	**	.146
-172	8.237	.050		8.443	8.620	8.619	8.457	**	**	**	.146
-173	8.487	.050		8.693	8.875	8.874	8.712	**	**	**	.146
-174	8.737	.050		8.943	9.130	9.129	8.967	**	**	**	.146
-175	8.987	.050		9.193	9.385	9.384	9.222	**	**	**	.146
-176	9.237	.055		9.443	9.645	9.644	9.482	**	**	**	.146
-177	9.487	.055		9.693	9.900	9.899	9.737	**	**	**	.146
-178	9.737	.055		9.943	10.155	10.154	9.992	**	**	**	.146
Tolerance			**±0.004**		**+.003 -.000**	**+.000 -.003**	**+.000 -.006**	**+.003 -.000**	**+.000 -.003**	**+.006 -.000**	**+.010 -.000**
-201	0.171	.005	0.139	0.449	.408	.406	.186	.185	.183	.405	.195
-202	0.234	.005		0.512	.472	.470	.250	.249	.247	.469	.195
-203	0.296	.005		0.574	.534	.532	.313	.312	.310	.531	.195
-204	0.359	.005		0.637	.599	.597	.377	.376	.374	.596	.195
-205	0.421	.005		0.699	.663	.661	.441	.440	.438	.660	.195
-206	0.484	.005		0.762	.726	.724	.505	.504	.502	.723	.195
-207	0.546	.007		0.824	.792	.790	.570	.569	.567	.789	.195
-208	0.609	.009		0.887	.858	.856	.636	.635	.633	.855	.195
-209	0.671	.009		0.949	.921	.919	.700	.699	.697	.918	.195
-210	0.734	.010		1.012	.986	.984	.765	.764	.762	.983	.195
-211	0.796	.010		1.074	1.050	1.048	.828	.827	.825	1.047	.195
-212	0.859	.010		1.137	1.114	1.112	.892	.891	.889	1.111	.195
-213	0.921	.010		1.199	1.177	1.175	.956	.955	.953	1.174	.195
-214	0.984	.010		1.262	1.242	1.240	1.020	1.019	1.017	1.239	.195
-215	1.046	.010		1.324	1.305	1.303	1.083	1.082	1.080	1.302	.195

****NOTE:** Standard glands are not provided for the larger diameter bore-mounted applications because Diameter F becomes larger than the outside diameter of the O-Ring seal, making the installation of the seal impractical.

TABLE C Static Radial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions				Cylinder Bore Diameter A	Piston Diameter B	Piston Groove Diameter C	Rod Bore Diameter D	Rod Diameter E	Rod Gland Diameter F	Gland Width G
	I.D.	± Tol.	W	(O.D.)							
Tolerance			±0.004		+.003 -.000	+.000 -.003	+.000 -.006	+.003 -.000	+.000 -.003	+.006 -.000	+.010 -.000
-216	1.109	.012	0.139	1.387	1.370	1.368	1.149	1.148	1.146	1.367	.195
-217	1.171	.012		1.449	1.435	1.433	1.213	1.212	1.210	1.432	.195
-218	1.234	.012		1.512	1.499	1.497	1.277	1.276	1.274	1.496	.195
-219	1.296	.012		1.574	1.562	1.560	1.340	1.339	1.337	1.559	.195
-220	1.359	.012		1.637	1.626	1.624	1.404	1.403	1.401	1.623	.195
-221	1.421	.012		1.699	1.690	1.688	1.468	1.467	1.465	1.687	.195
-222	1.484	.015		1.762	1.757	1.755	1.535	1.534	1.532	1.754	.195
-223	1.609	.015		1.887	1.884	1.882	1.662	1.661	1.659	1.881	.195
-224	1.734	.015		2.012	2.012	2.010	1.790	1.789	1.787	2.009	.195
-225	1.859	.018		2.137	2.143	2.141	1.921	1.920	1.918	2.140	.195
-226	1.984	.018		2.262	2.270	2.268	2.048	2.047	2.045	2.267	.195
-227	2.109	.018		2.387	2.398	2.396	2.176	2.175	2.173	2.395	.195
-228	2.234	.020		2.512	2.527	2.525	2.305	2.304	2.302	2.524	.195
-229	2.359	.020		2.637	2.655	2.653	2.433	2.432	2.430	2.652	.195
-230	2.484	.020		2.762	2.781	2.779	2.560	2.559	2.557	2.778	.195
-231	2.609	.020		2.887	2.909	2.907	2.688	2.687	2.685	2.906	.195
-232	2.734	.024		3.012	3.041	3.039	2.819	2.818	2.816	3.038	.195
-233	2.859	.024		3.137	3.169	3.167	2.947	2.946	2.944	3.166	.195
-234	2.984	.024		3.262	3.296	3.293	3.074	3.073	3.071	3.292	.195
-235	3.109	.024		3.387	3.423	3.421	3.202	3.201	3.199	3.420	.195
-236	3.234	.024		3.512	3.551	3.549	3.329	3.328	3.326	3.548	.195
-237	3.359	.024		3.637	3.679	3.677	3.457	3.456	3.454	3.678	.195
-238	3.484	.024		3.762	3.806	3.804	3.584	3.583	3.581	3.803	.195
-239	3.609	.028		3.887	3.937	3.935	3.716	3.715	3.713	3.934	.195
-240	3.734	.028		4.012	4.065	4.063	3.843	3.842	3.840	4.062	.195
-241	3.859	.028		4.137	4.193	4.191	3.971	3.970	3.968	4.190	.195
-242	3.984	.028		4.262	4.320	4.318	4.098	4.097	4.095	4.317	.195
-243	4.109	.028		4.387	4.448	4.446	4.226	4.225	4.223	4.445	.195
-244	4.234	.030		4.512	4.577	4.575	4.355	4.354	4.352	4.574	.195
-245	4.359	.030	▼	4.637	4.705	4.703	4.483	**	**	**	.195

NOTE: Standard glands are not provided for the larger diameter bore-mounted applications because Diameter F becomes larger than the outside diameter of the O-Ring seal, making the installation of the seal impractical.



Finishes are RMS values

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases

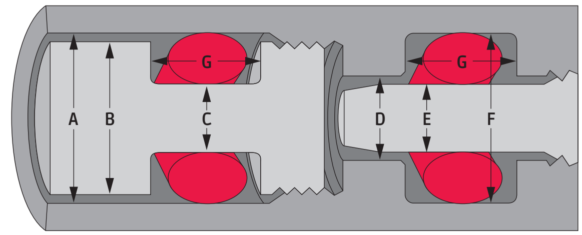


TABLE C Static Radial Seal Gland Dimensions

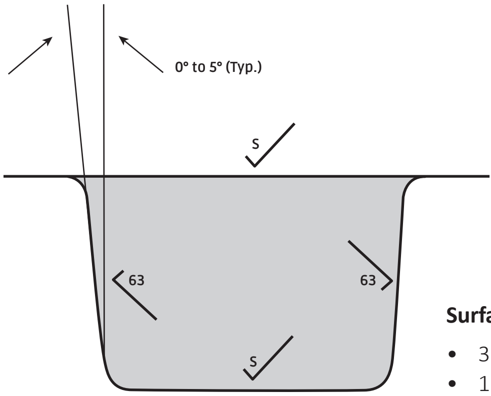
AS568 Number	O-Ring Dimensions				Cylinder Bore Diameter A	Piston Diameter B	Piston Groove Diameter C	Rod Bore Diameter D	Rod Diameter E	Rod Gland Diameter F	Gland Width G
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.004**		**+.003 -.000**	**+.000 -.003**	**+.000 -.006**	**+.003 -.000**	**+.000 -.003**	**+.006 -.000**	**+.010 -.000**
-246	4.484	.030	0.139	4.762	4.832	4.830	4.610	**	**	**	.195
-247	4.609	.030		4.887	4.960	4.958	4.738	**	**	**	.195
-248	4.734	.030		5.012	5.087	5.085	4.865	**	**	**	.195
-249	4.859	.035		5.137	5.220	5.218	4.998	**	**	**	.195
-250	4.984	.035		5.262	5.347	5.345	5.125	**	**	**	.195
-251	5.109	.035		5.387	5.475	5.473	5.253	**	**	**	.195
-252	5.234	.035		5.512	5.602	5.600	5.380	**	**	**	.195
-253	5.359	.035		5.637	5.730	5.728	5.508	**	**	**	.195
-254	5.484	.035		5.762	5.857	5.855	5.635	**	**	**	.195
-255	5.609	.035		5.887	5.985	5.983	5.763	**	**	**	.195
-256	5.734	.035		6.012	6.112	6.110	5.890	**	**	**	.195
-257	5.859	.035		6.137	6.240	6.238	6.018	**	**	**	.195
-258	5.984	.035		6.262	6.367	6.365	6.145	**	**	**	.195
-259	6.234	.040		6.512	6.627	6.625	6.405	**	**	**	.195
-260	6.484	.040		6.762	6.882	6.880	6.660	**	**	**	.195
-261	6.734	.040		7.012	7.137	7.135	6.915	**	**	**	.195
-262	6.984	.040		7.262	7.392	7.390	7.170	**	**	**	.195
-263	7.234	.045		7.512	7.653	7.651	7.431	**	**	**	.195
-264	7.484	.045		7.762	7.908	7.906	7.686	**	**	**	.195
-265	7.734	.045		8.012	8.163	8.161	7.941	**	**	**	.195
-266	7.984	.045		8.262	8.418	8.416	8.196	**	**	**	.195
-267	8.234	.050		8.512	8.678	8.676	8.456	**	**	**	.195
-268	8.484	.050		8.762	8.933	8.931	8.711	**	**	**	.195
-269	8.734	.050		9.012	9.188	9.186	8.966	**	**	**	.195
-270	8.984	.050		9.262	9.442	9.440	9.221	**	**	**	.195
-271	9.234	.055		9.512	9.703	9.701	9.481	**	**	**	.195
-272	9.484	.055		9.762	9.958	9.956	9.736	**	**	**	.195
-273	9.734	.055		10.012	10.213	10.211	9.991	**	**	**	.195
-274	9.984	.055		10.262	10.467	10.465	10.246	**	**	**	.195
-275	10.484	.055		10.762	10.977	10.975	10.756	**	**	**	.195

****NOTE:** Standard glands are not provided for the larger diameter bore-mounted applications because Diameter F becomes larger than the outside diameter of the O-Ring seal, making the installation of the seal impractical.

TABLE C Static Radial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions				Cylinder Bore Diameter A	Piston Diameter B	Piston Groove Diameter C	Rod Bore Diameter D	Rod Diameter E	Rod Gland Diameter F	Gland Width G
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.004**		**+.003 -.000**	**+.000 -.003**	**+.000 -.006**	**+.003 -.000**	**+.000 -.003**	**+.006 -.000**	**+.010 -.000**
-276	10.984	.065	0.139	11.262	11.498	11.496	11.276	**	**	**	.195
-277	11.484	.065		11.762	12.008	12.006	11.786	**	**	**	.195
-278	11.984	.065		12.262	12.517	12.515	12.296	**	**	**	.195
-279	12.984	.065		13.262	13.537	13.535	13.316	**	**	**	.195
-280	13.984	.065		14.262	14.558	14.556	14.336	**	**	**	.195
-281	14.984	.065		15.262	15.578	15.576	15.356	**	**	**	.195
-282	15.955	.075		16.233	16.578	16.576	16.357	**	**	**	.195
-283	16.955	.080		17.233	17.603	17.601	17.382	**	**	**	.195
-284	17.955	.085		18.233	18.628	18.626	18.407	**	**	**	.195
Tolerance			**±0.005**		**+.003 -.000**	**+.000 -.003**	**+.000 -.008**	**+.003 -.000**	**+.000 -.003**	**+.008 -.000**	**+.010 -.000**
-309	0.412	.005	0.210	0.832	.778	.775	.433	.431	.428	.773	.280
-310	0.475	.005		0.895	.843	.840	.498	.496	.493	.838	.280
-311	0.537	.007		0.957	.908	.905	.563	.561	.558	.903	.280
-312	0.600	.009		1.020	.973	.970	.629	.627	.624	.968	.280
-313	0.662	.009		1.082	1.037	1.034	.692	.690	.687	1.032	.280
-314	0.725	.010		1.145	1.103	1.100	.758	.756	.753	1.098	.280
-315	0.787	.010		1.207	1.165	1.162	.821	.819	.816	1.160	.280
-316	0.850	.010		1.270	1.230	1.227	.885	.883	.880	1.225	.280
-317	0.912	.010		1.332	1.292	1.289	.948	.946	.943	1.287	.280
-318	0.975	.010		1.395	1.358	1.355	1.013	1.011	1.008	1.353	.280
-319	1.037	.010		1.457	1.421	1.418	1.076	1.074	1.071	1.416	.280
-320	1.100	.012		1.520	1.487	1.484	1.142	1.140	1.137	1.482	.280
-321	1.162	.012		1.582	1.550	1.547	1.205	1.203	1.200	1.545	.280
-322	1.225	.012		1.645	1.615	1.612	1.270	1.268	1.265	1.610	.280
-323	1.287	.012		1.707	1.678	1.675	1.333	1.331	1.328	1.673	.280
-324	1.350	.012		1.770	1.741	1.738	1.397	1.395	1.392	1.736	.280
-325	1.475	.015		1.895	1.873	1.870	1.528	1.526	1.523	1.868	.280
-326	1.600	.015		2.020	2.000	1.997	1.655	1.653	1.650	1.995	.280
-327	1.725	.015		2.145	2.127	2.124	1.783	1.781	1.778	2.122	.280
-328	1.850	.015		2.270	2.255	2.252	1.910	1.908	1.905	2.250	.280

****NOTE:** Standard glands are not provided for the larger diameter bore-mounted applications because Diameter F becomes larger than the outside diameter of the O-Ring seal, making the installation of the seal impractical.



Finishes are RMS values

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases

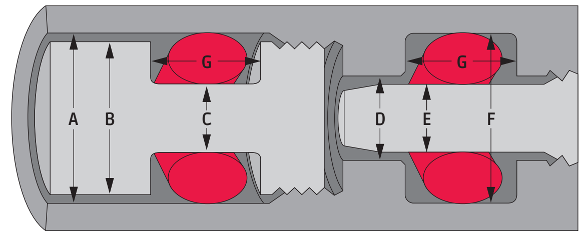


TABLE C Static Radial Seal Gland Dimensions

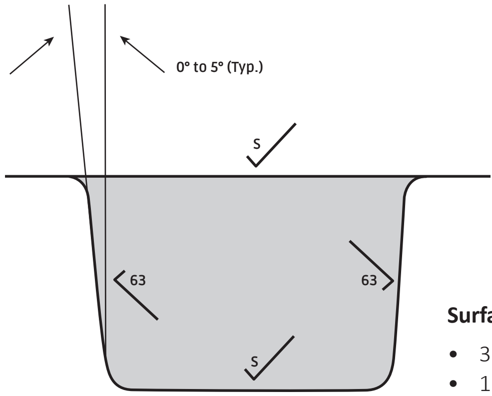
AS568 Number	O-Ring Dimensions				Cylinder Bore Diameter A	Piston Diameter B	Piston Groove Diameter C	Rod Bore Diameter D	Rod Diameter E	Rod Gland Diameter F	Gland Width G
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.005**		**+.003 -.000**	**+.000 -.003**	**+.000 -.008**	**+.003 -.000**	**+.000 -.003**	**+.008 -.000**	**+.010 -.000**
-329	1.975	.018	0.210	2.395	2.386	2.383	2.041	2.039	2.036	2.381	.280
-330	2.100	.018		2.520	2.513	2.510	2.168	2.166	2.163	2.508	.280
-331	2.225	.018		2.645	2.641	2.638	2.296	2.294	2.291	2.636	.280
-332	2.350	.018		2.770	2.768	2.765	2.423	2.421	2.418	2.763	.280
-333	2.475	.020		2.895	2.898	2.895	2.553	2.551	2.548	2.893	.280
-334	2.600	.020		3.020	3.025	3.022	2.680	2.678	2.675	3.020	.280
-335	2.725	.020		3.145	3.153	3.150	2.808	2.806	2.803	3.148	.280
-336	2.850	.020		3.270	3.279	3.276	2.935	2.933	2.930	3.274	.280
-337	2.975	.024		3.395	3.412	3.409	3.067	3.065	3.062	3.407	.280
-338	3.100	.024		3.520	3.539	3.536	3.194	3.192	3.189	3.534	.280
-339	3.225	.024		3.645	3.667	3.664	3.322	3.320	3.317	3.662	.280
-340	3.350	.024		3.770	3.794	3.791	3.449	3.447	3.444	3.789	.280
-341	3.475	.024		3.895	3.921	3.918	3.577	3.575	3.572	3.916	.280
-342	3.600	.028		4.020	4.054	4.051	3.709	3.707	3.704	4.049	.280
-343	3.725	.028		4.145	4.181	4.178	3.836	3.834	3.831	4.176	.280
-344	3.850	.028		4.270	4.309	4.306	3.964	3.962	3.959	4.304	.280
-345	3.975	.028		4.395	4.436	4.433	4.091	4.089	4.086	4.431	.280
-346	4.100	.028		4.520	4.563	4.560	4.219	4.217	4.214	4.558	.280
-347	4.225	.030		4.645	4.693	4.690	4.348	4.346	4.343	4.688	.280
-348	4.350	.030		4.770	4.820	4.817	4.476	4.474	4.471	4.815	.280
-349	4.475	.030		4.895	4.948	4.945	4.603	4.601	4.598	4.943	.280
-350	4.600	.030		5.020	5.076	5.073	4.731	4.729	4.726	5.071	.280
-351	4.725	.030		5.145	5.203	5.200	4.858	4.856	4.853	5.198	.280
-352	4.850	.030		5.270	5.331	5.328	4.986	4.984	4.981	5.326	.280
-353	4.975	.037		5.395	5.465	5.462	5.120	5.118	5.115	5.460	.280
-354	5.100	.037		5.520	5.593	5.590	5.248	5.246	5.243	5.588	.280
-355	5.225	.037		5.645	5.720	5.717	5.375	5.373	5.370	5.715	.280
-356	5.350	.037		5.770	5.847	5.844	5.503	5.501	5.498	5.842	.280
-357	5.475	.037		5.895	5.975	5.972	5.630	5.628	5.625	5.970	.280
-358	5.600	.037		6.020	6.103	6.100	5.758	5.756	5.753	6.098	.280

NOTE: Standard glands are not provided for the larger diameter bore-mounted applications because Diameter F becomes larger than the outside diameter of the O-Ring seal, making the installation of the seal impractical.

TABLE C Static Radial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions				Cylinder Bore Diameter A	Piston Diameter B	Piston Groove Diameter C	Rod Bore Diameter D	Rod Diameter E	Rod Gland Diameter F	Gland Width G
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.005**		**+.003 -.000**	**+.000 -.003**	**+.000 -.008**	**+.003 -.000**	**+.000 -.003**	**+.008 -.000**	**+.010 -.000**
-359	5.725	.037	0.210	6.145	6.230	6.227	5.885	5.883	5.880	6.225	.280
-360	5.850	.037		6.270	6.358	6.355	6.013	6.011	6.008	6.353	.280
-361	5.975	.037		6.395	6.485	6.482	6.140	6.138	6.135	6.480	.280
-362	6.225	.040		6.645	6.743	6.740	6.398	6.396	6.393	6.738	.280
-363	6.475	.040		6.895	6.998	6.995	6.653	6.651	6.648	6.993	.280
-364	6.725	.040		7.145	7.253	7.250	6.908	6.906	6.903	7.248	.280
-365	6.975	.040		7.395	7.508	7.505	7.163	7.161	7.158	7.503	.280
-366	7.225	.045		7.645	7.768	7.765	7.423	7.421	7.418	7.763	.280
-367	7.475	.045		7.895	8.023	8.020	7.678	7.676	7.673	8.018	.280
-368	7.725	.045		8.145	8.278	8.275	7.933	7.931	7.928	8.273	.280
-369	7.975	.045		8.395	8.533	8.530	8.188	8.186	8.183	8.528	.280
-370	8.225	.050		8.645	8.794	8.791	8.449	8.447	8.444	8.789	.280
-371	8.475	.050		8.895	9.049	9.046	8.704	**	**	**	.280
-372	8.725	.050		9.145	9.304	9.301	8.959	**	**	**	.280
-373	8.975	.050		9.395	9.559	9.556	9.214	**	**	**	.280
-374	9.225	.055		9.645	9.819	9.816	9.474	**	**	**	.280
-375	9.475	.055		9.895	10.074	10.071	9.729	**	**	**	.280
-376	9.725	.055		10.145	10.329	10.326	9.984	**	**	**	.280
-377	9.975	.055		10.395	10.584	10.581	10.239	**	**	**	.280
-378	10.475	.060		10.895	11.099	11.096	10.754	**	**	**	.280
-379	10.975	.060		11.395	11.609	11.606	11.264	**	**	**	.280
-380	11.475	.065		11.895	12.124	12.121	11.779	**	**	**	.280
-381	11.975	.065		12.395	12.634	12.631	12.289	**	**	**	.280
-382	12.975	.065		13.395	13.654	13.651	13.309	**	**	**	.280
-383	13.975	.070		14.395	14.679	14.676	14.334	**	**	**	.280
-384	14.975	.070		15.395	15.699	15.696	15.354	**	**	**	.280
-385	15.955	.075		16.375	16.703	16.700	16.359	**	**	**	.280
-386	16.955	.080	▼	17.375	17.728	17.725	17.384	**	**	**	.280

****NOTE:** Standard glands are not provided for the larger diameter bore-mounted applications because Diameter F becomes larger than the outside diameter of the O-Ring seal, making the installation of the seal impractical.



Finishes are RMS values

Surface finish (S):

- 32 for liquids
- 16 for vacuum and gases

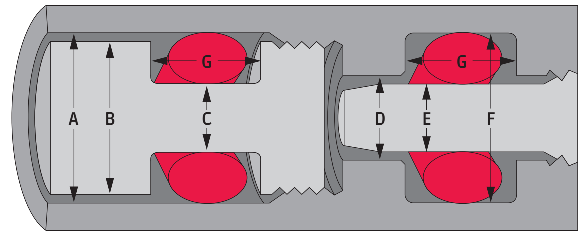


TABLE C Static Radial Seal Gland Dimensions

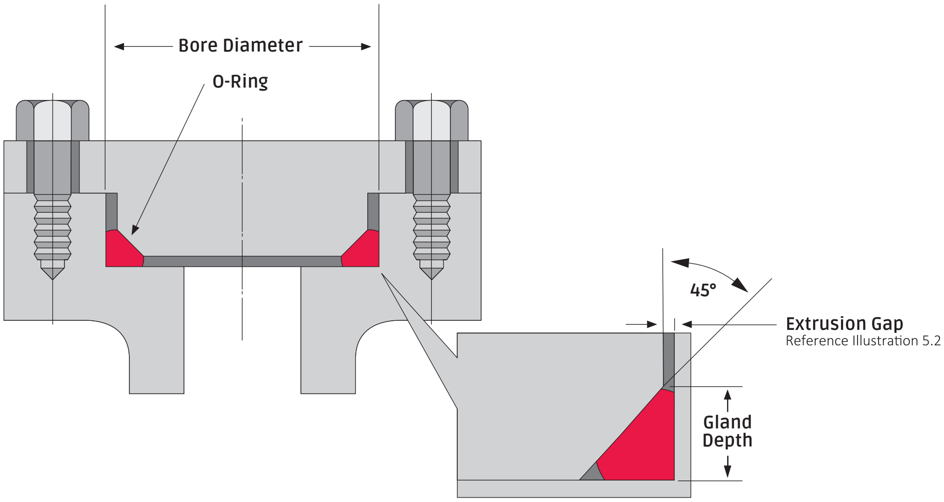
AS568 Number	O-Ring Dimensions I.D.	± Tol.	W	(O.D.)	Cylinder Bore Diameter A	Piston Diameter B	Piston Groove Diameter C	Rod Bore Diameter D	Rod Diameter E	Rod Gland Diameter F	Gland Width G
Tolerance			**±0.005**		**+.003 -.000**	**+.000 -.003**	**+.000 -.008**	**+.004 -.000**	**+.000 -.003**	**+.010 -.000**	**+.010 -.000**
-387	17.955	.085	0.210	18.375	18.753	18.750	18.409	**	**	**	.280
-388	18.955	.090		19.375	19.778	19.775	19.434	**	**	**	.280
-389	19.955	.095		20.375	20.803	20.800	20.459	**	**	**	.280
-390	20.955	.095		21.375	21.824	21.821	21.479	**	**	**	.280
-391	21.955	.100		22.375	22.849	22.846	22.504	**	**	**	.280
-392	22.940	.105		23.360	23.859	23.856	23.514	**	**	**	.280
-393	23.940	.110		24.360	24.884	24.881	24.539	**	**	**	.280
-394	24.940	.115		25.360	25.909	25.906	25.564	**	**	**	.280
-395	25.940	.120		26.360	26.934	26.931	26.589	**	**	**	.280
Tolerance			**±0.006**		**+.004 -.000**	**+.000 -.003**	**+.000 -.010**	**+.004 -.000**	**+.000 -.003**	**+.010 -.000**	**+.010 -.000**
-425	4.475	.033	0.275	5.025	5.065	5.061	4.608	4.606	4.601	5.059	.350
-426	4.600	.033		5.150	5.193	5.189	4.736	4.734	4.729	5.187	.350
-427	4.725	.033		5.275	5.321	5.317	4.863	4.861	4.856	5.315	.350
-428	4.850	.033		5.400	5.449	5.445	4.991	4.989	4.984	5.443	.350
-429	4.975	.037		5.525	5.579	5.575	5.122	5.120	5.115	5.573	.350
-430	5.100	.037		5.650	5.707	5.703	5.250	5.248	5.243	5.701	.350
-431	5.225	.037		5.775	5.835	5.831	5.377	5.375	5.370	5.829	.350
-432	5.350	.037		5.900	5.963	5.959	5.505	5.503	5.498	5.957	.350
-433	5.475	.037		6.025	6.090	6.086	5.632	5.630	5.625	6.084	.350
-434	5.600	.037		6.150	6.218	6.214	5.760	5.758	5.753	6.212	.350
-435	5.725	.037		6.275	6.344	6.340	5.887	5.885	5.880	6.338	.350
-436	5.850	.037		6.400	6.472	6.468	6.015	6.013	6.008	6.466	.350
-437	5.975	.037		6.525	6.599	6.595	6.142	6.140	6.135	6.593	.350
-438	6.225	.040		6.775	6.857	6.853	6.400	6.398	6.393	6.851	.350
-439	6.475	.040		7.025	7.112	7.108	6.655	6.653	6.648	7.106	.350
-440	6.725	.040		7.275	7.367	7.363	6.910	6.908	6.903	7.361	.350
-441	6.975	.040		7.525	7.623	7.619	7.165	7.163	7.158	7.617	.350
-442	7.225	.045		7.775	7.882	7.878	7.425	7.423	7.418	7.876	.350
-443	7.475	.045		8.025	8.137	8.133	7.680	7.678	7.673	8.131	.350
-444	7.725	.045		8.275	8.392	8.388	7.935	7.933	7.928	8.386	.350

****NOTE:** Standard glands are not provided for the larger diameter bore-mounted applications because Diameter F becomes larger than the outside diameter of the O-Ring seal, making the installation of the seal impractical.

TABLE C Static Radial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions				Cylinder Bore Diameter A	Piston Diameter B	Piston Groove Diameter C	Rod Bore Diameter D	Rod Diameter E	Rod Gland Diameter F	Gland Width G
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.006**		**+.004 -.000**	**+.000 -.003**	**+.000 -.010**	**+.004 -.000**	**+.000 -.003**	**+.010 -.000**	**+.010 -.000**
-445	7.975	.045	0.275	8.525	8.648	8.644	8.190	8.188	8.183	8.642	.350
-446	8.475	.055		9.025	9.168	9.164	8.711	8.709	8.704	9.162	.350
-447	8.975	.055		9.525	9.678	9.674	9.221	9.219	9.214	9.672	.350
-448	9.475	.055		10.025	10.188	10.184	9.731	**	**	**	.350
-449	9.975	.055		10.525	10.699	10.695	10.241	**	**	**	.350
-450	10.475	.060		11.025	11.213	11.209	10.756	**	**	**	.350
-451	10.975	.060		11.525	11.724	11.720	11.266	**	**	**	.350
-452	11.475	.060		12.025	12.233	12.229	11.776	**	**	**	.350
-453	11.975	.060		12.525	12.743	12.739	12.286	**	**	**	.350
-454	12.475	.060		13.025	13.253	13.249	12.796	**	**	**	.350
-455	12.975	.060		13.525	13.763	13.759	13.306	**	**	**	.350
-456	13.475	.070		14.025	14.283	14.279	13.826	**	**	**	.350
-457	13.975	.070		14.525	14.793	14.789	14.336	**	**	**	.350
-458	14.475	.070		15.025	15.303	15.299	14.846	**	**	**	.350
-459	14.975	.070		15.525	15.813	15.809	15.356	**	**	**	.350
-460	15.475	.070		16.025	16.323	16.319	15.866	**	**	**	.350
-461	15.955	.075		16.505	16.818	16.814	16.361	**	**	**	.350
-462	16.455	.075		17.005	17.328	17.324	16.871	**	**	**	.350
-463	16.955	.080		17.505	17.843	17.839	17.386	**	**	**	.350
-464	17.455	.085		18.005	18.358	18.354	17.901	**	**	**	.350
-465	17.955	.085		18.505	18.868	18.864	18.411	**	**	**	.350
-466	18.455	.085		19.005	19.378	19.374	18.921	**	**	**	.350
-467	18.955	.090		19.505	19.893	19.889	19.436	**	**	**	.350
-468	19.455	.090		20.005	20.403	20.399	19.946	**	**	**	.350
-469	19.955	.090		20.505	20.918	20.914	20.461	**	**	**	.350
-470	20.955	.090		21.505	21.938	21.934	21.481	**	**	**	.350
-471	21.955	.100		22.505	22.963	22.959	22.506	**	**	**	.350
-472	22.940	.105		23.490	23.973	23.969	23.516	**	**	**	.350
-473	23.940	.110		24.490	24.998	24.994	24.541	**	**	**	.350
-474	24.940	.115		25.490	26.023	26.019	25.566	**	**	**	.350
-475	25.940	.120		26.490	27.048	27.044	26.591	**	**	**	.350

****NOTE:** Standard glands are not provided for the larger diameter bore-mounted applications because Diameter F becomes larger than the outside diameter of the O-Ring seal, making the installation of the seal impractical.



- Bore Diameter should be 0% to 5% smaller than the nominal O-ring OD
- O-ring volume is typically 90% to 95% of gland void

TABLE D Static Crush Seal Gland Dimensions (for Triangular Grooves)

AS568 Number	O-Ring Cross Section				Gland Depth			
	In.	±	mm	±	In.	-.000 +	mm	-.000 +
004-050	.070	.003	1.78	.08	.095	.003	2.41	.08
102-178	.103	.003	2.62	.08	.137	.005	3.48	.13
201-284	.139	.004	3.53	.10	.186	.007	4.72	.18
309-395	.210	.005	5.33	.13	.279	.010	7.08	.25
425-475	.275	.006	6.99	.15	.371	.015	9.42	.38

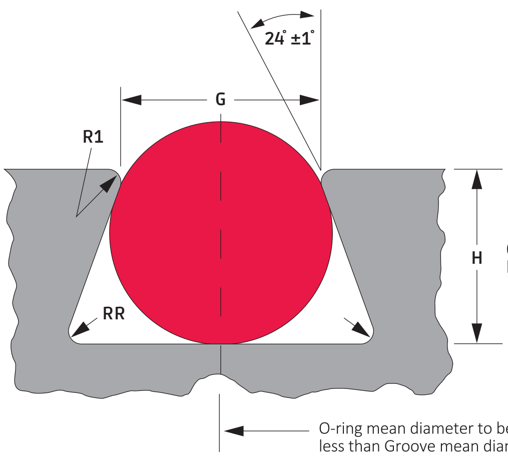
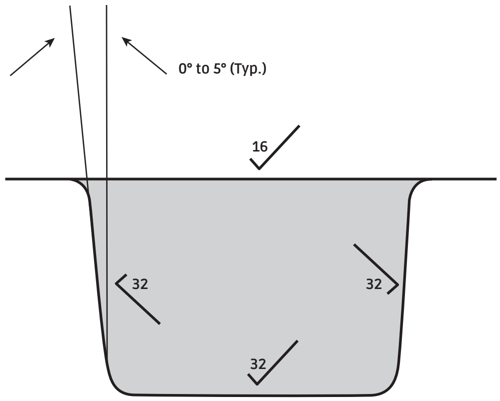


TABLE E Dovetail Gland Dimensions

AS568 Number	O-Ring Cross Section				G Groove Width				H Groove Depth		R, Radius		R, Radius	
					Sharp Edge		Rounded Edge							
	In.	±	mm	±	In. ±.002	mm ±.05	In. ±.002	mm ±.05	In. +.000 -.002	mm +.00 -.05	In.	mm	In.	mm
004- 050	.070	.003	1.78	.08	.057	1.45	.063	1.60	.052	1.32	.005	.13	1/64	.40
102- 178	.103	.003	2.62	.08	.085	2.16	.090	2.29	.083	2.11	.010	.25	1/64	.40
201- 284	.139	.004	3.53	.10	.115	2.92	.120	3.05	.115	2.92	.010	.25	1/32	.79
309- 395	.210	.005	5.33	.13	.160	4.06	.170	4.32	.180	4.57	.015	.38	1/32	.79
425- 475	.275	.006	6.99	.15	.220	5.59	.235	5.97	.234	5.94	.015	.38	1/16	1.59

TABLE F Dynamic Radial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions				A Cylinder Bore Dia.	B Piston Diameter	C Piston Gland Dia.	D Rod Bore Diameter	E Rod Diameter	F Gland Diameter	G Gland Width
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.003**		**+.001 -.000**	**+.000 -.001**	**+.000 -.001**	**+.001 -.000**	**+.000 -.001**	**+.001 -.000**	**+.010 -.000**
-006	0.114	0.005	0.070	0.254	0.230	0.229	0.121	0.123	0.121	0.230	0.100
-007	0.145	0.005		0.285	0.262	0.261	0.152	0.154	0.152	0.262	
-008	0.176	0.005		0.316	0.294	0.293	0.183	0.185	0.183	0.294	
-009	0.208	0.005		0.348	0.326	0.325	0.215	0.217	0.215	0.326	
-010	0.239	0.005		0.379	0.358	0.357	0.246	0.248	0.246	0.358	
-011	0.301	0.005		0.441	0.421	0.420	0.308	0.310	0.308	0.421	
-012	0.364	0.005		0.504	0.484	0.483	0.371	0.373	0.371	0.484	
-013	0.426	0.005		0.566	0.546	0.545	0.433	0.435	0.433	0.546	
-014	0.489	0.005		0.629	0.609	0.608	0.496	0.498	0.496	0.609	
Tolerance			**±0.003**		**+.002 -.000**	**+.000 -.001**	**+.000 -.002**	**+.002 -.000**	**+.000 -.002**	**+.002 -.000**	**+.010 -.000**
-015	0.551	0.007	0.070	0.691	0.672	0.671	0.561	0.562	0.561	0.672	0.100
-016	0.614	0.009		0.754	0.736	0.735	0.626	0.627	0.626	0.736	
-017	0.676	0.009		0.816	0.798	0.797	0.688	0.689	0.688	0.798	
-018	0.739	0.009		0.879	0.862	0.861	0.751	0.752	0.751	0.862	
-019	0.801	0.009		0.941	0.925	0.924	0.814	0.815	0.814	0.925	
-020	0.864	0.009		1.004	0.988	0.987	0.877	0.878	0.877	0.988	
Tolerance			**±0.003**		**+.002 -.000**	**+.000 -.002**	**+.000 -.002**	**+.002 -.000**	**+.000 -.002**	**+.002 -.000**	**+.010 -.000**
-106	0.174	0.005	0.103	0.380	0.351	0.350	0.182	0.184	0.182	0.351	0.135
-107	0.206	0.005		0.412	0.384	0.383	0.214	0.216	0.214	0.384	
-108	0.237	0.005		0.443	0.415	0.414	0.245	0.247	0.245	0.415	
-109	0.299	0.005		0.505	0.479	0.478	0.307	0.309	0.307	0.479	
-110	0.362	0.005		0.568	0.542	0.541	0.370	0.372	0.370	0.542	
-111	0.424	0.005		0.630	0.605	0.604	0.432	0.434	0.432	0.605	



Finishes are RMS values

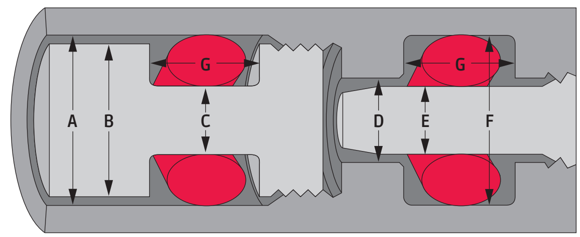
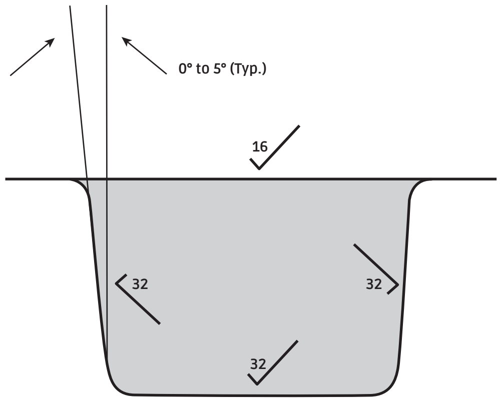


TABLE F Dynamic Radial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions				A Cylinder Bore Dia.	B Piston Diameter	C Piston Gland Dia.	D Rod Bore Diameter	E Rod Diameter	F Gland Diameter	G Gland Width
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.003**		**+.002 -.000**	**+.000 -.001**	**+.000 -.002**	**+.002 -.000**	**+.000 -.002**	**+.002 -.000**	**+.010 -.000**
-112	0.487	0.005	0.103	0.693	0.668	0.667	0.495	0.497	0.495	0.668	0.135
-113	0.549	0.005		0.755	0.732	0.731	0.559	0.561	0.559	0.732	
-114	0.612	0.009		0.818	0.796	0.795	0.624	0.626	0.624	0.796	
-115	0.674	0.009		0.880	0.859	0.858	0.686	0.688	0.686	0.859	
-116	0.737	0.009		0.943	0.922	0.921	0.749	0.751	0.749	0.922	
-117	0.799	0.010		1.005	0.986	0.985	0.813	0.815	0.813	0.986	
-118	0.862	0.010		1.068	1.049	1.048	0.876	0.878	0.876	1.049	
-119	0.924	0.010		1.130	1.110	1.109	0.938	0.940	0.938	1.110	
-120	0.987	0.010		1.193	1.174	1.173	1.001	1.003	1.001	1.174	
-121	1.049	0.010		1.255	1.236	1.235	1.063	1.065	1.063	1.236	
-122	1.112	0.010		1.318	1.299	1.298	1.126	1.128	1.126	1.299	
-123	1.174	0.012		1.380	1.363	1.362	1.190	1.192	1.190	1.363	
-124	1.237	0.012		1.443	1.426	1.425	1.253	1.255	1.253	1.426	
-125	1.299	0.012		1.505	1.489	1.488	1.316	1.318	1.316	1.489	
Tolerance			**±0.004**		**+.002 -.000**	**+.000 -.002**	**+.000 -.002**	**+.002 -.000**	**+.000 -.002**	**+.002 -.000**	**+.010 -.000**
-202	0.234	0.005	0.139	0.512	0.478	0.476	0.242	0.244	0.242	0.478	0.175
-203	0.296	0.005		0.574	0.541	0.539	0.304	0.306	0.304	0.541	
-204	0.359	0.005		0.637	0.605	0.603	0.367	0.369	0.367	0.605	
-205	0.421	0.005		0.699	0.668	0.666	0.429	0.431	0.429	0.668	
-206	0.484	0.005		0.762	0.732	0.730	0.492	0.494	0.492	0.732	
-207	0.546	0.007		0.824	0.795	0.793	0.556	0.558	0.556	0.795	
-208	0.609	0.009		0.887	0.859	0.857	0.621	0.623	0.621	0.859	
-209	0.671	0.009		0.949	0.922	0.920	0.683	0.685	0.683	0.922	
-210	0.734	0.010		1.012	0.986	0.984	0.747	0.749	0.747	0.986	
-211	0.796	0.010		1.074	1.049	1.047	0.810	0.812	0.810	1.049	
-212	0.859	0.010		1.137	1.112	1.110	0.873	0.875	0.873	1.112	
-213	0.921	0.010		1.199	1.175	1.173	0.935	0.937	0.935	1.175	
-214	0.984	0.010		1.262	1.238	1.236	0.998	1.000	0.998	1.238	
-215	1.046	0.010		1.324	1.299	1.297	1.060	1.062	1.060	1.299	
-216	1.109	0.012		1.387	1.365	1.363	1.125	1.127	1.125	1.365	

TABLE F Dynamic Radial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions				A Cylinder Bore Dia.	B Piston Diameter	C Piston Gland Dia.	D Rod Bore Diameter	E Rod Diameter	F Gland Diameter	G Gland Width
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.004**		**+.002 -.000**	**+.000 -.002**	**+.000 -.002**	**+.002 -.000**	**+.000 -.002**	**+.002 -.000**	**+.010 -.000**
-217	1.171	0.012	0.139	1.449	1.427	1.425	1.187	1.189	1.187	1.427	0.175
-218	1.234	0.012		1.512	1.489	1.487	1.250	1.252	1.250	1.489	
-219	1.296	0.012		1.574	1.552	1.550	1.313	1.315	1.313	1.552	
-220	1.359	0.012		1.637	1.616	1.614	1.376	1.378	1.376	1.616	
-221	1.421	0.012		1.699	1.678	1.676	1.438	1.440	1.438	1.678	
-222	1.484	0.015		1.762	1.744	1.742	1.504	1.506	1.504	1.744	
-223	1.609	0.015		1.887	1.868	1.866	1.629	1.631	1.629	1.868	
-224	1.734	0.015		2.012	1.994	1.992	1.754	1.756	1.754	1.994	
-225	1.859	0.018		2.137	2.122	2.120	1.883	1.885	1.883	2.122	
Tolerance			**±0.005**		**+.002 -.000**	**+.000 -.002**	**+.000 -.002**	**+.002 -.000**	**+.000 -.002**	**+.002 -.000**	**+.010 -.000**
-309	0.412	0.005	0.210	0.832	0.789	0.786	0.420	0.423	0.420	0.789	0.250
-310	0.475	0.005		0.895	0.853	0.850	0.483	0.486	0.483	0.853	
-311	0.537	0.007		0.957	0.916	0.913	0.547	0.550	0.547	0.916	
-312	0.600	0.009		1.020	0.981	0.978	0.612	0.615	0.612	0.981	
-313	0.662	0.009		1.082	1.044	1.041	0.674	0.677	0.674	1.044	
-314	0.725	0.010		1.145	1.108	1.105	0.738	0.741	0.738	1.108	
-315	0.787	0.010		1.207	1.170	1.167	0.801	0.804	0.801	1.170	
-316	0.850	0.010		1.270	1.234	1.231	0.864	0.867	0.864	1.234	
-317	0.912	0.010		1.332	1.295	1.292	0.926	0.929	0.926	1.295	
-318	0.975	0.010		1.395	1.359	1.356	0.989	0.992	0.989	1.359	
-319	1.037	0.010		1.457	1.420	1.417	1.051	1.054	1.051	1.420	
-320	1.100	0.012		1.520	1.485	1.482	1.116	1.119	1.116	1.485	
-321	1.162	0.012		1.582	1.548	1.545	1.178	1.181	1.178	1.548	
-322	1.225	0.012		1.645	1.610	1.607	1.241	1.244	1.241	1.610	
-323	1.287	0.012		1.707	1.673	1.670	1.304	1.307	1.304	1.673	
-324	1.350	0.012		1.770	1.737	1.734	1.367	1.370	1.367	1.737	
-325	1.475	0.015		1.895	1.865	1.862	1.495	1.498	1.495	1.865	
-326	1.600	0.015		2.020	1.990	1.987	1.620	1.623	1.620	1.990	
-327	1.725	0.015		2.145	2.114	2.111	1.745	1.748	1.745	2.114	
-328	1.850	0.015		2.270	2.240	2.237	1.871	1.874	1.871	2.240	



Finishes are RMS values

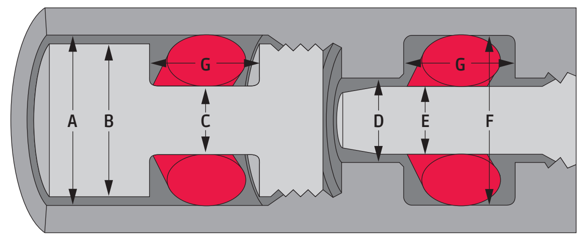
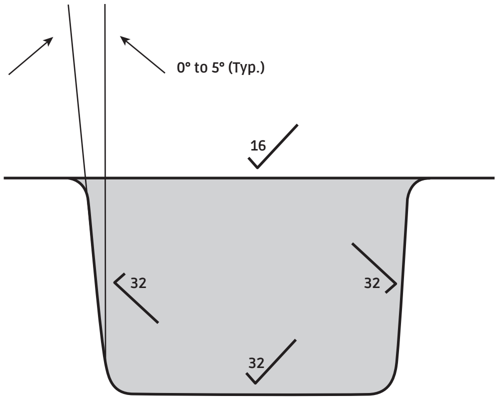


TABLE F Dynamic Radial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions				A Cylinder Bore Dia.	B Piston Diameter	C Piston Gland Dia.	D Rod Bore Diameter	E Rod Diameter	F Gland Diameter	G Gland Width
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.005**		**+.002 -.000**	**+.000 -.002**	**+.000 -.002**	**+.002 -.000**	**+.000 -.002**	**+.002 -.000**	**+.010 -.000**
-329	1.975	0.018	0.210	2.395	2.369	2.366	1.999	2.002	1.999	2.369	0.250
-330	2.100	0.018		2.520	2.493	2.490	2.124	2.127	2.124	2.493	
-331	2.225	0.018		2.645	2.618	2.615	2.249	2.252	2.249	2.618	
-332	2.350	0.018		2.770	2.745	2.742	2.375	2.378	2.375	2.745	
-333	2.475	0.020		2.895	2.871	2.868	2.502	2.505	2.502	2.871	
-334	2.600	0.020		3.020	2.997	2.994	2.627	2.630	2.627	2.997	
-335	2.725	0.020		3.145	3.121	3.118	2.752	2.755	2.752	3.121	
-336	2.850	0.020		3.270	3.247	3.244	2.878	2.881	2.878	3.247	
-337	2.975	0.024		3.395	3.376	3.373	3.007	3.010	3.007	3.376	
-338	3.100	0.024		3.520	3.502	3.499	3.132	3.135	3.132	3.502	
-339	3.225	0.024		3.645	3.626	3.623	3.257	3.260	3.257	3.626	
-340	3.350	0.024		3.770	3.752	3.749	3.383	3.386	3.383	3.752	
-341	3.475	0.024		3.895	3.877	3.874	3.508	3.511	3.508	3.877	
-342	3.600	0.028		4.020	4.007	4.004	3.637	3.640	3.637	4.007	
-343	3.725	0.028		4.145	4.133	4.130	3.763	3.766	3.763	4.133	
-344	3.850	0.028		4.270	4.257	4.254	3.888	3.891	3.888	4.257	
-345	3.975	0.028		4.395	4.382	4.379	4.013	4.016	4.013	4.382	
-346	4.100	0.028		4.520	4.507	4.504	4.138	4.141	4.138	4.507	
-347	4.225	0.030		4.645	4.635	4.632	4.266	4.269	4.266	4.635	
-348	4.350	0.030		4.770	4.760	4.757	4.391	4.394	4.391	4.760	
-349	4.475	0.030		4.895	4.885	4.882	4.516	4.519	4.516	4.885	
Tolerance			**±0.006**		**+.003 -.000**	**+.000 -.003**	**+.000 -.003**	**+.003 -.000**	**+.000 -.003**	**+.004 -.000**	**+.010 -.000**
-425	4.475	0.033	0.275	5.025	5.009	5.005	4.520	4.523	4.520	5.008	0.320
-426	4.600	0.033		5.150	5.134	5.130	4.645	4.648	4.645	5.133	
-427	4.725	0.033		5.275	5.260	5.256	4.771	4.774	4.771	5.259	
-428	4.850	0.033		5.400	5.385	5.381	4.896	4.899	4.896	5.384	
-429	4.975	0.037		5.525	5.514	5.510	5.025	5.028	5.025	5.513	
-430	5.100	0.037		5.650	5.639	5.635	5.150	5.153	5.150	5.638	
-431	5.225	0.037		5.775	5.765	5.761	5.276	5.279	5.276	5.764	
-432	5.350	0.037		5.900	5.890	5.886	5.401	5.404	5.401	5.889	

TABLE F Dynamic Radial Seal Gland Dimensions

AS568 Number	O-Ring Dimensions				A Cylinder Bore Dia.	B Piston Diameter	C Piston Gland Dia.	D Rod Bore Diameter	E Rod Diameter	F Gland Diameter	G Gland Width
	I.D.	± Tol.	W	(O.D.)							
Tolerance			**±0.006**		**+.003 -.000**	**+.000 -.003**	**+.000 -.003**	**+.003 -.000**	**+.000 -.003**	**+.004 -.000**	**+.010 -.000**
-433	5.475	0.037	0.275	6.025	6.015	6.011	5.526	5.529	5.526	6.014	0.320
-434	5.600	0.037		6.150	6.140	6.136	5.651	5.654	5.651	6.139	
-435	5.725	0.037		6.275	6.266	6.262	5.777	5.780	5.777	6.265	
-436	5.850	0.037		6.400	6.391	6.387	5.902	5.905	5.902	6.390	
-437	5.975	0.037		6.525	6.516	6.512	6.027	6.030	6.027	6.515	
-438	6.225	0.040		6.775	6.770	6.766	6.281	6.284	6.281	6.769	
-439	6.475	0.040		7.025	7.020	7.016	6.531	6.534	6.531	7.019	
-440	6.725	0.040		7.275	7.271	7.267	6.782	6.785	6.782	7.270	
-441	6.975	0.040		7.525	7.521	7.517	7.032	7.035	7.032	7.520	
-442	7.225	0.045		7.775	7.777	7.773	7.288	7.291	7.288	7.776	
-443	7.475	0.045		8.025	8.027	8.023	7.538	7.541	7.538	8.026	
-444	7.725	0.045		8.275	8.278	8.274	7.789	7.792	7.789	8.277	
-445	7.975	0.045		8.525	8.528	8.524	8.039	8.042	8.039	8.527	
-446	8.475	0.055		9.025	9.039	9.035	8.550	8.553	8.550	9.038	
-447	8.975	0.055		9.525	9.540	9.536	9.051	9.054	9.051	9.539	
-448	9.475	0.055		10.025	10.041	10.037	9.552	9.555	9.552	10.040	
-449	9.975	0.055		10.525	10.542	10.538	10.053	10.056	10.053	10.541	
-450	10.475	0.060		11.025	11.048	11.044	10.559	10.562	10.559	11.047	
-451	10.975	0.060		11.525	11.549	11.545	11.060	11.063	11.060	11.548	
-452	11.475	0.060		12.025	12.050	12.046	11.561	11.564	11.561	12.049	
-453	11.975	0.060		12.525	12.551	12.547	12.062	12.065	12.062	12.550	
-454	12.475	0.060		13.025	13.052	13.048	12.563	12.566	12.563	13.051	
-455	12.975	0.060		13.525	13.553	13.549	13.064	13.067	13.064	13.552	
-456	13.475	0.070		14.025	14.064	14.060	13.575	13.578	13.575	14.063	
-457	13.975	0.070		14.525	14.565	14.561	14.076	14.079	14.076	14.564	
-458	14.475	0.070		15.025	15.066	15.062	14.577	14.580	14.577	15.065	
-459	14.975	0.070		15.525	15.567	15.563	15.078	15.081	15.078	15.566	
-460	15.475	0.070		16.025	16.068	16.064	15.579	15.582	15.579	16.067	



Finishes are RMS values

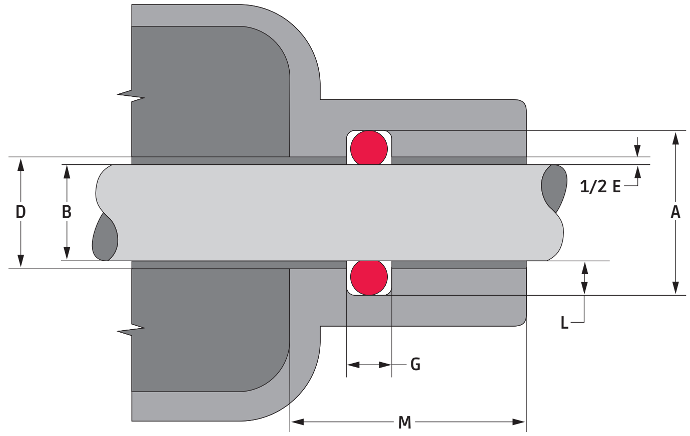


TABLE G Rotary O-Ring Seal Gland Dimensions Under 900 PSI

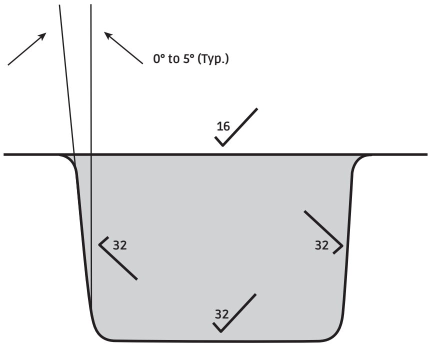
AS568	L Gland Depth	E Diametrical Clearance	M Bearing Lenth Min.
-004 to-045	.065 to .067	.012 to .016	.700
-102 to-163	.097 to .099	.012 to .016	1.030
-210 to-258	.133 to .135	.016 to .020	1.390

- 16 RMS rod finish max
- Due to centrifugal force, do not locate groove in shaft
- Locate seal as close as possible to lubricating fluid
- Feet per minute = (RPM x shaft diameter (inches) x 3.1416) / 12
- To allow for heat transfer, bearing length should be 10 times the cross section of the o-ring used

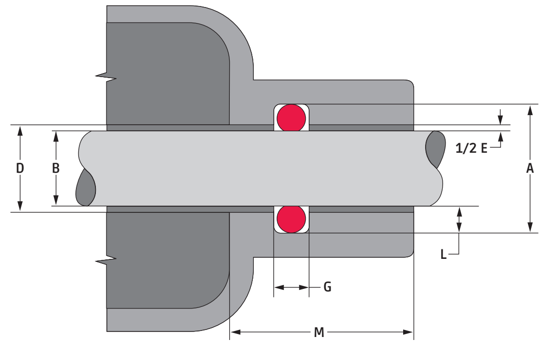
AS568 Number	O-Ring Dimensions			Shaft Diameter B	Groove Diameter A	Rod Bore Diameter D	Groove Width G
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.000 -.001**	**+.003 -.000**	**+.003 -.000**	**+.004 -.000**
- 004	.070 ± .005	.070 ± .003	0.210	.072	.202	.084	.075
- 005	.101 ± .005		0.241	.103	.233	.115	
- 006	.114 ± .005		0.254	.116	.246	.128	
- 007	.145 ± .005		0.285	.147	.277	.159	
- 008	.176 ± .005		0.316	.178	.308	.190	
- 009	.208 ± .005		0.348	.210	.340	.222	
- 010	.239 ± .005		0.379	.241	.371	.253	
- 011	.301 ± .005		0.441	.303	.433	.315	
- 012	.364 ± .005		0.504	.366	.496	.378	
- 013	.426 ± .005		0.566	.428	.558	.440	
- 014	.489 ± .005		0.629	.491	.621	.503	
- 015	.551 ± .007		0.691	.553	.683	.565	

TABLE G Rotary O-Ring Seal Gland Dimensions Under 900 PSI

AS568 Number	O-Ring Dimensions			Shaft Diameter B	Groove Diameter A	Rod Bore Diameter D	Groove Width G
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.000 -.001**	**+.003 -.000**	**+.003 -.000**	**+.004 -.000**
- 016	.614 ± .009	.070 ± .003	0.754	.616	.746	.628	.075
- 017	.676 ± .009	↓	0.816	.678	.808	.693	↓
- 018	.739 ± .009		0.879	.741	.871	.753	
- 019	.801 ± .009		0.941	.803	.933	.815	
- 020	.864 ± .009		1.004	.866	.996	.878	
- 021	.926 ± .009		1.066	.928	1.058	.940	
- 022	.989 ± .010		1.129	.991	1.121	1.003	
- 023	1.051 ± .010		1.191	1.053	1.183	1.065	
- 024	1.114 ± .010		1.254	1.116	1.246	1.128	
- 025	1.176 ± .011		1.316	1.178	1.308	1.190	
- 026	1.239 ± .011		1.379	1.241	1.371	1.253	
- 027	1.301 ± .011		1.441	1.303	1.433	1.315	
- 028	1.364 ± .013		1.504	1.366	1.496	1.378	
- 029	1.489 ± .013		1.629	1.491	1.621	1.503	
- 030	1.614 ± .013		1.754	1.616	1.746	1.628	
- 031	1.739 ± .015		1.879	1.741	1.871	1.753	
- 032	1.864 ± .015		2.004	1.866	1.996	1.878	
- 033	1.989 ± .018		2.129	1.991	2.121	2.003	
- 034	2.114 ± .018		2.254	2.116	2.246	2.128	
- 035	2.239 ± .018		2.379	2.241	2.371	2.253	
- 036	2.364 ± .018		2.504	2.366	2.496	2.378	
- 037	2.489 ± .018		2.629	2.491	2.621	2.503	
- 038	2.614 ± .020		2.754	2.616	2.746	2.628	
- 039	2.739 ± .020		2.879	2.741	2.871	2.753	
- 040	2.864 ± .020		3.004	2.866	2.996	2.878	
- 041	2.989 ± .024		3.129	2.991	3.121	3.003	
- 042	3.239 ± .024		3.379	3.241	3.371	3.253	
- 043	3.489 ± .024		3.629	3.491	3.621	3.503	
- 044	3.739 ± .027		3.879	3.741	3.871	3.753	
- 045	3.989 ± .027	↓	4.129	3.991	4.121	4.003	↓



Finishes are RMS values



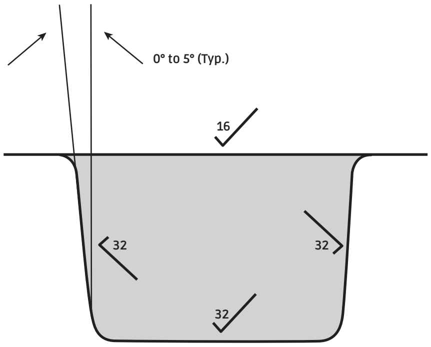
- 16 RMS rod finish max
- Due to centrifugal force, do not locate groove in shaft
- Locate seal as close as possible to lubricating fluid
- Feet per minute = (RPM x shaft diameter (inches) x 3.1416) / 12
- To allow for heat transfer, bearing length should be 10 times the cross section of the o-ring used

TABLE G Rotary O-Ring Seal Gland Dimensions Under 900 PSI

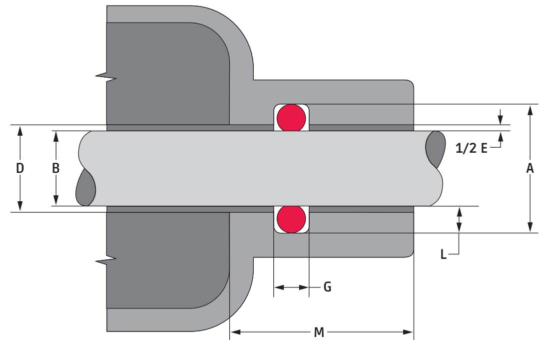
AS568 Number	O-Ring Dimensions			Shaft Diameter B	Groove Diameter A	Rod Bore Diameter D	Groove Width G
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.000 -.001**	**+.003 -.000**	**+.003 -.000**	**+.004 -.000**
- 102	.049 ± .005	.103 ± .003	0.255	.051	.245	.063	.108
- 103	.081 ± .005		0.287	.083	.277	.095	
- 104	.112 ± .005		0.318	.114	.308	.126	
- 105	.143 ± .005		0.349	.145	.339	.157	
- 106	.174 ± .005		0.380	.176	.370	.188	
- 107	.206 ± .005		0.412	.208	.402	.220	
- 108	.237 ± .005		0.443	.239	.433	.251	
- 109	.299 ± .005		0.505	.301	.495	.313	
- 110	.362 ± .005		0.568	.364	.558	.376	
- 111	.424 ± .005		0.630	.426	.620	.438	
- 112	.487 ± .005		0.693	.489	.683	.501	
- 113	.549 ± .005		0.755	.551	.745	.563	
- 114	.612 ± .009		0.818	.614	.808	.626	
- 115	.674 ± .009		0.880	.676	.870	.688	
- 116	.737 ± .009		0.943	.739	.933	.751	
- 117	.799 ± .010		1.005	.801	.995	.813	
- 118	.862 ± .010		1.068	.864	1.058	.876	
- 119	.924 ± .010		1.130	.926	1.120	.938	
- 120	.987 ± .010		1.193	.989	1.183	1.001	
- 121	1.049 ± .010		1.255	1.051	1.245	1.063	
- 122	1.112 ± .010		1.318	1.114	1.308	1.126	
- 123	1.174 ± .012		1.380	1.176	1.370	1.188	
- 124	1.237 ± .012		1.443	1.239	1.433	1.251	
- 125	1.299 ± .012		1.505	1.301	1.495	1.313	
- 126	1.362 ± .012		1.568	1.364	1.558	1.376	
- 127	1.424 ± .012		1.630	1.426	1.620	1.438	
- 128	1.487 ± .012		1.693	1.489	1.683	1.501	
- 129	1.549 ± .015		1.755	1.551	1.745	1.563	
- 130	1.612 ± .015		1.818	1.614	1.808	1.626	
- 131	1.674 ± .015		1.880	1.676	1.870	1.688	

TABLE G Rotary O-Ring Seal Gland Dimensions Under 900 PSI

AS568 Number	O-Ring Dimensions			Shaft Diameter B	Groove Diameter A	Rod Bore Diameter D	Groove Width G
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.000 -.001**	**+.003 -.000**	**+.003 -.000**	**+.004 -.000**
- 132	1.737 ± .015	.103 ± .003	1.943	1.739	1.933	1.751	.108
- 133	1.799 ± .015		2.005	1.801	1.995	1.813	
- 134	1.862 ± .015		2.068	1.864	2.058	1.876	
- 135	1.925 ± .017		2.131	1.927	2.121	1.939	
- 136	1.987 ± .017		2.193	1.989	2.183	2.001	
- 137	2.050 ± .017		2.256	2.052	2.246	2.064	
- 138	2.112 ± .017		2.318	2.114	2.308	2.126	
- 139	2.175 ± .017		2.381	2.177	2.371	2.189	
- 140	2.237 ± .017		2.443	2.239	2.433	2.251	
- 141	2.300 ± .020		2.506	2.302	2.496	2.314	
- 142	2.362 ± .020		2.568	2.364	2.558	2.376	
- 143	2.425 ± .020		2.631	2.427	2.621	2.439	
- 144	2.487 ± .020		2.693	2.489	2.683	2.501	
- 145	2.550 ± .020		2.756	2.552	2.746	2.564	
- 146	2.612 ± .020		2.818	2.614	2.808	2.626	
- 147	2.675 ± .022		2.881	2.677	2.871	2.689	
- 148	2.737 ± .022		2.943	2.739	2.933	2.751	
- 149	2.800 ± .022		3.006	2.802	2.996	2.814	
- 150	2.862 ± .022		3.068	2.864	3.058	2.876	
- 151	2.987 ± .024		3.193	2.989	3.183	3.001	
- 152	3.237 ± .024		3.443	3.239	3.433	3.251	
- 153	3.487 ± .024		3.693	3.489	3.683	3.501	
- 154	3.737 ± .028		3.943	3.739	3.933	3.751	
- 155	3.987 ± .028		4.193	3.989	4.183	4.001	
- 156	4.237 ± .030		4.443	4.239	4.443	4.251	
- 157	4.487 ± .030		4.693	4.489	4.683	4.501	
- 158	4.737 ± .030		4.943	4.739	4.933	4.751	
- 159	4.987 ± .035		5.193	4.989	5.183	5.001	
- 160	5.237 ± .035		5.443	5.239	5.433	5.251	
- 161	5.487 ± .035		5.693	5.489	5.683	5.501	
- 162	5.737 ± .035		5.943	5.739	5.933	5.751	
- 163	5.987 ± .035		6.193	5.989	6.183	6.001	



Finishes are RMS values



- 16 RMS rod finish max
- Due to centrifugal force, do not locate groove in shaft
- Locate seal as close as possible to lubricating fluid
- Feet per minute = (RPM x shaft diameter (inches) x 3.1416) / 12
- To allow for heat transfer, bearing length should be 10 times the cross section of the o-ring used

TABLE G Rotary O-Ring Seal Gland Dimensions Under 900 PSI

AS568 Number	O-Ring Dimensions			Shaft Diameter B	Groove Diameter A	Rod Bore Diameter D	Groove Width G
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.000 -.001**	**+.003 -.000**	**+.003 -.000**	**+.004 -.000**
- 201	0.171 ± .005	.139 ± .004	0.449	.173	.439	.189	.144
- 202	0.234 ± .005		0.512	.236	.502	.252	
- 203	0.296 ± .005		0.574	.298	.564	.314	
- 204	0.359 ± .005		0.637	.361	.627	.377	
- 205	0.421 ± .005		0.699	.423	.689	.439	
- 206	0.484 ± .005		0.762	.486	.752	.502	
- 207	0.546 ± .007		0.824	.548	.814	.564	
- 208	0.609 ± .009		0.887	.611	.877	.627	
- 209	0.671 ± .009		0.949	.673	.939	.689	
- 210	0.734 ± .010		1.012	.736	1.002	.752	
- 211	0.796 ± .010		1.074	.798	1.064	.814	
- 212	0.859 ± .010		1.137	.861	1.127	.877	
- 213	0.921 ± .010		1.199	.923	1.189	.939	
- 214	0.984 ± .010		1.262	.986	1.252	1.002	
- 215	1.046 ± .010		1.324	1.048	1.314	1.064	
- 216	1.109 ± .012		1.387	1.111	1.377	1.127	
- 217	1.171 ± .012		1.449	1.173	1.439	1.189	
- 218	1.234 ± .012		1.512	1.236	1.502	1.252	
- 219	1.296 ± .012		1.574	1.298	1.564	1.314	
- 220	1.359 ± .012		1.637	1.361	1.627	1.377	
- 221	1.421 ± .012		1.699	1.423	1.689	1.439	
- 222	1.484 ± .015		1.762	1.486	1.752	1.502	
- 223	1.609 ± .015		1.887	1.611	1.877	1.627	
- 224	1.734 ± .015		2.012	1.736	2.002	1.752	
- 225	1.859 ± .018		2.137	1.861	2.127	1.877	
- 226	1.984 ± .018		2.262	1.986	2.252	2.002	
- 227	2.109 ± .018		2.387	2.111	2.377	2.127	
- 228	2.234 ± .020		2.512	2.236	2.502	2.252	
- 229	2.359 ± .020		2.637	2.361	2.627	2.377	
- 230	2.484 ± .020		2.762	2.486	2.752	2.502	

TABLE G Rotary O-Ring Seal Gland Dimensions Under 900 PSI

AS568 Number	O-Ring Dimensions			Shaft Diameter B	Groove Diameter A	Rod Bore Diameter D	Groove Width G
	I.D. ± Tol.	W. ± Tol.	O.D. (ref)				
Tolerance				**+.000 -.001**	**+.003 -.000**	**+.003 -.000**	**+.004 -.000**
- 231	2.609 ± .020	.139 ± .004	2.887	2.611	2.877	2.627	.144
- 232	2.734 ± .024		3.012	2.736	3.002	2.752	
- 233	2.859 ± .024		3.137	2.861	3.127	2.877	
- 234	2.984 ± .024		3.262	2.986	3.252	3.002	
- 235	3.109 ± .024		3.387	3.111	3.377	3.127	
- 236	3.234 ± .024		3.512	3.236	3.502	3.252	
- 237	3.359 ± .024		3.637	3.361	3.627	3.377	
- 238	3.484 ± .024		3.762	3.486	3.752	3.502	
- 239	3.609 ± .028		3.887	3.611	3.877	3.627	
- 240	3.734 ± .028		4.012	3.736	4.002	3.752	
- 241	3.859 ± .028		4.137	3.861	4.127	3.877	
- 242	3.984 ± .028		4.262	3.986	4.252	4.002	
- 243	4.109 ± .028		4.387	4.111	4.377	4.127	
- 244	4.234 ± .030		4.512	4.236	4.502	4.252	
- 245	4.359 ± .030		4.637	4.361	4.627	4.377	
- 246	4.484 ± .030		4.762	4.486	4.752	4.502	
- 247	4.609 ± .030		4.887	4.611	4.877	4.627	
- 248	4.734 ± .030		5.012	4.736	5.002	4.752	
- 249	4.859 ± .035		5.137	4.861	5.127	4.877	
- 250	4.984 ± .035		5.262	4.986	5.252	5.002	
- 251	5.109 ± .035		5.387	5.111	5.377	5.127	
- 252	5.234 ± .035		5.512	5.236	5.502	5.252	
- 253	5.359 ± .035		5.637	5.361	5.627	5.377	
- 254	5.484 ± .035		5.762	5.486	5.752	5.502	
- 255	5.609 ± .035		5.887	5.611	5.877	5.627	
- 256	5.734 ± .035		6.012	5.736	6.002	5.752	
- 257	5.859 ± .035		6.137	5.861	6.127	5.877	
- 258	5.984 ± .035	↓	6.262	5.986	6.252	6.002	↓

5 Critical Operating Environmental Factors

CHEMICAL COMPATIBILITY

Regardless of all other critical design factors, if the basic composition of the o-ring material is not compatible with its chemical environment, the o-ring will eventually fail.

A primary step in o-ring selection, therefore, is to match your application's chemicals with the o-ring material that offers the best chemical resistance. To do this, refer to the "Chemical Compatibility" table on our website applerubber.com.

THE EFFECT OF PRESSURE

Differential pressure affects an o-ring by forcing it to the low pressure side of the gland, causing the cross section to distort (See Illustration 5.1). This motion blocks the diametrical clearance gap between the mating surfaces and forms a seal. If the o-ring cannot resist increasingly high pressure, part of the o-ring will be forced (extruded) into the diametrical gap. This condition leads to premature failure, leakage and system contamination. O-Rings operate optimally within a certain range of pressure. Differential pressure does aid in sealing potential by compensating for the elastomer's tendency to assume a compression set over time, which reduces o-ring compression and utility.

Methods commonly used to prevent o-ring extrusion under pressure include:

- Increasing the o-ring hardness (durometer) (See Illustration 5.2)
- The use of back-up rings to block the diametrical clearance gap and provide support for the o-ring
- Reducing the diametrical clearance gap dimension
- Lowering of system pressure

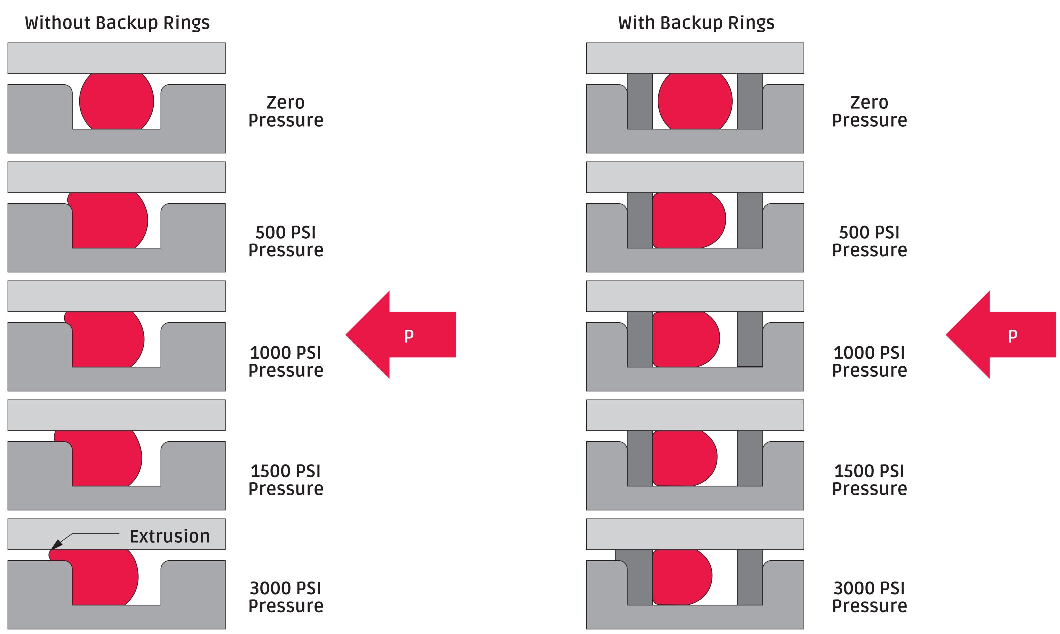


Illustration 5.1, Effect of Pressure

EXTRUSION LIMIT OF O-RINGS

As shown in Illustration 5.2, the extrusion limit of o-rings under pressure is determined by the size of the diametrical clearance gap and the hardness of the o-ring material.

If the point representing the intersection of the lines of sealed pressure and diametrical clearance falls to the right of the material's hardness curve, either the material hardness must be increased, or back-up rings will be required.

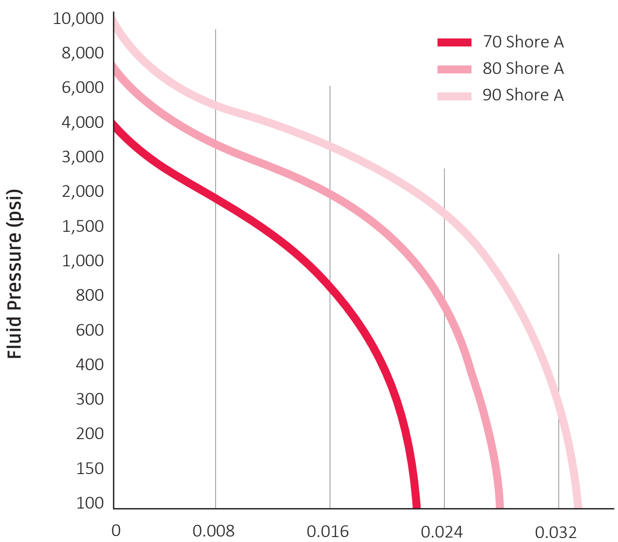


Illustration 5.2, Extrusion Limit

» Examples

- Material hardness of 70 Shore A. Sealed pressure of 1,000 psi. Diametrical clearance of .016".

  Intersection of sealed pressure and diametrical clearance lines falls to the right of material hardness curve. Increase hardness, use back-up rings, or reduce diametrical clearance.

- Material hardness of 80 Shore A. Sealed pressure of 1,000 psi. Diametrical clearance of .016".

  Intersection of sealed pressure and diametrical clearance lines falls to the left of material hardness curve. This is acceptable.

  The use of two back-up rings (one on each side of the rings) is preferred. This will help prevent installation errors, assuring that the clearance gap is always correctly blocked, regardless of pressure direction.

SEAL COMPRESSION (SQUEEZE)

O-Ring compression is a result of three factors: the force applied to compress the seal, durometer, and cross section. These relationships are demonstrated in Illustration 5.3. Additionally, o-ring stretch affects seal compression by reducing cross section, which reduces the sealing potential of the o-ring. This relationship is demonstrated in the equation below.

O-ring CS Reduced Due to Stretch (calculated)

The calculated value assumes the o-ring volume does not change and the cross-section remains round when stretched.

$$CS_R = \text{O-Ring CS} - \left[\text{O-Ring CS} \cdot \left(1 - \frac{10}{\sqrt{100 + \%\ \text{Stretch}}}\right)\right]$$

Rule of Thumb

When using only one back-up ring, be sure to install it on the low pressure side of the o-ring.

CALCULATING SEAL COMPRESSION

Illustration 5.3 is comprised of a great deal of information regarding o-ring compression. Within the body of the graph are the various durometers for standard cross sections. Nonstandard cross sections and omitted durometers can be inferred from the generally linear relationship between the amount of applied compressive force and seal compression, durometer and cross section.

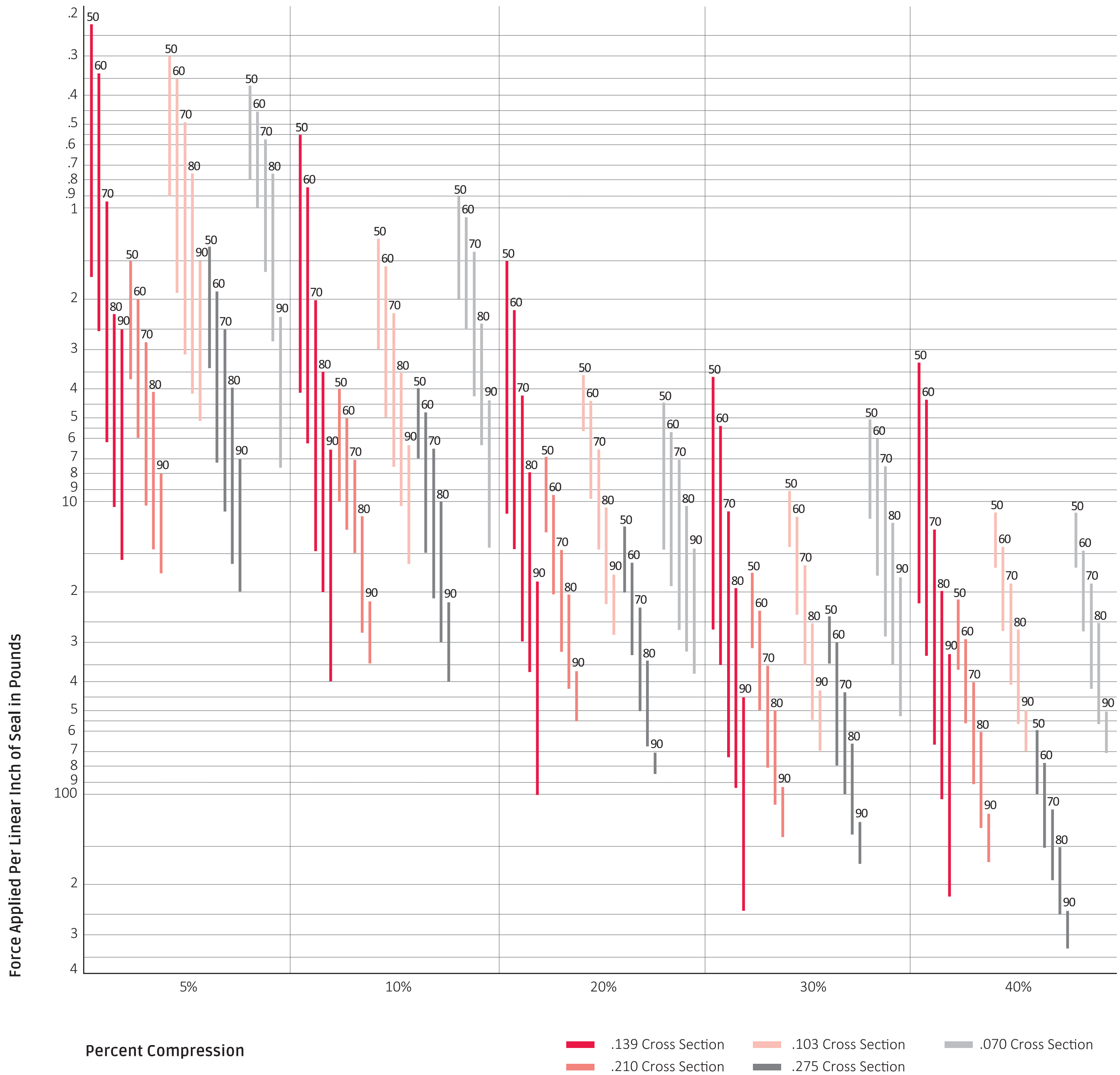


Illustration 5.3, Calculating Seal Compression

THE EFFECTS OF FRICTION

Breakout friction is an important consideration in intermittently moving applications. It can cause excessively high hydraulic pressures to develop. This pressure can tear portions of the seal that adhere to the gland wall when machine movement has been stopped for an extended period of time.

Once a system is up and running, the designer must then consider seal running friction as a potential source of problems. In continuously moving applications, excessive running friction can cause heat to develop, which results in o-ring swell. Once swelling occurs, more heat is generated from increased friction which causes additional swelling and seal failure. High running friction, in combination with high system pressures, may also produce excessive wear in soft metal parts.

METHODS USED TO CONTROL FRICTION

» Squeeze

Both running and breakout friction are reduced when squeeze is reduced.

» Durometer (Hardness)

Breakout friction decreases with decreasing hardness. Running friction decreases with increasing hardness.

» Cross Section

O-Rings with smaller cross sections tend to produce less friction.

» Lubrication

Seal adhesion can be minimized by the use of lubrication. Compatibility between the elastomer and lubricant should be predetermined to avoid seal shrinkage or swelling.

» Compound Additives

Rubber can be compounded with additives such as oils, graphite, Teflon™, etc. to lower the coefficient of friction.

» Gland Machining

An optimum finished surface of 8 to 16 RMS will help control friction. Finishes below 5 RMS will not hold the lubricant because it eliminates micropores.

» Groove Width

By increasing the groove width, the seal will be allowed more room to expand perpendicular to the compressive force.

» Material

Materials vary in their friction characteristics. For example, Teflon™ has a very low coefficient of friction. For more complete information on individual materials see Section 6.

» Pressure

Decrease system pressure to reduce the amount of running friction.

Rule of Thumb

Static seal cross sections are generally compressed from 10% to 40%, whereas Dynamic seals are from 10% to only 30%.

THE EFFECT OF TEMPERATURE

Over time, excessive heat degrades o-ring materials physically and/or chemically, which may render them non-functional. Excessive heat is known to cause o-ring materials to both swell and harden, taking a permanent compression set (deformation of shape) within the gland.

Cold temperatures, without proper material selection to resist the effect of extreme cold, results in o-ring shrinkage and possible leakage due to a reduction in surface contact. Extreme cold also affects o-rings by making them brittle and less flexible.

For optimum sealing performance, always attempt to keep the o-ring application within the temperature ranges listed on the individual material data sheets shown in Section 6, “Material Selection Guide.”

For quick reference, o-ring material working temperature ranges are as shown in Illustration 5.4.

This chart refers to the range of temperatures for families of compounds. A specific compound may not have the full temperature range shown.The red bar graph section designates the range provided by special compounds.

Illustration 5.4, Typical O-Ring Material Working Temperature Ranges

AF - TETRAFLUOROETHYLENE/PROPYLENE (AFLAS®)
BN - NITRILE (BUNA-N)
EP - ETHYLENE-PROPYLENE
CR - CHLOROPRENE (NEOPRENE)
HN - HYDROGENATED NITRILE
VT - FLUOROCARBON
SL - SILICONE
FS - FLUOROSILICONE
SB - SBR
PY - POLYACRYLATE
CP - CAST POLYURETHANE
MP - MILLABLE POLYURETHANE
BU - BUTYL
EH - EPICHLOROHYDRIN
KA - PERFLUOROELASTOMER
NA - NATURAL RUBBER
VA - ETHYLENE ACRYLIC (VAMAC)
TF - POLYTETRAFLUOROETHYLENE (TEFLON™)

TOLERANCE STACK-UP

In any sealing application, the tolerances of ALL the parts in contact with the o-ring must be considered in order to create an effective seal. The combination of these tolerances is the tolerance stack-up.

Illustration 5.5 shows a situation where the o-ring cross section tolerance is ± 0.003", the groove diameter tolerance is ± 0.002", and the bore diameter tolerance is ± 0.001". In this example the metal and o-ring dimensions can vary up to 0.012". If the nominal o-ring size is 0.030", it is easy to see that the tolerance stack-up is nearly half the size of the o-ring.

This can result in too much or too little compression which can cause the o-ring to fail.

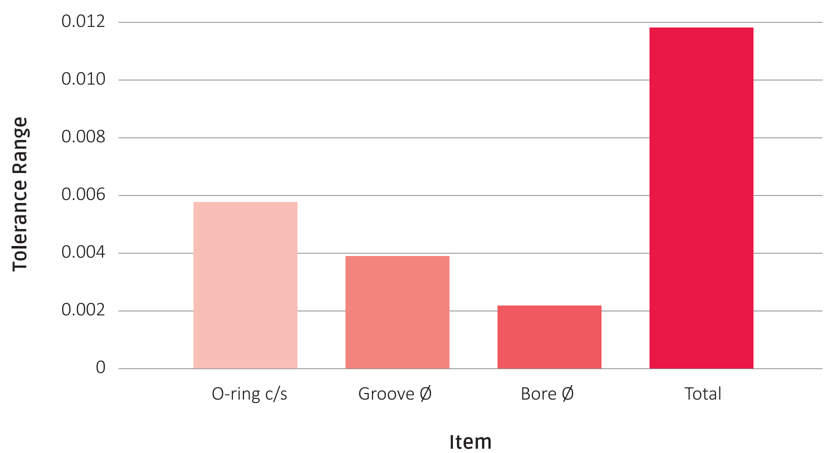


Illustration 5.5, Effects of Tolerance Stack Up

6 Material Selection Guide

BASIC CONCEPTS OF RUBBER

What is "Rubber"?

"Rubber" refers to elastomeric compounds that consist of various monomer units forming polymers that are heat cured (vulcanized). Polymers are long molecular chains and are derived from the Greek "poly" (many) and "meros" (parts). The base monomer or monomers is used to classify the type of rubber, for example: Nitrile, Silicone or Neoprene.

What is a Rubber Compound?

Rubber is composed of many different ingredients that include the base elastomer, vulcanization agents, fillers and plasticizers. For example, the addition of fillers can reinforce or modify properties, or additional plasticizer can increase elongation and lower durometer.

Why Does Rubber Act "Rubbery"?

A polymer is considered a very viscous liquid or an elastic solid (i.e. rubber). The polymeric chains in rubber tend to be very long and flexible by nature and can rotate about their axis, which results in an entangled mass of contorted chains.

When a deformation of the rubber occurs, these tangled chains uncoil and recoil when the force is released. Therefore, elastic rebound or rubbery behavior is possible due to contortions of long, flexible polymeric chains, which allows rubber to be so resilient.

How is Rubber Made?

The elastomer is the basic component of all rubber recipes and is selected in order to obtain specific physical properties in the final product. Processing aids and softeners, such as oils and plasticizers, modify rubber to aid in mixing or molding operations. Sulfur is one of the most widely used vulcanizing agents to promote crosslinking which is used in conjunction with accelerators and accelerator activators to reduce cure times and enhance physical properties. Carbon black is one of the most common fillers because it reinforces the molecular structure. Antidegradants, such as antioxidants and antiozonants, retard the deterioration of rubber products. Lubricants, colors or any other miscellaneous ingredients may also be added.

What is Vulcanization?

The long, flexible polymeric chains of rubber, when heated, react with vulcanizing agents to form three-dimensional structures. These vulcanizing agents (usually sulfur or peroxide) are necessary to facilitate chemical crosslinking of polymeric chains. Once the rubber has been vulcanized or "cured", physical properties are enhanced and the compound is more resistant to deterioration.

What is Compression Set?

Elastic recovery is a measure of the elastomer's ability to return to its original shape once a compressive force has been removed. Failure of the seal to return to its original shape after compression is the condition termed "compression set" and all seals exhibit some degree of compression set. Determination of the amount of compression set is governed by ASTM designation D395 test procedure.

What is the difference between a Thermoset and Thermoplastic?

One classification method of polymeric materials is according to physical properties at elevated temperatures. Thermoset polymers become permanently "set" in the presence of heat and do not soften in the presence of subsequent heating. Conversely, a thermoplastic material will soften when heated (and eventually liquefy) and harden when cooled. This process is reversible and repeatable, as opposed to thermosetting polymers where the process is irreversible. Also, thermoset polymers possess superior mechanical, thermal, and chemical properties as well as better dimensional stability than thermoplastics. This is why thermoset (rubber) parts are generally preferred for sealing applications.

This section contains descriptions of the elastomers used in seal applications. These elastomers form the base of a wide variety of compounds, designated for specific applications. Every compound has specific characteristics and many compounds have common attributes. Therefore, it is important to consider all aspects of the compound prior to use. Also, as compound availability is customer driven, lead time may vary.

Butyl

Trade Name(s):
Butyl . . . Exxon Chemical, Lanxess

ASTM D1418 Designation: IIR

ASTM D2000/SAE J200 Type, Class: AA, BA

Apple Compound Designation: BU

Standard Color: Black

Description: An all-petroleum product, Butyl is a copolymer of isobutylene and isoprene. Butyl is also known as Polyisobutylene or Polyisobutene.

Key Use(s): Applications requiring an airtight seal; used for chemical weapons, agricultural chemicals, tire inner tubes, etc.

Temperature Range: Standard Compound: -50°F to +250°F

Hardness (Shore A): 40 to 80

Features: With outstanding low permeability to gases, Butyl is especially effective in airtight sealing applications. It also features good to excellent resistance to ozone and sunlight aging.

Butyl further features excellent shock dampening capabilities. Only slightly affected by oxygenated solvents and other polar liquids, Butyl is often utilized in seals for hydraulic systems using synthetic fluids. It is good with MEK, and silicone fluids and greases.

Limitations: Because it is a petroleum product, Butyl has poor resistance to hydrocarbon solvents and oils, and diester-based lubricants. Halogenated butyl has been introduced to expand oil and chemical resistance to this polymer. Chlorobutyl and Bromobutyl have better resistance. These polymers have been accepted by the medical industry for stoppers and septums for pharmaceutical applications.

Chloroprene (Neoprene)

Trade Names(s):
Neoprene . . . DuPont Performance Elastomers
Baypren . . . Lanxess
Chloroprene . . . Denka

ASTM D1418 Designation: CR

ASTM D2000/SAE J200 Type, Class: BC, BE

Apple Compound Designation: CR

Standard Color: Black

Description: One of the earliest of the synthetic materials to be developed as an oil-resistant substitute for Natural Rubber, Neoprene is a homopolymer of chloroprene (chlorobutadiene).

Key Use(s): Numerous component uses in the transportation field. Recommended for exposure to weathering. Preferred sealing material for refrigeration industry.

Temperature Range: Standard Compound:-40°F to +250°F. Special Compounds:-67°F to +250°F. (Dry Heat Only)

Hardness (Shore A): 40 to 90

Features: Neoprene can be used in innumerable sealing applications due to its broad base of such desirable working properties as: good resistance to petroleum oils; good resistance to ozone, sunlight and oxygen aging; relatively low compression set; good resilience; outstanding physical toughness; and reasonable production cost.

Limitations: Neoprene is generally attacked by strong oxidizing acids, esters, ketones, chlorinated, aromatic and nitro hydrocarbons.

Because Nitrile is economically competitive with Neoprene, and generally has superior performance characteristics in most situations, it has largely replaced Neoprene in the o-rings of today.

Epichlorohydrin

Trade Name(s):
Hydrin . . . Zeon

ASTM D1418 Designation: CO, ECO

ASTM D2000/SAE J2000 TYPE, CLASS: CH

Apple Compound Designation: EH

Standard Color: Black

Description: Available in homopolymer (CO), copolymer (ECO), and terpolymer (GECO) formats, Epichlorohydrins are oil resistant compounds.

Key Use(s): Ideal for fuel and air conditioning system components. Used in the petroleum industry where a higher temperature capability than NBR is required.

Temperature Range: Standard Compound: -40°F to 275°F

Hardness (Shore A): 50 to 90

Features: Epichlorohydrin features excellent resistance to hydrocarbon oils and fuels; low solvent and gas permeability; excellent resistance to ozone and weathering; and stable cycling from low to high temperature. Good replacement to butyl when gas permeability and oil resistance are needed.

Limitations: Compression set is only "fair" at elevated temperatures (250°F to 275°F). Epichlorohydrin is attacked by ketones; esters; aldehydes; chlorinated and nitro hydrocarbons; and is not recommended for exposure to brake fluids.

Ethylene/Acrylic (Vamac®)

Trade Name(s):
Vamac® . . . Dupont

ASTM D1418 Designation: AEM

ASTM D2000/SAE J200 Type, Class: EE, EF, EG, EA

Apple Compound Designation: VA

Standard Color: Black

Description: A copolymer of ethylene and methyl acrylate, with small amount of third monomer added to provide a cure to active groups in the polymer chain, Vamac® exhibits properties similar to those of polyacrylate, but with an extended low temperature limit and better mechanicals.

Key Use(s): Seals for automotive applications, such as automatic transmissions and power steering systems.

Temperature Rage: Standard Compound:-13°F to +338°F (Dry Heat Only)

Hardness (Shore A): 50 to 90

Features: Ideal for automotive sealing uses, Vamac® features excellent heat resistance, outstanding resistance to ozone and sunlight aging moderate resistance to swelling in oils, and very low permeability to gases.

Vamac®'s mechanical properties, adhesion to metals, tear resistance, flex life, abrasion resistance and compression set resistance are all rated as "good."

Resistance to water, engine coolant mixtures (glycols), dilute acids and alkalis is also good.

Limitations: Vamac® is not recommended for exposure to concentrated acids, aromatic hydrocarbons, gasoline, ketones, brake fluids and phosphate esters.

Ethylene-Propylene

Trade Name(s):
Vistalon. . . Exxon Mobil
Nordel . . . Dow Chemical
Kaltan . . . Arlanxeo
Royalene . . . Lion Elastomer

ASTM D1418 Designation: EPDM

ASTM D2000/SAE J200 Type, Class: AA, BA, CA, DA

Apple Compound Designation: EP

Standard Color: Black

Description: A copolymer of ethylene and propylene (EPR), combined with a third comonomer diene (EPDM), Ethylene Propylene has gained wide seal industry acceptance for its excellent ozone and chemical resistance characteristics.

Key Use(s): Outdoor weather resistant uses, automotive brake systems, automobile cooling systems, low torque drive belts, watertight applications with low water permeability.

Temperature Range: Standard Compound:-76°F to +275°F. Special Compound:-76°F to 302°F.

Hardness (Shore A): 40 to 95

Features: When compounded using peroxide curing agents, high temperature service can reach +350°F. Good resistance to acids and solvents (i.e. MEK and Acetone).

Limitations: Have no resistance to hydrocarbon fluids.

Fluorocarbon (Viton™)

Trade Name(s):
Viton™ . . . Chemours Company
Dyneon . . . 3M Company
DAI-EL . . . Daikin
Technoflow . . . Solvay

ASTM D1418 Designation: FKM

ASTM D2000/SAE Type, Class: HK

Apple Compound Designation: VT

Standard Color: Black

Description: Combining high temperature resistance with outstanding chemical resistance, Fluorocarbon-based compounds approach the ideal for a universal o-ring material.

Key Use(s): Seals for aircraft engines. Seals for automotive fuel handling systems. High temperature/ low compression set applications. Wide chemical exposure situations. Low outgassing makes excellent vacuum seals.

Temperature Range: Standard Compound:-13°F to +446°F. Special Compounds:-40°F to +446°F.

Hardness (Shore A): 45 to 90

Features: High fluorine grades offer higher resistance to swell in high octane and oxygenated fuel blends. This gives superior performance in Ethanol/ Methanol blended gasoline. Also, Fluorocarbon offers improved resistance to steam for higher temperature services. Low temperature bases can improve performance to-40°F. New polymers being offered have improved chemical resistance and low temperature performance.

Viton™ Extreme™ ETP offers similar chemical compatibility as FFKM with temperature resistance to +446°F.

Special compounds, using new polymer technologies, provide improved low temperature performance with a TR(10) of-40°F and brittleness to-76°F.

Limitations: Fluorocarbons are not recommended for exposure to ketones, amines, low molecular weight esters and ethers, nitro hydrocarbons, hot hydrofluoric or chlorosulfonic acids, or Skydrol® fluids. They are also not recommended for situations requiring good low temperature flexibility.

Fluorosilicone

Trade Name(s):
FE . . . Shin-Etsu
Elastosil. . . Wacker
Silastic LS . . . Dow
FSE . . . Momentive Performance Silicone

ASTM D1418 Designation: FVMQ

ASTM D2000/SAE J200 Type, Class: FK

Apple Compound Designation: FS

Standard Color: Blue

Description: Fluorosilicone combines the good high and low temperature stability of Silicones with the fuel, oil, and solvent resistance of Fluorocarbons.

Key Use(s): Aerospace fuel systems. Auto fuel emission control systems. Primarily for static sealing and low outgassing applications.

Temperature Range: Standard Compound:-75°F to +400°F

Rule of Thumb

When it is said that an elastomer is good for an application, it is meant that some compounds which include that elastomer are acceptable, not all. For instance, some compounds of EP are good for brake fluid applications, but most are not acceptable.

Hardness (Shore A): 40 to 80

Features: Fluorosilicone is most often used in aerospace applications for systems requiring fuel and/or diester-based lubricant resistance up to 400°F.

Although generally specified for aerospace use, due to its excellent fuel resistance and high temperature stability, Fluorosilicone is becoming an increasingly popular material for a wider range of sealing applications.

Featuring good compression set and resilience properties, fluorosilicone compounds are suitable for exposure to air, sunlight, ozone, chlorinated and aromatic hydrocarbons.

Limitations: Due to limited physical strength, poor abrasion resistance, and high friction characteristics, Fluorosilicone elastomers are not generally recommended for dynamic sealing. They are predominantly designed for static sealing use. They are also not recommended for exposure to brake fluids, hydrazine, or ketones.

Liquid Silicone Rubber (LSR)

LSR is a low viscosity silicone elastomer intended for use in liquid injection molding (LIM) equipment. It offers high thermal stability and flexibility at low temperatures, high transparency and is easily colored. Also, self-lubricated and electrically conductive grades are available as well as FDA and medical compliant grades. Liquid silicone rubber is widely used to mold complex profiles because of its excellent flow characteristics. See Silicone for other key benefits.

Medical Grade Silicone

When properly prepared, the benefits include fulfillment of USP Class VI and ISO 10993 requirements, and can be sterilized with autoclave, gamma, ETO. Less than 30 day implant and long-term implant grades available. Medical grade pigments are also available.

Limitations: Generally, low abrasion and tear resistance, and high friction characteristics preclude silicones from effectively sealing some dynamic applications. Silicones are also highly permeable to gases and are generally not recommended for exposure to ketones (MEK, acetone) or concentrated acids.

Natural Rubber

ASTM D1418 Designation: NR

ASTM D2000/SAE J200 Type, Class: AA

Apple Compound Designation: NA

Standard Color: Black

Description: Natural Rubber is the vulcanized product of the juice of the Hevea tree (latex).

Key Use(s): Seals in brake systems. Seals in food and beverage applications. Most popular material for non-hydraulic sealing applications. Mainly used for dampeners due to its ability to absorb vibration.

Temperature Range: Standard Compound:-58°F to +158°F (Dry Heat Only)

Hardness (Shore A): 40 to 90

Features: Natural Rubber features high tensile strength, high resilience, high abrasion and high tear resistance properties, with a good friction surface and excellent adhesion to metals. Until the invention of synthetic elastomers in the 1930's, Natural Rubber was the only polymer available for o-ring manufacture.

Natural Rubber features good resistance to organic acids and alcohols, with moderate resistance to aldehydes.

Limitations: Not widely used in sealing industry due to poor compression set performance and lack of resistance to many fluids. Widely banned for medical applications.

Nitrile (Buna-N)

Trade Name(s):
Perbunan . . . Arlanxeo
Nipol . . . Zeon
Krynac . . . Arlanxeo

ASTM D1418 Designation: NBR

ASTM D2000/SAE J200 Type, Class: BF, BG, BK, CH

Apple Compound Designation: BN

Standard Color: Black

Description: Presently, the seal industry's most widely used and economical elastomer, Nitrile combines excellent resistance to petroleum-based oils and fuels, silicone greases, hydraulic fluids, water and alcohols, with a good balance of such desirable working properties as low compression set, high tensile strength and high abrasion resistance. Use of Carboxylated Nitrile can have superior abrasion resistance, while still having improved oil resistance.

Key Use(s): Oil resistant applications of all types. Low temperature military uses. Off-road equipment. Automotive, marine, aircraft fuel systems. Can be compounded for FDA applications.

Temperature Range: Standard Compound:-40°F to +257°F. Special Compounds:-67°F to +275°F (Dry Heat Only)

Hardness (Shore A): 40 to 90

Features: Comprised of the copolymer butadiene and acrylonitrile, in varying proportions. Use of Carboxylated Nitrile can have superior abrasion resistance, while still having improved oil resistance.

Limitations: Nitrile compounds are attacked by small amounts of Ozone. Phthalate type plasticizers are commonly used in compounding Nitrile rubber. These plasticizers can migrate out and cause problems with certain plastics. Also, new regulation on certain phthalates have limited their use.

Nitrile, Hydrogenated (HNBR)

Trade Name(s):
Zetpol . . . Zeon
Therban . . . Arlanxeo

ASTM D1418 Designation: HNBR

ASTM D2000/SAE J200 Type, Class: DH

Apple Compound Designation: HN, ZT

Standard Color: Black

Description: HNBR is the product of the hydrogenation of Nitrile rubber, resulting in varying degrees of saturation of the polymeric chain, along with a range of enhanced physical strength and chemical resistance properties.

Key Use(s): Oil resistant applications, including exposure to such oil additives as detergents, antioxidants and anti-wear agents. Exposure to oil soured with metal sludge. Seals for oil well applications. Seals for automotive fuel handling systems. Seals for general industrial usage.

Temperature Range: Standard Compound:-30°F to +300°F. (Dry Heat Only) Special Compounds:-76°F to +347°F.

Hardness (Shore A): 50 to 90

Features: Like Nitrile, increasing acrylonitrile content improves oil resistance at a cost of reduced low temperature performance. Saturation of polymer chains improves ozone and weathering resistance. Higher physical properties are good for downhole applications where high pressure is used.

Limitations: Like Nitrile, HNBR is not recommended for exposure to ethers, esters, ketones, or chlorinated hydrocarbons.

Perfluoroelastomer®

Trade Name(s):
Chemraz . . . Green, Tweed and Co.
Kalrez . . . DuPont
Tecnoflon PFR . . . Solvay

ASTM D1418 Designation: FFKM

ASTM D2000/SAE J200 Type, Class: N/A

Apple Compound Designation: KA

Standard Color: Black

Description: FFKM parts are made from a perfluoroelastomer possessing exceptional resistance to degradation by aggressive fluids and/or gases.

Key Use(s): Seals for use in the chemical and petroleum industries as well as for the manufacturing of semiconductors and analytical and process instruments. It is also used for high temperature applications and for paint and coating operations.

Temperature Range: Standard Compound:-13°F to +600°F

Hardness (Shore A): 65 to 90

Features: FFKM combines the toughness of an elastomeric material with the chemical inertness of Teflon™. It resists attack by nearly all chemical reagents and provides long-term service where corrosive additives can cause other elastomers to swell or degrade. In addition, FFKM parts are less likely to cold flow than Teflon™ seals.

Limitations: Withstanding degradation by virtually ALL chemicals, FFKM can swell significantly when exposed to some fluorinated solvents, fully halogenated freons and uranium hexafluoride. In addition, FFKM parts should not be exposed to molten or gaseous alkali metals.

As the thermal coefficient of expansion for FFKM is stated by the manufacturer to be “about 50% greater than for fluoroelastomers”, gland volume may have to be increased to allow for this expansion in elevated temperature situations.

Because of its high cost, FFKM is generally used when no other elastomer is appropriate.

Polyacrylate

Trade Name(s):
HyTemp ACM . . . Zeon

ASTM D1418 Designation: ACM

ASTM D2000/SAE J200 Type, Class: DH; DF

Apple Compound Designation: PY

Standard Color: Black

Description: Polyacrylates are copolymers (ethyl acrylates) possessing outstanding resistance to petroleum fuels and oils.

Key Use(s): Sealing automatic transmissions and power steering systems. Sealing petroleum oils up to 300°F.

Temperature Range: Standard Compound: -25°F to +300°F

Hardness (Shore A): 40 to 90

Features: With excellent resistance to hot oil, automatic transmission and Type A power steering fluids, the greatest use for Polyacrylate is found in automobile manufacture, where o-rings of this material are employed to seal components of automatic transmission and power steering systems.

Highly resistant to sunlight and ozone degradation, Polyacrylate also features an enhanced ability to resist flex cracking.

Limitations: While resistance to hot air aging is superior to Nitrile, Polyacrylate strength, compression set, water resistance properties and low temperature capabilities are inferior to many other polymers.

Polyacrylates are also not generally recommended for exposure to alcohol, glycols, alkalis, brake fluids, or to chlorinated or aromatic hydrocarbons.

Polyurethane, Cast

Trade Name(s):
Vibrathane . . . Lanxess

ASTM D1418 Designation: No designation at the time of publication.

ASTM D2000/SAE J200 Type, Class: No designation at the time of publication.

Apple Compound Designation: CP

Standard Color: Amber

Description: Cast Polyurethane is outstanding over other o-ring elastomers in abrasion resistance and tensile strength. Additionally, Cast Polyurethane surpasses the performance of Millable Polyurethane in its higher tensile strength.

Key Use(s): Seals for high hydraulic pressures. Situations where highly stressed parts are subject to wear. Used for wheels, rolls, slurry parts, bumpers, couplers, and shock absorbers. Wiper seals for axially moving piston rods.

Temperature Range: Standard Compound: -30°F to +175°F

Hardness (Shore A): 70 and 90

Features: With tensile strength of up to 6,000 psi, elongation of 350 to 650%, and exceedingly high abrasion resistance, the physical properties of Cast Polyurethane are among the best of all o-ring elastomers.

Although they swell slightly upon exposure, Cast Polyurethane compounds feature excellent resistance to mineral-based oils and petroleum products, aliphatic solvents, alcohols and ether. They are also compatible with hydraulic fluids, weak acids and bases, and mixtures containing less than 80% aromatic constituents.

Limitations: Cast Polyurethanes are not recommended for exposure to concentrated acids and bases, ketones, esters, very strong oxidizing agents, pure aromatic compounds and brake fluids. With the exception of special compounds, they are also not recommended for exposure to hot water or steam.

Polyurethane, Millable

Trade Name(s):
Millathane® . . . TSE Industries Inc.

ASTM D1418 Designation: AU, EU

ASTM D2000/SAE J200 Type, Class: BG

Apple Compound Designation: MP

Standard Color: Black

Description: Millable Polyurethane is outstanding over most other o-ring elastomers in abrasion resistance and tensile strength.

Key Use(s): Seals for high hydraulic pressures. Situations where highly stressed parts are subject to wear.

Temperature Range: Standard Compound: -30°F to +175°F

Hardness (Shore A): 40 to 90

Features: Millable Polyurethane offers superior seal performance in hydraulic situations, where high pressures, shock loads, or abrasive contamination is anticipated.

Millable Polyurethane possesses chemical compatibility similar to that of Nitrile, offering good resistance to petroleum-based oils, hydrocarbon fuels and hydraulic fluids, the oxidizing effects of ozone, and the aging effects of sunlight. It also has good tear resistance.

Limitations: Unless specially compounded, at elevated temperatures Millable Polyurethane begins to soften, losing its physical strength and chemical resistance advantages over other polymers.

Tending to rapidly deteriorate when exposed to concentrated acids, ketones, esters, chlorinated and nitro hydrocarbons, Millable Polyurethanes are also prone to hot water and steam degradation.

Silicone

Trade Name(s):
Elastosil . . . Wacker
KE . . . Shin-Etsu
Silastic . . . Dow
Silplus . . . Momentive Performance Materials

ASTM D1418 Designation: MQ, PMQ, VMQ, PVMQ

ASTM D2000/SAE J200 Type, Class: FC, FE, GE

Apple Compound Designation: SL

Standard Color: Red

Description: A group of elastomers, made from silicon, oxygen, hydrogen and carbon, Silicones are renowned for their retention of flexibility and low compression set characteristics, within one of the widest working temperature ranges for elastomers.

Key Use(s): Static seals in extreme temperature situations. Seals for medical devices, compatible with FDA regulations. Low outgassing and excellent dampening properties.

Temperature Range: Standard Compound:-85°F to +400°F. Special Compounds:-148°F to +400°F.

Hardness (Shore A): 5 to 80

Features: Phenyl (PVMQ) based silicones can perform to-148°F. Metal fillers and conductive carbon black make silicone conductive for EMF/RF applications.

Styrene Butadiene

Trade Name(s):
Too numerous to list.

ASTM D1418 Designation: SBR

ASTM D2000/SAE J200 Type, Class: AA, BA

Apple Compound Designation: SB

Standard Color: Black

Description: Also known as Buna S, or GR-S (Government Rubber-Styrene), Styrene Butadiene was the elastomer substituted for Natural Rubber during World War II. Compounded properties are similar to those of Natural Rubber.

Key Use(s): Isolation dampeners

Temperature Range: Standard Compound:-50°F to +212°F (Dry Heat Only)

Hardness (Shore A): 40 to 90

Features: The main use for Styrene Butadiene today is in the manufacture of automobile tires.

Limitations: SBR is not recommended for exposure to petroleum oils, most hydrocarbons, strong acids, or ozone.

This material is seldom used in modern sealing applications. It has been replaced by better performing materials.

Tetrafluoroethylene/Propylene (AFLAS®)

Trade Name(s):

AFLAS® . . . AGC Chemicals

ASTM D1418 Designation: FKM

ASTM D2000/SAE J200 Type, Class: HK

Apple Compound Designation: AF

Standard Color: Black

Description: A copolymer of tetrafluoroethylene/ propylene, TFE/P can offer a combination of high temperature and chemical resistance.

Key Use(s): Seals for oil field, aerospace, chemical and general industrial environments.

Temperature Range: Standard Compound: +14°F to +446°F

Hardness (Shore A): 60 to 90

Features: Resistance to a wide range of chemicals, high temperatures and electrical capabilities give broad application diversity. TFE/P have resistance to acids and bases, steam/hot water, corrosion inhibitors, oils and lubricants, and industrial solvents. TFE/P also offer improved low temperature properties over most fluoroelastomers.

Limitations: Tests have shown that other FKM elastomers are recommended for automotive fuels since they have less volume swell than TFE/P. Also, TFE/P has shown to have less than desirable results when exposed to toluene, ethers, ketones and acetic acid.

Rule of Thumb

Material cost does not correlate with performance, it depends on the application.

Thermoplastic Elastomers

Description: Thermoplastic elastomers combine the processing advantages of plastics with the rubber-like performance of elastomers. Known as two-phase systems, these copolymers are comprised of both hard (plastic) and soft (elastomeric) molecular regions, with each region contributing advantages and limitations to the final material performance. Chemically, fully-cured thermoset rubber particles are dispersed throughout a continuous thermoplastic matrix. Examples of this class of material are Santoprene™ and Geolast™ from Exxon Mobil and Dynaflex™ from PolyOne.

Key Use(s): A broad range of applications that spans from bumpers to bellows, vibrational dampers, couplers, and grommets. Also used throughout the automotive, major and small appliances, and aerospace industries.

Features: In virtually all cases, the substitution of these materials for traditional thermosetting materials results in such benefits as significantly increased production speeds (via conventional plastic injection molding machines) and the ability to reuse clean scrap without a loss in physical properties. This results in a reduced part cost due to minimize scrap loss.

Also, they are available in a broad range of durometers and colors and, by adjusting the percentage of hard (plastic) segments in the copolymer matrix, the physical properties can be modified. For example, as styrene content is increased in polystyrene elastomer block copolymers, they change from weak rubber-like materials to strong elastomers, to leathery materials, to finally hard, glass-like products (with styrene content above 75%).

Limitations: The physical properties of thermoplastic elastomers are highly dependent upon the properties of the plastic and elastomeric regions of the copolymer. Consequently, as temperature changes, so does the behavior of the TPE. The low temperature limit is defined by the glass transition temperature of the rubber phase, below which the material is brittle. Likewise, the high temperature limit is defined by the melting point of the plastic phase, above which the material softens and begins to flow. This results in lowering the overall heat resistance of the copolymer.

Also, as temperature increases, compression set increases which limits the overall component size and complexity due to stack-up tolerances. Likewise, the chemical resistance of the thermoplastic is determined by the limits of BOTH materials comprising the system.

Rule of Thumb | **You must test all seals in their actual environment because every application is unique.**

PLEASE NOTE THE FOLLOWING

The applications, suggestions and recommendations contained in this book are meant to be used as a professional guide only. Because no two situations or installations are the same, these comments, suggestions, and recommendations are necessarily general and should not be relied upon by any purchaser without independent verification based on the particular installation or use. We strongly recommend that the seal you select be rigorously tested in the actual application

General Properties Of O-Ring Elastomers

E Excellent **F** Fair ● No designation at time of publication
G Good **P** Poor

Elastomers	Apple Rubber Material Designation	ASTM D1418 Designation	ASTM D2000/SAE J200 Type, Class	Economy	Low/High Temp. Limits °F	Tensile Strength	Hardness Range Shore A	Resilience-Rebound	Compression Set	Adhesion to Metals	Abrasion Resistance	Tear Resistance	Weather Resistance	Ozone Resistance	Water Swell Resistance	Steam Resistance Under 300°F	Gas Impermeability	Acid Resistance, Conc.	Alkali Resistance, Conc.	Alcohols	Lubricating Oils Petroleum Based	Aliphatic Hydrocarbons	Aromatic Hydrocarbonds	Halogenated Hydrocarbons	Phosphate Ester	Polar Solvents (keytones)
Butyl	BU	IIR	AA; BA	F	-50 to +250	F-G	30-90	P-G	F-G	G	F-G	G	G	G	E	G	E	G-E	G-E	E	P	P	P	P	G	G
Chloroprene (Neoprene®)	CR	CR	BC; BE	G	-40 to +250	F	40-90	G	F-G	E	G-E	E	G-E	G-E	F-G	G	F-G	P	P	G-E	G	F	P	P	P	P
Epichlorohydrin	EH	CO; ECO	CH	F	-40 to +275	F	50-90	G	G	F-G	G	E	G-E	G	F-G	F-G	F	F	P-G	G	G-E	G	E	G	P	F
Ethylene Acrylic (Vamac®)	VA	AEM	EE	F	-13 to +338	F	50-90	F	P-G	G	G	G	E	E	G	P	P	P-G	P-G	F	G	G	P	F-G	P	G
Ethylene-Propylene	EP	EPM; EPDM	AA; BA; CA; DA	E	-40 to +275	G	40-95	G	F-G	G-E	G-E	F-G	E	E	E	E	F	E	E	G-E	P	P	P	P	E	G-E
Fluorocarbon	VT	FKM	HK	F	-13 to +446	F	45-90	F-G	G-E	G-E	G	F-G	E	E	G	P-G	G-E	E	P	F-G	E	E	E	E	G	P
Fluorosilicone	FS	FVMQ	FK	P	-75 to +400	P	40-80	E	G-E	G-E	P	P	E	E	E	F-G	P-G	G	F-G	G	E	F-G	G	G	P-G	P
Natural Rubber	NA	NR	AA	G	-58 to +158	G-E	40-90	E	G	E	E	E	P	P	E	P	F-P	F-G	F-G	G	P	P	P	P	P	F-G
Nitrile (Buna-N)	BN	NBR; XNBR	BF; BG; BK; CH	E	-40 to +257	G	40-90	G	G	E	G-E	G	P-F	P	G	F-G	F-G	F-G	P-G	F-G	G-E	G-E	F-G	P-F	P	P
Nitrile, Hydrogenated	HN	HNBR	DH	F	-30 to +300	G-E	50-90	G	G-E	G-E	G-E	G	G-E	G	G	E	G	G	G	E	E	G-E	F-P	P	P	P
Perfluoroelastomer (Kalrez®, Chemraz®)	KA	FFKM	KK	P	-13 to +600	F-G	65-90	F	F-G	G-E	F-G	F	E	E	G	E	G-E	E	E	E	G	E	E	F-G	E	P
Polyacrylate	PY	ACN	DF; DH	F	-25 to +300	F	40-90	F	G	G	F-G	E	E	G	P	P	G-E	P	F	P	F-G	E	P-G	P-G	P	P
Polytetrafluoro-ethylene (Teflon™)	TF	FEP	●	P	-300 to +450	F	98	P	P	P	E	E	E	G	G	E	G	E	E	E	E	E	E	E	P	P
Polyurethane, Cast	CP	AU; EU	BG	P	-30 to +175	E	70 & 90	F-G	P-G	E	E	E	E	G	G	P	G-E	P	P	G	G	P	F	P	P	P
Polyurethane, Millable	MP	AU; EU	BG	F	-30 to +175	G-E	40-90	F-G	G	E	G	E	E	E	G	P	G-E	P	P	G	G	P	F	P	P	P
Silicone	SL	MQ; PMQ VMQ; PVMQ	FC; FE; GE	G	-85 to +400	P	5-80	G-E	G-E	E	P	F-G	E	E	E	E	P	F-G	F-G	F-G	P	P	P	P	P-G	P
Styrene Butadiene	SB	SBR	AA; BA	E	-50 to +212	G	40-90	P-G	G	E	E	P	F-G	P	G	F-G	F	G	F-E	G	P	P	P	P	G	P-G
Tetrafluoroethylene/ Propylene (AFLAS®)	AF	FKM	HK	P	+14 to +446	F	60-90	F-G	F-G	G	G	G	E	E	E	G-E	G	G	E	E	G	F	P	P	G	F

Chemical Compatibility Table

All recommendations for Room Temperature	AFLAS® [TFE/P]	Nitrile (Buna-N)	Butyl	Epichlorohydrin	Ethylene-Propylene	Fluorocarbon (Viton™)	Fluorosilicone	FFKM	Natural Rubber	Chloroprene (Neoprene)	Nitrile, Hydrogenated	Polyacrylate	Polyurethane (Millable, Cast)	Silicone	Styrene Butadiene	Teflon™ Virgin	Vamac®
Acetaldehyde	◆	■	●	●	●	■	■	●	▲	◆	■	■	■	●	◆	●	□
Acetamide	●	●	●	□	●	▲	●	●	■	●	●	■	■	◆	■	●	●
Acetic Acid, Glacial	■	■	●	■	●	◆	■	●	▲	■	▲	■	■	▲	▲	●	■
Acetic Anhydride	●	◆	▲	■	▲	■	■	●	▲	▲	■	■	■	◆	■	●	■
Acetone	■	■	●	■	●	■	■	●	◆	■	◆	■	■	■	◆	●	■
Acetophenone	▲	■	●	■	●	■	■	●	■	■	■	■	■	■	■	●	□
Acetyl Chloride	●	■	■	■	■	●	●	●	■	■	■	■	■	◆	■	●	□
Acetylene Gas	●	●	●	▲	●	●	◆	◆	▲	●	▲	■	▲	◆	◆	●	□
Acrylonitrile	●	■	■	□	■	■	■	●	◆	●	■	■	■	■	■	●	□
Air, Below 200°	●	●	●	▲	■	●	●	●	◆	■	▲	●	●	●	▲	●	●
Alkazene	▲	■	■	■	■	▲	▲	●	■	■	■	■	■	■	■	●	□
Aluminum Acetate	▲	▲	●	▲	●	■	■	●	●	▲	▲	■	■	■	▲	●	□
Aluminum Chloride	●	●	●	●	●	●	●	●	●	●	●	●	◆	▲	●	●	●
Aluminum Fluoride	●	●	●	●	●	●	●	●	▲	●	●	□	■	▲	●	●	□
Aluminum Nitrate	●	●	●	●	●	●	□	●	●	●	●	□	◆	▲	●	●	□
Aluminum Sulfate	●	●	●	□	●	●	●	●	●	●	●	■	■	●	■	●	●
Ammonia, Gas, Hot	●	■	▲	□	▲	■	■	●	■	▲	■	■	■	●	■	●	■
Ammonia, Gas, Cold	●	●	●	□	●	■	■	●	●	●	●	■	◆	●	●	●	■
Ammonia, Anhydrous	●	▲	●	□	●	■	■	●	■	●	▲	■	■	◆	■	●	■
Ammonium Carbonate	●	■	●	▲	●	●	□	●	●	●	■	■	■	◆	●	●	□
Ammonium Chloride	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Ammonium Hydroxide, Concentrated	▲	■	●	▲	●	▲	▲	●	■	●	□	■	■	●	■	●	■
Ammonium Nitrate	●	●	●	●	●	●	●	●	◆	●	●	▲	■	●	▲	●	□
Ammonium Persulfate Solution	▲	■	●	□	●	●	□	●	●	●	■	■	■	■	■	●	□
Ammonium Phosphate	▲	●	●	●	●	●	□	●	●	●	●	●	□	●	●	●	●
Ammonium Sulfate	▲	●	●	□	●	●	●	●	●	●	●	■	●	●	●	●	●
Amyl Acetate	◆	■	◆	■	◆	■	■	●	■	■	■	■	■	■	■	●	■
Amyl Alcohol	●	▲	▲	●	●	▲	●	●	●	●	▲	■	■	■	▲	●	□
Amyl Borate	▲	●	■	●	■	●	□	●	■	●	●	▲	□	■	■	●	□
Amyl Chloronaphthalene	▲	■	■	□	■	●	▲	●	■	■	■	■	■	■	■	●	□
Aniline	●	■	●	■	●	◆	◆	●	■	■	■	■	■	■	■	●	□
Aniline Oil	▲	■	▲	□	▲	■	◆	●	■	■	■	■	■	■	■	●	□
Animal Oil	▲	●	▲	●	●	●	●	●	■	▲	●	●	▲	●	■	●	■
Argon	●	●	▲	□	●	●	▲	●	■	■	●	▲	◆	▲	□	●	□
Arachlor 1248	●	◆	◆	□	◆	●	▲	●	■	■	■	■	■	▲	■	□	□

- ● Good
- ▲ Fair (OK for static seal)
- ◆ Questionable (OK for static seal)
- ■ Poor
- □ Insufficient data at time of publication

Chemical Compatibility Table

All recommendations for 70° temperature	AFLAS® [TFE/P]	Nitrile (Buna-N)	Butyl	Epichlorohydrin	Ethylene-Propylene	Fluorocarbon (Viton™)	Fluorosilicone	FFKM	Natural Rubber	Chloroprene (Neoprene)	Nitrile, Hydrogenated	Polyacrylate	Polyurethane (Millable, Cast)	Silicone	Styrene Butadiene	Teflon™ Virgin	Vamac®
Aromatic Fuel 50%	▲	▲	■	□	■	●	▲	●	■	■	▲	□	■	■	■	□	■
Askarel Transformer Oil	▲	▲	■	□	■	●	▲	●	■	■	▲	■	■	■	■	●	□
ASTM Fuel A	●	●	■	●	■	●	▲	●	■	▲	●	●	●	■	■	●	●
ASTM Fuel B	●	◆	■	●	■	●	▲	●	■	■	●	■	■	■	■	●	□
ASTM Fuel C	●	◆	■	□	■	●	▲	●	■	■	▲	■	■	■	■	●	■
ASTM Fuel D	■	◆	■	□	■	●	▲	●	■	■	▲	■	▲	■	■	●	□
ASTM Oil One	●	●	■	■	●	●	●	●	■	●	●	●	●	●	■	●	●
ASTM Oil Two	●	●	■	□	■	●	●	●	■	●	●	●	▲	□	■	●	●
ASTM Oil Three	●	●	■	□	■	●	●	●	■	◆	●	●	●	▲	■	●	▲
ASTM Oil Four	●	▲	■	□	■	●	▲	●	■	■	▲	▲	■	■	■	●	●
Automatic Transmission Fluid	●	●	■	□	■	●	□	●	■	▲	●	●	▲	■	■	●	■
Automotive Brake Fluid	▲	◆	▲	□	●	■	■	●	■	▲	◆	■	■	●	●	●	□
Beer	●	●	●	●	●	●	●	●	●	●	●	■	▲	●	●	●	▲
Benzaldehyde	●	■	●	■	●	■	◆	●	■	■	■	■	■	■	■	●	■
Benzene	▲	■	■	■	■	●	▲	●	■	■	■	■	■	■	■	●	■
Benzene Sulfonic Acid	▲	■	■	□	■	●	▲	●	■	▲	■	■	■	■	■	●	□
Benzine (Ligroin)	▲	●	■	□	■	●	●	●	■	▲	●	●	▲	■	■	●	■
Benzoic Acid	▲	◆	■	□	◆	●	▲	◆	■	■	◆	◆	■	◆	■	●	□
Benzophenone	▲	◆	▲	□	▲	●	●	●	□	□	□	■	■	■	■	□	□
Benzyl Alcohol	●	■	▲	■	▲	●	▲	●	■	▲	□	■	■	▲	■	●	■
Benzyl Benzoate	▲	■	▲	□	▲	●	●	●	■	■	■	■	□	□	■	●	□
Benzyl Chloride	●	■	■	□	■	●	▲	●	■	■	■	■	■	■	■	●	□
Bleach Liquor	●	◆	●	□	●	●	▲	●	■	□	▲	■	■	▲	□	●	□
Borax Solutions	□	▲	●	□	●	●	▲	●	▲	●	●	▲	●	▲	▲	●	●
Boric Acid	●	●	●	●	●	●	●	●	●	●	●	■	●	●	●	●	●
Brake Fluid	●	■	●	■	●	■	■	●	■	■	▲	■	□	□	●	●	■
Bromine Gas	●	■	■	□	■	●	▲	●	■	■	□	■	■	■	■	●	□
Bromobenzene	▲	■	■	■	■	●	●	●	■	■	■	■	■	■	■	●	■
Bunker Oil	▲	●	■	□	■	●	●	●	■	■	●	●	▲	▲	■	●	■
Butadiene Monomer	▲	◆	■	■	■	●	▲	●	■	■	■	■	■	■	■	●	□
Butane	▲	●	■	●	■	●	●	●	■	●	●	●	●	●	■	●	●
Butter	●	●	◆	●	●	●	●	●	■	▲	●	●	●	▲	■	●	●
Butyl Alcohol	●	●	▲	□	▲	●	▲	●	●	●	●	■	■	▲	●	●	●
Butyl Carbitol	▲	■	●	□	●	◆	■	●	■	◆	■	■	■	■	■	●	■
Butyl Cellosolve	▲	◆	●	□	●	■	■	●	■	■	◆	■	■	■	■	●	■

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Chemical Compatibility Table

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Butyraldehyde	▲	■	▲	□	▲	■	■	●	■	◆	■	■	■	■	■	●	■
Calcium Carbonate	●	●	●	□	●	●	●	●	●	●	●	■	■	●	●	●	●
Calcium Chloride	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Calcium Hydroxide	●	●	●	●	●	●	●	●	●	●	●	■	●	●	●	●	□
Calcium Hypochlorite	●	▲	●	▲	●	●	▲	●	◆	◆	▲	■	■	▲	●	●	▲
Calcium Nitrate	●	●	●	●	●	●	●	●	●	●	●	●	●	▲	●	●	□
Calcium Sulfide	●	●	●	▲	●	●	●	●	▲	●	●	■	●	▲	▲	●	□
Carbitol	●	▲	▲	□	▲	▲	▲	●	▲	◆	▲	■	■	▲	▲	●	■
Carbolic Acid (Phenol)	□	■	▲	□	▲	●	●	●	■	■	■	■	◆	■	■	●	■
Carbon Bisulfide	●	◆	■	■	■	●	●	●	■	■	◆	◆	■	■	■	●	□
Carbon Monoxide	●	●	●	▲	●	●	▲	●	◆	●	●	□	●	●	▲	●	●
Carbon Tetrachloride	■	◆	■	▲	■	●	◆	●	■	■	▲	■	■	■	■	●	■
Castor Oil	●	●	▲	●	▲	●	●	●	●	●	●	●	●	●	●	●	●
Cellosolve	◆	■	▲	■	▲	■	■	●	■	■	■	■	■	■	■	●	■
China Wood Oil, Tung Oil	▲	●	◆	□	■	●	▲	●	■	●	●	●	◆	■	■	●	▲
Chloracetic Acid	□	■	▲	□	●	■	■	●	■	■	■	■	■	□	■	●	□
Chlordane	▲	▲	■	□	■	●	▲	●	■	◆	▲	□	□	■	■	□	□
Chlorinated Solvents	▲	■	■	□	■	●	●	●	■	■	■	■	■	■	■	●	□
Chlorine Dioxide	▲	■	◆	□	◆	●	▲	□	■	■	■	■	■	◆	■	●	□
Chlorine, Wet	□	■	◆	▲	◆	●	▲	●	■	■	◆	■	■	■	■	●	■
Chlorine, Dry	□	■	■	▲	■	●	●	●	■	■	◆	■	■	■	■	●	■
Chlorine Trifluoride	■	■	■	■	■	■	◆	●	■	■	■	■	■	■	■	●	□
Chloroform	■	■	■	□	■	●	■	●	■	■	■	■	■	■	■	●	■
Chlorosulfonic Acid	●	■	■	□	■	■	■	●	■	■	□	■	■	■	■	●	■
Chrome Plating Solution	□	■	▲	□	▲	●	▲	●	■	■	■	■	■	▲	■	●	□
Chromic Acid	●	■	◆	□	◆	●	◆	●	■	■	■	■	■	◆	■	●	■
Citric Acid	●	●	●	●	●	●	●	●	●	●	●	□	●	●	●	●	●
Cod Liver Oil	●	●	●	□	●	●	●	●	■	▲	●	●	●	▲	■	●	●
Coffee	●	●	●	□	●	●	●	●	●	●	●	■	■	●	●	●	●
Coolanol Monsanto	▲	●	■	□	■	●	▲	●	■	▲	●	■	■	■	■	□	□
Corn Oil	▲	●	◆	●	◆	●	●	●	■	◆	●	●	●	●	■	●	●
Creosote, Coal Tar	▲	●	■	■	■	●	●	●	■	▲	●	●	◆	■	■	●	■
Creosylic Acid	●	■	■	□	■	●	▲	●	■	■	●	■	■	■	■	●	□
Crude Oil (Asphalt Base)	●	▲	■	▲	■	●	▲	●	■	◆	●	●	●	■	■	●	●

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Cyclohexane	▲	●	■	□	■	●	▲	●	■	◆	●	▲	▲	■	■	●	◆
Denatured Alcohol	●	●	●	●	●	●	●	●	●	●	●	■	■	●	●	●	■
Di-ester Lubricant MIL-L-7808	▲	▲	■	□	■	●	●	●	■	■	▲	▲	■	■	■	●	□
Diacetone Alcohol	▲	■	●	■	●	■	■	●	■	▲	■	■	■	▲	■	●	■
Diacetone	▲	■	●	□	●	■	■	●	■	■	■	■	■	■	■	●	■
Dibenzyl Ether	▲	■	▲	■	▲	■	□	●	■	■	■	□	▲	□	■	●	□
Dibutyl Phthalate	▲	■	◆	▲	●	◆	◆	●	■	■	■	■	■	▲	■	●	■
Dichiaro-Butane	●	▲	■	□	■	●	▲	●	■	■	▲	■	■	■	■	●	□
Diesel Oil	●	●	■	●	■	●	●	●	■	◆	●	▲	◆	■	■	●	●
Diethylamine	■	▲	▲	□	▲	■	■	●	▲	▲	◆	■	◆	▲	▲	●	□
Diethylene Glycol	●	●	●	●	●	●	●	●	●	●	●	▲	■	▲	●	●	□
Dimethyl Formamide	●	▲	▲	□	▲	■	■	●	■	■	◆	■	■	▲	■	●	□
Dimethyl Phthalate	▲	■	▲	□	▲	●	▲	●	■	■	■	■	■	□	■	●	■
Dioxane	■	■	▲	□	▲	■	◆	●	■	■	▲	■	■	■	■	●	□
Diphenyl	●	■	■	□	■	●	▲	●	■	■	■	■	■	■	■	●	□
Dow Corning 550	□	●	●	□	●	●	▲	●	●	●	●	●	●	◆	●	●	●
Dow Guard	□	●	●	□	●	●	●	●	●	●	●	◆	◆	●	●	□	□
Dowtherm	●	■	■	■	▲	●	●	●	■	■	■	■	■	◆	■	●	□
Elco 28 Lubricant	□	●	■	□	■	●	●	■	■	◆	●	●	●	▲	■	□	●
Epoxy Resins	□	□	●	□	●	■	□	●	□	●	□	□	□	□	□	□	□
Ethane	□	●	■	□	■	●	▲	●	■	▲	●	●	◆	■	■	●	●
Ethanol	●	●	●	●	●	●	●	●	●	●	●	■	■	▲	●	●	■
Ethyl Acetoacetate	■	■	▲	▲	■	■	■	●	■	□	■	■	■	▲	◆	□	●
Ethyl Alcohol	●	●	●	●	●	●	●	●	●	●	●	■	■	▲	●	●	■
Ethyl Benzene	●	■	■	■	■	●	●	●	■	■	■	■	■	■	■	●	■
Ethyl Benzoate	▲	■	●	□	●	●	●	●	●	■	■	■	■	■	■	●	□
Ethyl Cellulose	□	▲	▲	□	▲	■	■	●	▲	▲	▲	■	▲	◆	▲	●	□
Ethyl Chloride	□	●	■	▲	◆	●	●	●	■	■	●	◆	◆	■	▲	●	■
Ethyl Chlorocarbonate	□	■	■	□	■	●	▲	●	■	■	■	■	■	■	■	●	□
Ethyl Ether	□	◆	■	▲	◆	■	◆	●	■	◆	◆	■	◆	■	■	●	◆
Ethyl Formate	□	■	▲	■	▲	●	●	●	■	▲	■	□	□	□	■	●	□
Ethyl Hexanol	□	●	●	□	●	●	●	●	●	●	□	■	■	▲	●	●	●
Ethyl Mercaptan	□	■	■	■	◆	▲	□	●	■	◆	□	□	●	◆	■	●	□
Ethyl Oxalate	□	●	■	■	●	●	▲	●	●	●	□	■	●	■	●	●	□
Ethyl Pentachlorobenzene		■	■	◆	■	●	▲	●	■	■	□	■	■	■	■	●	□

Chemical Compatibility Table

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Ethyl Silicate	□	●	●	●	●	●	●	●	▲	●	●	□	■	□	▲	●	□
Ethylene	□	●	▲	□	▲	●	●	●	◆	◆	●	▲	▲	□	■	●	□
Ethylene Chloride	□	■	◆	□	■	▲	◆	●	■	■	■	■	■	■	■	□	□
Ethylene Diamine	□	●	●	●	●	■	■	●	▲	●	●	■	■	●	▲	●	□
Ethylene Dichloride	●	■	◆	■	◆	●	◆	●	■	■	□	■	■	■	■	●	■
Ethylene Glycol	●	●	●	●	●	●	●	●	●	●	●	◆	□	●	●	●	●
Ethylene Oxide	□	■	◆	■	◆	■	■	●	■	■	□	■	■	■	■	●	■
Ethylene Trichloride	□	■	◆	□	◆	●	◆	●	■	■	■	■	■	■	■	●	■
Formaldehyde	●	◆	●	▲	●	■	■	●	▲	▲	◆	■	◆	▲	▲	●	■
Freon 11 (MF)	□	▲	■	□	■	▲	▲	▲	■	■	▲	□	■	■	■	●	■
Freon 12	□	●	▲	●	▲	▲	◆	▲	▲	●	●	●	●	■	●	●	□
Freon 13	□	●	●	●	●	●	■	▲	●	●	●	□	◆	■	●	●	□
Freon 21	□	■	■	▲	■	■	□	●	■	■	■	□	□	■	■	●	□
Freon 22	□	■	■	●	●	■	■	●	▲	●	■	▲	■	■	●	●	■
Freon 31	□	■	●	□	●	■	■	▲	▲	●	■	□	□	□	▲	●	□
Freon 32	□	●	●	□	●	■	□	▲	●	●	●	□	□	□	●	●	□
Freon 112	□	▲	■	□	■	▲	□	▲	■	▲	▲	□	▲	■	■	●	□
Freon 113	■	●	■	●	■	▲	■	▲	■	●	●	●	▲	■	▲	●	□
Freon 114	□	●	●	●	■	●	▲	▲	●	●	●	●	●	■	●	●	□
Freon142b	■	●	■	□	■	■	□	▲	▲	●	▲	●	□	■	■	●	□
Freon 502 (F22+F316)	□	▲	●	□	●	■	□	▲	●	●	▲	□	□	□	●	□	□
Freon C318	□	●	●	□	●	■	□	▲	●	●	●	□	□	□	●	●	□
FREON R134A	□	▲	□	□	●	■	□	□	□	●	▲	□	□	□	□	□	□
Freon TF	■	●	◆	●	■	▲	■	▲	■	●	●	□	□	■	▲	●	◆
Fuel Oil	●	●	■	●	■	●	●	●	■	▲	●	●	▲	■	■	●	●
Furan	□	■	■	□	◆	□	□	●	■	■	■	■	■	■	■	●	□
Furfural	▲	■	▲	■	▲	■	■	●	■	■	■	■	◆	□	■	●	■
Furfuryl Alcohol	□	■	▲	□	▲	□	■	●	■	■	■	■	■	■	■	●	□
Gallic Acid	□	▲	▲	□	▲	●	●	●	●	▲	▲	■	■	□	▲	●	□
Gasoline, Automotive	▲	●	■	●	■	●	●	●	■	■	●	■	▲	■	■	●	■
Gelatin	●	●	●	●	●	●	●	●	●	●	●	■	■	●	●	●	●
Glucose	●	●	●	●	●	●	●	●	●	●	●	●	■	●	●	●	●
Glycerin	●	●	●	●	●	●	●	●	●	●	●	◆	●	●	●	●	●
Glycols, General	●	●	●	●	●	●	●	●	●	●	●	■	■	●	●	●	●
Grease, Petroleum Base	●	●	■	▲	■	●	●	●	■	▲	●	●	●	■	■	●	●

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Helium	□	●	●	□	●	●	●	●	●	●	●	●	●	●	●	●	●
Heptane	▲	●	■	□	■	●	●	●	■	▲	●	●	▲	■	■	●	●
Hexane	●	●	■	●	■	●	●	●	■	▲	●	●	▲	■	■	●	■
Hexyl Alcohol	●	▲	◆	□	◆	●	▲	●	●	▲	●	■	■	▲	▲	●	■
Hydraulic Oil, Petroleum Base	▲	●	■	●	■	●	●	●	■	▲	●	●	●	◆	■	●	●
Hydrazine	▲	▲	●	□	●	■	■	●	■	▲	■	□	■	◆	▲	●	□
Hydrobromic Acid	●	■	●	□	●	◆	●	●	●	■	■	■	■	■	■	●	□
Hydrobromic Acid, Gas	●	■	●	□	●	●	■	●	▲	■	■	■	■	■	◆	●	□
Hydrochloric Acid, cold	●	◆	●	■	●	●	▲	●	▲	◆	◆	■	■	◆	■	●	□
Hydrocyanic Acid	●	▲	▲	□	●	●	▲	●	▲	▲	▲	■	■	◆	▲	●	□
Hydrofluoric Acid, cold	●	■	◆	□	◆	●	■	●	■	■	■	■	◆	■	■	●	□
Hydrogen Gas	●	●	●	●	●	●	◆	●	▲	●	●	▲	●	◆	▲	●	●
Hydrogen Peroxide	●	■	◆	▲	▲	▲	▲	●	■	■	◆	■	□	◆	■	●	□
Hydroquinone	□	◆	▲	□	▲	▲	▲	●	▲	■	■	■	□	□	■	●	■
Iodine	□	▲	▲	□	▲	●	●	●	■	■	●	□	■	◆	▲	●	●
Iso Octane	●	●	■	●	■	●	▲	■	■	●	●	●	▲	■	●	●	■
Isobutyl Alcohol	●	▲	●	□	●	●	▲	●	●	●	▲	■	■	●	▲	●	■
Isopropanol	●	●	●	●	●	●	▲	●	●	▲	▲	■	■	●	●	●	■
Isopropyl Acetate	□	■	▲	□	▲	■	■	●	■	■	■	■	■	■	■	●	■
Isopropyl Chloride	□	■	■	□	■	●	▲	●	■	■	■	■	■	■	■	●	□
Isopropyl Ether	■	▲	■	□	■	■	◆	●	■	■	▲	◆	▲	■	■	●	■
JP 3 MIL-J5624	▲	●	■	●	■	●	●	●	■	◆	●	▲	◆	■	■	●	□
JP 4 MIL-J5624	□	●	■	●	■	●	●	●	■	◆	●	▲	◆	■	■	●	□
JP 5 MIL-J5624	□	●	■	●	■	●	●	●	■	◆	●	▲	▲	■	■	●	□
JP 6 MIL-J25656	□	●	■	●	■	●	●	●	■	◆	●	▲	◆	■	■	●	□
Kerosene	●	●	■	●	■	●	●	●	■	▲	●	●	●	■	■	●	●
Lacquers	□	■	■	■	■	■	■	●	■	■	■	■	■	■	■	●	□
Lacquer Solvents	■	■	■	■	■	■	■	●	■	■	■	■	■	■	■	●	■
Lard, Animal Fat	●	●	▲	●	▲	●	●	●	■	▲	●	●	●	▲	■	●	●
Lindol, Hydraulic Fluid (Phosphale EslerType)	□	■	●	□	●	▲	◆	●	■	■	●	■	■	◆	■	●	■
Linoleic Acid	□	▲	■	□	■	▲	□	●	■	■	▲	□	□	▲	■	●	□
Linseed Oil	●	●	◆	●	●	●	●	●	■	▲	●	●	▲	●	■	●	●
Liquefied Petroleum Gas (LPG)	●	●	■	●	■	●	◆	●	■	▲	●	◆	●	◆	■	●	●
Lubricating Oils, Petroleum Base	●	●	■	●	■	●	●	●	■	▲	■	●	▲	▲	■	●	●
Lye	●	▲	●	▲	●	▲	●	●	▲	●	▲	■	▲	▲	▲	●	□

● Good

▲ Fair (OK for static seal)

◆ Questionable (OK for static seal)

■ Poor

□ Insufficient data at time of publication

Chemical Compatibility Table

All recommendations for 70° temperature	AFLAS® [TFE/P]	Nitrile (Buna-N)	Butyl	Epichlorohydrin	Ethylene-Propylene	Fluorocarbon (Viton™)	Fluorosilicone	FFKM	Natural Rubber	Chloroprene (Neoprene)	Nitrile, Hydrogenated	Polyacrylate	Polyurethane (Millable, Cast)	Silicone	Styrene Butadiene	Teflon™ Virgin	Vamac®
Malathion	□	▲	■	□	■	●	▲	●	■	■	▲	□	■	■	■	□	□
Maleic Acid	●	■	▲	□	■	●	□	●	◆	◆	■	■	□	■	■	●	●
Mercuric Chloride	●	●	●	●	●	●	●	●	●	●	●	□	●	●	●	●	□
Mercury	●	●	●	●	●	●	●	●	●	●	●	□	●	●	●	●	●
Methane	●	●	■	●	■	●	▲	●	■	▲	●	▲	◆	■	■	●	●
Methanol	●	●	■	▲	●	◆	●	●	●	●	●	■	■	●	●	●	■
Methyl Acetate	□	■	●	■	●	■	■	●	◆	▲	■	■	■	■	◆	●	■
Methyl Acrylate	□	■	▲	□	▲	■	■	●	■	▲	■	■	■	■	■	●	■
Methyl Alcohol	●	●	●	▲	●	◆	●	●	●	●	●	■	■	●	●	●	●
Methyl Bromide	□	▲	■	□	■	●	●	●	■	■	▲	◆	■	□	■	●	□
Methyl Butyl Ketone	□	■	●	□	●	■	■	●	■	■	■	■	■	■	◆	●	■
Methyl Cellosolve	●	◆	▲	□	▲	■	■	●	■	▲	◆	■	■	■	■	●	■
Methyl Chloride	●	■	◆	□	◆	▲	▲	●	■	■	■	■	■	■	■	●	■
Methyl Ether	□	●	■	□	■	■	●	●	■	◆	●	■	□	●	●	●	□
Methyl Ethyl Ketone (MEK)	■	■	▲	■	●	■	■	●	■	◆	■	■	■	■	■	●	■
Methyl Isobutyl Ketone (MIBK)	■	■	◆	■	▲	■	■	●	■	■	■	■	■	■	■	●	■
Methyl Mercaptan	□	■	◆	■	◆	■	■	●	■	■	■	■	■	■	■	●	□
Methyl Methacrylate	□	■	■	■	◆	■	■	●	■	■	■	■	■	■	■	●	■
Methyl Oleate	□	■	▲	■	▲	▲	▲	●	■	■	■	■	□	■	■	●	□
Methyl Salicylate	▲	■	▲	□	▲	▲	□	●	◆	■	■	□	□	□	◆	●	□
Methylacrylic Acid	□	■	▲	□	▲	■	■	●	■	▲	■	■	■	■	■	●	□
Methylene Chloride	▲	■	■	□	◆	▲	▲	●	■	■	■	■	■	■	■	●	■
MIL-F-25558 (RJ-1)	□	●	■	●	■	●	●	●	■	▲	●	●	●	◆	■	●	□
MIL-F-25656	□	●	■	□	■	●	▲	●	■	■	●	▲	▲	■	■	□	□
MIL-G-25760	□	●	■	▲	■	●	●	●	◆	◆	●	◆	▲	■	◆	□	□
MIL-H-5606	●	●	■	●	■	●	●	●	■	▲	●	●	▲	■	■	□	□
MIL-H-7083	□	●	●	▲	●	▲	●	●	▲	▲	●	◆	◆	●	●	□	□
MIL-J 5624 JP-3, JP-4, JP-5	□	●	■	●	■	●	●	●	■	◆	●	▲	◆	■	■	●	□
MIL-L-25681	□	●	●	●	●	●	▲	●	▲	▲	●	▲	◆	■	●	□	□
MIL-R-25576 (RP-1)	□	●	■	●	■	●	●	●	■	◆	●	●	●	■	■	□	□
MIL-S-3136, Type 1 Fuel	□	●	■	●	■	●	●	●	■	▲	●	▲	▲	■	■	□	□
MIL-S-81087	□	●	●	□	●	●	▲	●	●	●	●	●	●	■	●	□	□
Milk	□	●	●	□	●	●	●	●	●	●	●	■	■	●	●	●	●
Mineral Oils	□	●	■	●	◆	●	●	●	■	▲	●	●	●	▲	■	●	●
Monovinyl Acetylene	□	●	▲	□	▲	●	□	●	▲	▲	●	■	■	▲	▲	●	□

- ● Good
- ▲ Fair (OK for static seal)
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- ■ Poor
- □ Insufficient data at time of publication

Chemical Compatibility Table

All recommendations for 70° temperature	AFLAS® [TFE/P]	Nitrile (Buna-N)	Butyl	Epichlorohydrin	Ethylene-Propylene	Fluorocarbon (Viton™)	Fluorosilicone	FFKM	Natural Rubber	Chloroprene (Neoprene)	Nitrile, Hydrogenated	Polyacrylate	Polyurethane (Millable, Cast)	Silicone	Styrene Butadiene	Teflon™ Virgin	Vamac®
N-Hexaldehyde	□	■	▲	●	●	■	■	●	■	●	■	□	▲	▲	■	■	□
N-Octane	□	▲	■	□	■	●	▲	●	■	▲	▲	■	■	■	■	●	■
Naphtha	●	▲	■	●	■	●	▲	●	■	◆	▲	▲	▲	■	■	●	■
Naphthalene	●	■	■	□	■	●	●	●	■	■	■	□	▲	■	■	●	□
Naphthalenic Acid	▲	▲	■	□	■	●	●	●	■	■	▲	□	□	■	■	●	□
Natural Gas	□	●	■	●	■	●	◆	●	▲	●	●	▲	▲	●	◆	●	●
Neatsfoot Oil	□	●	▲	□	▲	●	●	●	■	■	●	●	●	▲	■	●	□
Nitric Acid (Dilute)	▲	■	■	■	▲	●	▲	●	■	▲	■	■	◆	▲	■	●	■
Nitrobenzene	●	■	▲	■	●	▲	■	●	■	■	■	■	■	■	■	●	■
Nitroethane	●	■	▲	□	▲	■	■	●	▲	◆	■	■	■	■	▲	●	□
Nitrogen, Gas	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Nitrogen Tetroxide	□	■	◆	□	◆	■	■	▲	■	■	■	■	■	■	■	●	□
Nitromethane	●	■	▲	□	▲	■	■	●	▲	▲	■	■	■	■	▲	●	□
Nitropropane	▲	■	▲	□	▲	■	■	●	■	◆	■	■	■	■	▲	●	□
N-Pentane	□	▲	■	□	■	●	▲	●	■	▲	▲	■	■	■	■	●	□
Octyl Alcohol	□	▲	◆	□	◆	●	▲	●	▲	▲	▲	■	■	▲	▲	●	■
OleicAcid	●	◆	■	●	■	▲	□	●	■	◆	◆	■	▲	■	■	●	□
Oleum Spirits	□	▲	■	■	■	●	▲	●	■	◆	▲	◆	■	■	■	●	■
Oronite 8200	□	▲	■	□	■	●	●	□	■	●	▲	□	●	■	■	□	□
Oxalic Acid	●	▲	●	◆	●	●	●	●	▲	▲	▲	▲	▲	▲	●	●	●
Oxygen, Cold	●	▲	●	▲	●	●	●	●	▲	●	■	▲	●	●	▲	●	□
Oxygen, 200-400°F	●	■	■	■	◆	▲	■	●	●	■	■	■	■	▲	■	●	□
Ozone	●	■	▲	●	●	●	▲	●	■	▲	◆	▲	●	●	■	●	●
Peanut Oil	●	●	◆	●	◆	●	●	●	■	◆	●	●	▲	●	■	●	□
Petroleum Oil, below 250°F	□	●	■	●	■	●	▲	●	■	▲	●	▲	▲	▲	■	●	□
Phenol	●	■	▲	◆	▲	●	●	●	■	◆	■	■	◆	■	■	●	■
Phenylhydrazine	●	■	▲	□	▲	●	□	●	●	■	■	■	□	□	▲	●	□
Phosphoric Acid 20%	●	▲	▲	□	●	●	▲	●	▲	▲	▲	◆	●	▲	▲	●	▲
Phosphorous Trichloride	●	■	●	□	●	●	●	●	■	■	■	■	□	□	■	●	□
Pine Oil	●	■	■	▲	■	●	●	●	■	■	■	●	●	■	■	●	□
Potassium Nitrate	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Potassium Sulfate	●	●	●	●	●	●	●	●	▲	●	●	■	●	●	■	■	□
Producer Gas	□	●	■	□	■	●	▲	●	■	▲	●	▲	●	▲	■	▲	□
Propane	□	●	■	●	■	●	▲	●	■	▲	●	●	●	●	■	●	●
Propanol	●	●	●	●	●	●	●	●	●	●	●	■	■	●	●	■	■

● Good
▲ Fair (OK for static seal)
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Chemical Compatibility Table

All recommendations for 70° temperature	AFLAS® [TFE/P]	Nitrile (Buna-N)	Butyl	Epichlorohydrin	Ethylene-Propylene	Fluorocarbon (Viton™)	Fluorosilicone	FFKM	Natural Rubber	Chloroprene (Neoprene)	Nitrile, Hydrogenated	Polyacrylate	Polyurethane (Millable, Cast)	Silicone	Styrene Butadiene	Teflon™ virgin	Vamac®
Propyl Acetate	□	■	▲	■	▲	■	■	●	■	■	■	■	■	■	■	■	□
Propyl Alcohol	●	●	●	●	●	●	●	●	●	●	●	■	■	●	●	●	■
Propylene	□	■	■	□	■	●	▲	●	■	■	■	■	■	■	■	●	□
Propylene Oxide	□	■	▲	□	▲	■	■	●	■	■	■	■	■	■	■	●	□
Pydraul, 230C, 312C, 540C	□	■	■	■	■	●	■	●	■	■	■	■	■	■	■	●	■
Pydraul, 30E, SOE, 65E, 90E	□	■	●	■	●	●	●	●	■	■	■	■	■	●	■	●	■
Pydraul, 10E	□	■	●	■	●	●	■	●	■	■	■	■	■	■	■	●	□
Pyranol, Transformer Oil	□	●	■	■	■	●	●	●	■	▲	●	●	▲	■	■	●	●
Pyrogard 42,43, 53, 55 (Phosphate Ester)	□	■	●	□	●	●	■	□	■	■	■	■	■	■	■	●	□
Radiation	▲	◆	■	□	▲	◆	■	●	◆	◆	◆	◆	◆	▲	◆	●	◆
Rapeseed Oil	□	▲	●	●	●	●	●	●	■	▲	▲	▲	▲	■	■	●	□
Red Oil (MIC-H-5606)	□	●	■	●	■	●	●	●	■	▲	●	●	●	■	■	●	□
RJ-1 (MIL-F-25558)	□	●	■	●	■	●	●	●	■	▲	●	●	●	■	■	□	□
RP-1 (MIL-R-25576)	□	●	■	●	■	●	●	●	■	▲	●	●	●	■	■	□	□
Sea Water	●	●	●	□	●	●	●	●	●	▲	●	■	▲	●	●	●	●
Silicone Greases	●	●	●	●	●	●	●	●	●	●	●	●	●	◆	●	●	●
Silicone Oils	●	●	●	●	●	●	●	●	●	●	●	●	●	■	●	●	●
Silver Nitrate	●	▲	●	■	●	●	●	●	●	●	▲	●	●	●	●	●	□
Skydrol 500	▲	■	▲	■	●	■	◆	●	■	■	■	■	■	◆	■	●	■
Sodium Bicarbonate	●	●	●	●	●	●	●	●	●	●	●	■	●	●	●	●	●
Sodium Carbonate	●	●	●	●	●	●	●	●	●	●	●	■	▲	●	●	●	●
Sodium Chloride	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Sodium Hydroxide	●	▲	●	▲	●	▲	▲	●	●	●	▲	◆	■	▲	●	●	□
Soybean Oil	●	●	◆	●	◆	●	●	●	■	▲	●	●	▲	●	■	●	▲
Steam to 350°F	●	■	■	■	◆	■	■	●	■	■	◆	■	■	■	■	●	■
Stearic Acid	●	▲	▲	▲	▲	●	◆	●	▲	▲	▲	■	●	▲	●	●	□
Stoddard Solvent	●	●	■	●	■	●	●	●	■	▲	●	●	●	■	■	●	◆
Styrene	▲	■	■	□	■	▲	◆	●	■	■	■	■	◆	■	■	●	■
Sucrose Solutions	●	●	●	□	●	●	●	●	●	●	▲	■	■	●	●	●	□
Sulfur Chloride	□	■	◆	□	■	●	●	●	■	◆	■	■	◆	◆	■	▲	□
Sulfur Dioxide Gas, Dry	□	■	▲	□	●	▲	▲	●	▲	■	■	■	□	▲	◆	●	▲
Sulfur Dioxide Gas, Wet	●	■	●	□	●	▲	▲	●	■	▲	■	■	◆	▲	□	●	▲
Sulfur Dioxide, liquefied Under Pressure	□	■	▲	□	●	▲	▲	●	■	■	■	■	□	▲	■	□	□
Sulfur Hexafluoride	□	▲	●	●	●	●	▲	●	■	●	▲	■	▲	▲	■	●	□
Sulfur Trioxide	□	■	▲	□	▲	●	▲	●	▲	■	■	■	■	▲	■	●	□

● Good
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Chemical Compatibility Table

All recommendations for 70° temperature	AFLAS® [TFE/P]	Nitrile (Buna-N)	Butyl	Epichlorohydrin	Ethylene-Propylene	Fluorocarbon (Viton™)	Fluorosilicone	FFKM	Natural Rubber	Chloroprene (Neoprene)	Nitrile, Hydrogenated	Polyacrylate	Polyurethane (Millable, Cast)	Silicone	Styrene Butadiene	Teflon™ Virgin	Vamac®
Sulfuric Acid (Concentrated)	●	■	■	■	◆	●	■	●	■	■	■	■	■	■	■	●	■
Sulfurous Acid	●	▲	●	□	▲	◆	□	●	▲	▲	▲	■	■	■	▲	●	□
Tannic Acid	●	●	●	▲	●	●	●	●	●	●	●	■	●	▲	▲	●	▲
Tartaric Acid	●	●	▲	▲	▲	●	●	●	◆	▲	●	□	●	●	▲	●	▲
Tertiary Butyl Alcohol	●	▲	▲	□	▲	●	▲	●	▲	▲	▲	■	■	▲	▲	●	■
Tertiary Butyl Mercaptan	□	■	■	□	■	●	■	●	■	■	■	■	■	■	■	●	□
Tetrabromoethane	□	■	■	□	■	●	▲	●	■	■	■	■	■	■	■	●	□
Tetrabutyl Titanate	□	▲	▲	□	●	●	●	●	▲	▲	▲	□	□	□	▲	●	□
Tetrachloroethane	□	■	■	□	■	●	▲	●	■	■	■	■	■	■	■	●	□
Tetrachloroethylene	□	■	■	□	■	●	▲	●	■	■	■	■	■	■	■	●	□
Tetraethyl Lead	□	▲	■	□	■	●	▲	●	■	▲	▲	□	▲	□	■	●	□
Tetrahydrofuran	□	■	□	□	◆	■	■	●	■	■	■	■	◆	■	■	●	■
Tetralin	□	■	■	□	■	▲	●	●	■	■	■	■	■	■	■	●	□
Toluene	■	■	■	□	■	▲	▲	●	■	■	■	■	■	■	■	●	■
Transmission Fluid, Type A	□	●	■	●	■	●	●	●	■	▲	●	●	●	▲	■	●	●
Triethanolamine	●	▲	▲	□	●	■	■	●	▲	■	◆	■	■	■	▲	●	▲
Turbine Oil	□	▲	■	●	■	●	▲	●	■	■	●	●	●	■	■	●	●
Turpentine	◆	●	■	●	■	●	▲	●	■	■	●	▲	■	■	■	●	□
Varnish	□	▲	■	□	■	●	▲	●	■	■	▲	■	◆	■	■	●	●
Vinegar	●	▲	●	□	●	●	◆	●	▲	▲	▲	■	■	●	▲	●	▲
W-H-910	□	◆	□	▲	●	●	▲	●	▲	▲	◆	□	■	□	●	□	□
Wagner 218 Brake Fluid	▲	◆	▲	■	●	■	■	●	▲	▲	◆	■	■	◆	●	●	■
Water, Fresh	●	●	●	●	●	●	●	●	●	●	●	■	◆	●	●	●	●
Whiskey	□	●	●	□	●	●	●	●	●	●	●	■	▲	●	●	●	●
White Pine Tar	□	▲	■	□	■	●	●	●	■	■	▲	□	□	■	■	●	□
Xylen	▲	■	■	■	■	●	●	●	■	■	■	■	■	■	■	●	■

● Good
▲ Fair (OK for static seal)
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■ Poor
□ Insufficient data at time of publication

Common Military Specifications

AMS- Aerospace Material Specifications **MIL**- Military Specifications **ASTM**- Automotive Applications

Material Specification	Durometer (+/-5)	Elastomer	Temperature Range °F	Description
AMS 3208	50	Neoprene	-40 to +212	Weather Resistant
AMS 3209	70	Neoprene	-40 to +212	Weather Resistant
AMS 3237F	40	Butyl	-30 to +100	Phosphate Ester Resistant
AMS 3238F	70	Butyl	-30 to +100	Phosphate Ester Resistant
AMS 3301	40	Silicone	-85 to +401	General Purpose
AMS 3302	50	Silicone	-85 to +401	General Purpose
AMS 3303	60	Silicone	-85 to +401	General Purpose
AMS 3304	70	Silicone	-85 to +401	General Purpose
AMS 3305	80	Silicone	-85 to +401	General Purpose
AMS 3336	60	Phenyl Silicone	-121 to +446	Extreme Low Temperature Resistant
AMS 3337	70	Phenyl Silicone	-121 to +446	Extreme Low Temperature Resistant
AMS 3338	80	Phenyl Silicone	-121 to +446	Extreme Low Temperature Resistant
AMS 3382	75, 90	AFLAS®	+23 to +450	Hydraulic Fluid and Synthetic Oil Resistant
AMS 7271	65	Nitrile	-67 to +257	Fuel and Low Temperature Resistant
AMS 7272	70	Nitrile	-15 to +302	Synthetic Lubricant Resistant
AMS-R-83285	60, 80	Ethylen-Propylene	-40 to +212	General Purpose
AMS-R-83485 (MIL-R)	75	Fluorocarbon	-40 to +400	Low Temperature, Fuel Resistant, Low Compresion Set
High Temperature Fluid Resistant and Low Compression Set				
AMS 7259	90	Fluorocarbon	-20 to +400	Resistance QPL Listing
AMS 7276	75		-20 to +400	
AMS 3216	75	Fluorocarbon	-20 to +400	Non QPL
AMS 3218	90		-20 to +400	
AMS-R-83248 (MIL-R)	75, 90		-20 to +500	
AMS-R-25988 (MIL-DTL)				
Class 1	40, 50, 60, 70, 80	Fluorosilicone	-76 to +392	Oil and Fuel Resistant
Class 2	50		-76 to +392	High-Strength Oil and Fuel Resistant
Class 3	75		-76 to +437	High Modulus Oil and Fuel Resistant
A-A-59588 / ZZR-765				
Class 1A	40, 50, 60, 70, 80	Phenyl Silicone	-100 to +425	Low Temp Resistant
Class 1B	40, 50, 60, 70, 80	Phenyl Silicone	-100 to +425	Low Temp Resistant, Low Compression Set
Class 2A	25, 40, 50, 60, 70, 80	Silicone	-80 to +425	High Temperature
Class 2B	25, 40, 50, 60, 70, 80	Silicone	-80 to +425	High Temperatuere, Low Compression Set
Class 3A	30, 50, 60	Phenyl Silicone	-103 to +400	Low Temperature, Tear and Flex Resistant
Class 3B	30, 50, 60, 70, 80	Silicone	-94 to +400	Tear and Flex Resistant

( ) = Military equivalent

Common Military Specifications

AMS- Aerospace Material Specifications **MIL**- Military Specifications **ASTM**- Automotive Applications

Material Specification	Durometer (+/-5)	Elastomer	Temperature Range °F	Description
MIL-PFR-6855				
Class 1	30, 40, 50, 60, 70, 80	Nitrile	-40 to +212	Fuel and Petroleum Oil Resistant
Class 2		Neoprene		Petroleum Oil, Weather, and Ozone Resistant
Class 3		Stryene-Butadiene		Non-Oil Resistant
Class 4		Neoprene		Petroleum Oil, Weather, and Ozone Resistant (contact with Acryilic and Polycarbonate Plastic)
Class 5		Stryene-Butadiene		Non-Oil Resistant (contact with Acryilic and Polycarbonate Plastic)
ASTM D2000				
M1AA710	70	SBR, EP	-40 to +158	Non-Oil Resistant
M1BA710	70	EP	-40 to +212	Non-Oil Resistant
M1BC710	70	Neoprene	-40 to +212	Some Oil Resistant
M1BG710	70	Nitrile	-40 to +212	Oil Resistant
M1CA710	70	EP	-40 to +257	Non-Oil Resistant
M1CH710	70	Nitrile, Epichlorohydrin	-40 to +257	Oil Resistant
M1DA710	70	EP	-67 to +302	Non-Oil Resistant
M1DH710	70	HNBR, Polyacrylic	-40 to +302	Oil Resistant
M1FK606	60	Fluorosilicone	-67 to +392	Oil Resistant, High Heat, Low Temperature
M1GE706	70	Silicone	-67 to +437	High Heat, Low Temperature
M1HK710	70	Fluorocarbon	-13 to +482	Oil Resistant, High Heat

( ) = Military equivalent

7 Special Elastomer Applications

Optimum sealing performance has proven troublesome in certain sealing environments. Therefore, for the following o-ring applications, specific elastomers and actions are recommended.

In some cases, a variety of elastomers may be “acceptable” in a given application. The final material choice may be guided by the secondary operating conditions of the systems; or in the case of “equal” performance, by considerations of cost and availability. We are using the o-ring as an example, but much of this information applies to other seal types.

FRICTION

Standard methods employed for minimizing the effects of o-ring friction include reducing seal squeeze; increasing compound hardness; specifying a low friction compound, such as Teflon™; surface treatment with a low friction coating; and texturing the rubber surface to reduce the amount of contact area.

INTERNAL LUBRICATION

The use of internally lubricated compounds has proven especially effective in applications requiring low friction performance without the reduction of squeeze.

» Best Choice(s)

To date, homogeneously dispersed lubrication in the form of Erucamide (natural fatty acids), Teflon™ and Paraffin waxes have been successfully incorporated into Ethylene Propylene, Nitrile, Neoprene, Fluorocarbon, and Silicone.

EXTERNAL LUBRICATION

Surface treatment of o-rings with lubricants helps to protect against abrasion, pinching, or cutting during installation in parts assembly. External lubrication helps seat the o-rings into grooves with minimum twisting and maximum assembly speed. Parylene, Teflon™ and silicone oil are great choices for external lubricants.

In hydraulic systems where lubricating fluids are nearly always present, surface treatment of o-rings is less essential.

In pneumatic or vacuum application where system fluids are predominantly absent, o-ring surface lubrication is mandatory for effective, low friction opersation and the prevention of seal leakage. O-ring surface lubricants help prevent leakage from around the seal by filling the micropores of both the o-ring and surrounding metal surfaces.

A final benefit of o-ring lubrication is the protection it offers some elastomers from the degrading effects of exposure to oxygen and ozone. In this regard, o-ring surface lubrication acts as a barrier, helping to prevent premature seal aging and extending o-ring service life.

» Precautionary Notes

In all cases requiring o-ring lubrication, make certain to select a lubricant that is compatible with both the o-ring compound and the system chemicals being used. The lubricant, or additive which it contains, should not cause excessive shrinkage or swelling of the o-ring compound.

Also, check the recommended temperature range for the lubricant of choice, making certain to operate within stated limits.

Finally, if system filtration is being employed, check to see that the lubricant is capable of passing through filters prior to use with the system o-rings.

As a general guide, Table H (O-Ring Lubricant Guide), at the end of this section, lists a number of lubricants used with specific o-ring compounds, in the application shown.

Rule of Thumb | **Do not use a lubricant composed of the same material as the o-ring because “like” will dissolve “like.” For example, a silicone lubricant should not be used with a silicone o-ring.**

ROTARY APPLICATIONS

In rotary applications, a turning shaft protrudes through the I.D. of the o-ring, continuously exposing the inside surface of the o-ring to friction-generated heat from the rotating shaft.

Elastomers are poor thermal conductors: if heat is generated faster than it can be dissipated, o-ring failure may result.

To help minimize o-ring heat buildup, especially in applications with shaft rotating speeds in excess of 180 surface feet per minute, the following mechanical design safeguards should be considered where applicable:

- Reduce squeeze to as little as .002" to minimize friction
- Provide ample diametrical clearance to increase fluid flow and dissipate heat
- Select an o-ring made of a hard, self-lubricating compound
- Maintain a system pressure not greater than 250 psi
- Avoid applications requiring lower than-40°F, or higher than +250°F operating temperatures
- Locate the gland as close as possible to the lubricating fluid and as far away as possible from the shaft support bearings
- Assure that relative motion occurs only between the o-ring I.D. and the rotating shaft. Not between the o-ring outside diameter and the gland. This can be accomplished by minimizing eccentric shaft rotation (machining shafts concentric to within 0.0005" TIR), finishing shaft surfaces to 16 RMS for smooth, non-abrasive running; and machining gland surfaces to rougher than 32 RMS to discourage o-ring movement within the gland.

» Best Choice(s)

In rotary applications, polymer selection is based upon abrasion resistance, heat resistance, and the other environmental considerations mentioned above. For related polymer performance properties, refer to the “Material Selection Guide” in Section 6.

EXTREME HIGH TEMPERATURE SITUATIONS

Exposure of o-ring elastomers to extreme high temperatures can cause physical and/or chemical deterioration. When exposed to extremely high temperatures, the o-ring will initially soften and swell within the gland, which causes increased friction in dynamic applications.

High pressure applications are especially prone to failure here because room temperature tests may provide inaccurate results. Over time, irreversible chemical changes occur that increase seal hardness as well as induce compression set and volumetric changes.

In the case of thermoplastic materials, prolonged exposure to high temperatures may cause partial reversion back to basic components. This occurs because thermoplastics are a class of polymers that are composed of individual molecules that are linear in structure and held together and crosslinked by weak intermolecular forces which can be broken by the heat and pressure. Any rubber compound has a point of heat failure which must be individually addressed. (See Temperature Graph 5.4 in Section 5)

Conversely, thermosets are cross-linked by stronger bonds more resistant to heat and pressure.

» Best Choice(s)

A number of special compounds have been developed to provide dependable o-ring sealing performance in high temperature situations. These include Viton™, AFLAS®, perfluoroelastomers, Silicone, Fluorosilicone, and Teflon™. These compounds feature heat resistance to at least 400°F, with FFKM rated to 600°F (for short periods of time).

An additional number of o-ring materials feature temperature resistance to 300°F, with special resistances to particular fluids or environmental factors. Ethylene propylene, for example, features excellent resistance to steam.

Thermoset rubbers can take short durations of high temperature beyond their service temperatures. The longer exposure will eventually cause seal failure and quicker service duration.

Rule of Thumb	**Resistance of elastomers to chemical attack is greatly reduced at elevated temperatures.**

LOW TEMPERATURE SITUATIONS

Low temperature performance is one of the most overlooked properties in seal performance. Exposure to low temperature can contract elastomeric materials, resulting in decreased compression and possible leakage. When seal materials are exposed to a lower temperature than their designed limit, seals become less flexible and brittle. Seals can fail by two modes under low temperature: 1) The seal material will harden when the low temperature limit is reached and resist deformation to pressure causing leak paths; 2) The seal will undergo a compression set, so when heated above the low temperature, this allows for leak. Material selection is key for the low temperature seal performance.

LOW TEMPERATURE TESTING

Three standard low temperature tests are performed to measure material performance. Brittleness (ASTM D2137) measures the ability of a material to withstand breaking when bent at a given temperature for a period of time. Temperature Retraction (ASTM D1329) measures the temperature at which a material returns from an elongated state. Torsional Stiffness Ratio (ASTM D1053) measures the ratio from when a material is twisted, first at room temperature and then at a given low temperature. These tests give some idea of low temperature performance but have limited value for seal applications. One example is that a material might not break at-40°C, but the material could be stiff enough to allow leak paths.

A good indicator for seal performance is Compression Set at Low Temperature (ASTM D1229). This test measures set at 3 min. after exposure to a given temperature and at 30 min. This gives a clear indication of what will happen to a material when exposed to low temperature and allowed to return to higher temperatures. A quick indicator is the Glass Transition Temperature (Tg). This shows the temperature at which the material becomes hard.

» Best Choice(s)

Vinyl Silicone (VMQ) is considered the general polymer. These types of polymers have brittle points to-80°F as tested in A-A-59588 (ZZ-R-765 Class 2B). Phenyl Silicone (PVMQ) is an extreme low temperature polymer with brittle points down to-130°F as tested in A-A-59588 Class 1. Drawbacks with Silicone use are excessive swelling in aliphatic and aromatic hydrocarbon fuels and many lubricating oils.

Fluorosilicone (FVMQ) can be used to-104°F in oil and fuel applications. The addition of the Fluorine group to the polymer chain gives the polymer swell resistance. Many aircraft applications use Fluorosilicone because of low temperatures at higher altitudes and contact with JP-4, de-icing agents and hydraulic oils.

General polymers can be used, but service temperatures need to be watched. Many EP polymers work at-85°F. Nitrile (Buna) compounds when formulated correctly can withstand -40°F to-85°F. With Nitrile, the better the low temperature performance, the more swell you will have in oils and fuels. Fluorocarbons (Viton™) can be used from-13°F to-40°F. To reach the lower limit, low temperature polymers must be used. This normally costs more than standard polymers but must be used for this type of service.

Teflon™ is outstanding in low temperature service. With good resistance to gas permeation, Teflon™ is capable of sealing to-300°F. Teflon™'s drawback is poor elastic memory and a tendency to “creep” when not confined. Addition of fillers and energizers can help limit some of these drawbacks.

ABRASION RESISTANCE

Applications involving oscillation, reciprocation, or rotation induce friction and typically generate wear regions on one surface of the seal. This leads to premature seal failure, system contamination, and eventually system malfunction. When feasible, the use of lubricants, improved surface finishes, or system filtration reduces the effect from friction. However, proper compound selection is essential for extended seal utility.

» Best Choice(s)

Carboxylated Nitrile (XNBR) has superior wear resistance properties, when compared to that of the base compound Nitrile, through the addition of carbon in the crosslinking organization. Polyurethane also has outstanding resistance to abrasion and is typically employed in high-pressure applications.

FDA FOOD APPLICATIONS

Seals proposed for use by the food processing field are often required by law to be comprised of only the compound ingredients determined by the U.S. Food and Drug Administration (FDA) to be safe for food contact.

Such o-ring compounds must consist exclusively of the ingredients listed in the FDA's "White List" located in the Code of Federal Regulations (Title 21) section number 177.2600. It is the responsibility of the o-ring manufacturer to utilize food grade materials only from the white list of FDA sanctioned ingredients. These compounds tend to have a high compression set due to the limit of cures allowed.

» Best Choice(s)

Food service o-rings that have thus far met FDA white list requirements have been produced primarily from the elastomers Ethylene Propylene, Fluorocarbon, Nitrile and Silicone.

MEDICAL APPLICATIONS

Medical equipment seal applications, and/or applications involving implantation of devices within the human body require strict compliance with FDA Class VI and ISO 10993 imposed regulations.

Regarding all medical o-ring applications, please contact your Apple Rubber representative from the initial stages of product design and we will work with you step-by-step to meet all applicable governmental requirements.

» Best Choice(s)

Since all medical devices are unique by their nature, the best choice will be different for each application. Normally, materials that comply with USP Class VI or ISO10993 are used.

NSF APPLICATIONS

The National Sanitation Foundation (NSF) is recognized for its health related specifications and is available for certification of rubber compounds used in the drinking water industry. Prior to NSF certification, extensive testing, such as a water extraction analysis, must be performed on the submitted rubber compound. Please contact Apple Rubber for specific application requirements regarding NSF material certification.

» Best Choice(s)

Because each compound must be individually submitted for NSF approval, there is no relative superior compound selection.

UNDERWRITERS LABORATORIES RECOGNIZED COMPOUNDS

The Underwriters Laboratories is an organization that has established standards for elastomeric compounds in specific service environments. In order to display the UL trademark label, annual tests must be performed to ensure that the compounds will exceed the conditions they normally encounter.

Apple Rubber has a variety of compounds listed by UL of applications such as propane, natural gas and heating oils. Apple Rubber routinely submits new compounds for UL approval in different service environments.

If you want a UL-registered compound, you must be sure to specify it.

WATER AND STEAM STERILIZATION

Immersion in water adversely affects many elastomers by inducing considerable compound swell. As increased swell means increased o-ring volume and friction, excessive water swell precludes the use of a number of elastomers in dynamic (moving) situations.

As water is converted to steam, o-ring elastomers are exposed to the degrading effects of heat, in addition to water swell. If heat ranges are exceeded, o-ring materials may assume the condition of a sponge, soaking up gases and fluids, leading to a partial or total loss of sealing properties.

» Best Choice(s)

Silicone, Ethylene Propylene, AFLAS®, and Hydrogenated Nitrile, for example, are good performers in water and steam.

Perfluoroelastomers are excellent performers in both water and steam, especially at elevated temperatures.

GAMMA STERILIZATION

Gamma radiation affects polymers by either breaking the intermolecular bonds (which promotes embrittlement) or increasing the degree of cross linking (which increases compression set). Both of these reactions occur simultaneously, with one being predominant, depending on the elastomer and additives used. Additionally, radiation may affect physical properties such as tensile strength, elongation and discoloration of certain elastomers.

» Best Choice(s)

Due to low levels of radiation used in sterilization, Silicone, peroxide cured EP, or Viton™ can be used.

ETO STERILIZATION

Low dosage of ethylene oxide is used. Ethylene oxide can swell most seal materials.

» Best Choice(s)

Peroxide cured EP and Silicones can be used since low exposure to Ethylene oxide is normal for the sterilization process.

AUTOMOTIVE FUELS

Gasoline is a varying blend of aromatic and aliphatic hydrocarbons with alcohols at varying levels are being used to decrease oil consumption. Alcohols are very oxidizing and can cause swell.

Standard FKM materials work for non-blended gasoline. High Fluorine FKM is needed for blended fuels. NBR and HNBR can be used for all blends.

» Best Choice(s)

A check of the “General Properties of o-ring Elastomers” chart in Section 6 shows that Teflon™, Fluorocarbon and Epichlorohydrin possess enhanced resistance to exposure to aromatics, aliphatics and alcohols, over a working temperature range suitable for automotive use. Check with an Apple Rubber representative for biofuels and high-methanol fuels.

Additionally, Nitriles, specially compounded to reduce swelling in gasoline, are sometimes employed for automotive use.

BRAKE FLUID APPLICATIONS

Contact with brake fluid inevitably causes either seal swelling or shrinkage to some degree, depending on the elastomeric compound. This results in excessive or insufficient compression and leads to seal failure. Swell or increase in volume is also usually accompanied by a decrease in hardness, which causes a reduction in abrasion and tear resistance and may allow seal extrusion under high pressure. Also, seal failure due to swelling is accelerated in dynamic applications because of the heat generated from friction.

» Best Choice(s)

Ethylene Propylene, when specifically compounded for brake fluid service, is the elastomeric compound of choice. It allows a relatively nominal amount of swell while attaining service temperatures to 250°F. With the addition of different types of brake fluid, please contact Apple Rubber for assistance in the matching of elastomer compound to service fluid. Some automobiles use mineral oil-based brake fluids which can attack EP rubber.

CONTACT WITH PLASTIC SURFACES

With the increasing use of plastic parts in many areas of modern manufacturing, it has become mandatory for o-rings to effectively seal against an ever-widening variety of plastic as well as metal surfaces.

The problem encountered with o-ring contact with plastics is the adverse effect of compound ingredients, such as plasticizers, inducing surface cracking (“crazing”) in plastics. This crazing may eventually lead to physical weakness and/or failure of the plastic structure.

» Best Choice(s)

Ethylene-Propylene, Fluorocarbon and Silicones; special formulated Nitriles can be used. Normal Nitriles use the same plasticizers that soften most plastics. It is very important to identify when a seal material is going to be used with plastics.

NOTE: The above listed information is intended to be used as a general guide only. Please contact us for specific information.

FACE SEAL APPLICATIONS (NON-ROUND)

Some face seal applications may require a rectangular groove configuration. In order to use a standard round o-ring, the inside corner radius of the groove should not be less than three times (3X) the o-ring cross-section diameter.

Use the recommended gland design for static seals from Table A in Section 4. The length of the o-ring centerline should be equal to the length of the groove centerline. Following is an equation to assist in determining the o-ring inside diameter.

o-ring ID = (Groove CL length / 3.14) - o-ring CS

If standard round o-ring cannot be applied to your face seal application, then contact Apple Rubber for assistance with designing a custom molded gasket solution.

LOW PERMEABILITY

To some degree all elastomers are permeable to gases. The rate of gas permeation through an o-ring varies by material compounding; material hardness; degree of squeeze; presence or absence of lubrication; size of o-ring cross section; and the pressure, temperature and type of gas being sealed.

Typically, harder compounds containing more carbon black feature lower diffusion rates.

In the case of Nitriles, increasing acrylonitrile content results in decreased permeability.

Laboratory tests indicate that lubricated o-rings are significantly less permeable than unlubricated rings. These same tests further demonstrate that increased seal squeeze results in decreased permeability in unlubricated situations.

» Best Choice(s)

In general, Butyl is best in airtight situations. FKM is best for vacuum applications.

NOTE: Fluorosilicone and Silicone provide the least resistance to gas permeation.

VACUUM SITUATIONS

To make effective vacuum seals, o-rings must be comprised of elastomeric materials featuring low gas permeability, low weight loss under vacuum, and good compression set characteristics.

» Best Choice(s)

Fluorocarbon offers good to excellent resistance to gas permeation and low weight loss in vacuum applications.

As an added measure of leak prevention, lubrication of o-rings with vacuum grease helps to fill the microscopic pores of surrounding glandular surfaces which have been machined to the recommended 16 to 32 RMS finish.

OUTGASSING

Most rubber compounds contain small quantities of oil and other ingredients that will become volatile under vacuum conditions. Evidence of this "outgassing" is apparent as a thin film deposited on surrounding surfaces. Optical and electrical contact applications are of special concern in this situation as they incorporate sensitive surfaces that must remain uncontaminated. Other compounds exhibit some degree of weight loss in the form of water vapor which may act as a contaminant in some applications. While this process is inevitable, it is accelerated at elevated temperatures and in high vacuum situations.

» Best Choice(s)

"Post curing" elastomeric compounds such as Viton™, Fluorosilicone, and Silicone prior to service removes many of the unwanted volatiles and improves physical properties by increasing the degree of crosslinking. Other compounds, such as Nitrile and natural rubber, do not usually benefit as much from this process as the previous compounds.

COMPRESSION SET RESISTANCE

The final requirement for effective vacuum sealing involves the specification of o-ring elastomers with good compression set characteristics. Employing a seal squeeze of up to 40% inhibits media flow through the seal. This squeeze also forces the o-ring to conform to the surface irregularities of the gland, helping to further prevent leakage. Keep in mind, however, that because of the decreased groove depth, increased groove width is essential.

» Best Choice(s)

In terms of compression set resistance, Fluorocarbon silicone (Fluorosilicone) exhibits excellence compression set at high temperatures. Compression set is a factor of temperature and time. Most compounds are good at room temperature applications.

DRIVE BELT APPLICATIONS

O-Rings provide excellent service in low power drive belt assemblies because they are inexpensive, easy to install, and the use of tensioning devices are not required.

When using o-rings as drive belts, certain design considerations should be observed such as maintaining between 8% to 12% stretch on the seal inside diameter. Also, the pulley grooves should be round and match the o-ring's cross section in depth and width while ensuring that the pulley diameter at the bottom of the groove is no less than 4 times the o-ring cross section.

» Best Choice(s)

Ethylene propylene (EP) (peroxide cured) is the primary elastomeric choice because of the low stress relaxation, good flex life, abrasion resistance, and high temperature resistance. However, poor resistance to petroleum-based lubricating oil limits its application range.

Polyurethane, unlike EP, demonstrates excellent resistance to petroleum-based lubricating oils while maintaining high abrasion resistance, tensile strength, and flex life. Stress relaxation (loss of tension), however, is relatively higher and the service temperature limit (to 130°F) is somewhat lower, when compared to EP.

Neoprene is generally specified when service temperatures exceed the limit of Polyurethane (to 180°F) and possible contact with petroleum fluids. Abrasion resistance is good, but EP displays superior flex life and stress relaxation properties. HNBRs are now being used for their superior tensile strength and oil resistance.

AGE CONTROL/SHELF LIFE

As it relates to the internal chemical degradation of elastomer performance properties over time, the term "aging" is misleading. In fact, it is the exposure of o-ring elastomers to stressful environmental factors during storage that ultimately causes changes in performance properties over time.

Based on ARP5316, which addresses general requirements for data recording, packaging and storing aerospace elastomeric seals, the following conditions are recommended:

- Ambient temperature not exceeding 100°F
- Exclusion of air (oxygen)
- Exclusion of contamination
- Exclusion of light (especially ultra-violet)
- Exclusion of ozone-generating electrical devices
- Exclusion of radiation
- Storage of o-rings in sealed polyethylene bags, inside cardboard containers helps assure maximum shelf life

COMPOUND COLORIZATION

In non-silicone o-ring performance applications, it must be remembered that partial or total replacement of carbon black with tinted, non-black fillers WILL result in some modifications of physical properties.

In all cases of compound colorization, therefore, it is essential that colorized o-ring samples be tested in the actual application under consideration, prior to inclusion in the manufacturing process.

AUTOMATIC ASSEMBLY

The increasing use of automatic equipment for the feeding and installation of o-rings requires greater emphasis on the dimensional quality of the o-ring and its packaging. With automatic installation, there are two environments that must be addressed: the environment of the application, and the environment of the automatic assembly process. Each of these applications will require separate dimensional and material considerations. Of course, the installation considerations must always remain secondary to the requirements of the application environment.

Some of the factors that must be considered when automatically installing o-rings are distortion, coating, and foreign matter. Failure to consider one of these factors may cause an unacceptable frequency of downtime.

CONCENTRATED ACIDS AT ELEVATED TEMPERATURES

A number of elastomers possess good resistance when exposed to dilute acids at room temperature.

These materials include AFLAS®, Butyl, Epichlorohydrin, Ethylene Propylene, Fluorocarbon, Fluorosilicone, Perfluoroelastomer, Natural Rubber, Chloroprene (Neoprene) Nitrile, and Teflon™.

The acid resistance of these compounds, however, significantly lessens with both increasing acid concentrations and rising temperatures.

» Best Choice(s)

As temperatures and concentrations of nitric and hydrochloric acids rise, perfluoroelastomers such as Kalrez or Chemraz have demonstrated good performance in lab tests.

As temperatures rise above 158°F, only the chemical inertness of Teflon™ can be relied upon for maintenance of a seal exposed to hydrochloric or nitric acids.

NOTE: Teflon™ has been laboratory tested (by DuPont) for 168 hours of exposure to 37% hydrochloric acid, at 248°F, with only 0.03% of observed weight gain. It has further been tested for 12 months of exposure to 10% nitric acid, at 158°F, with 0.1% weight gain. Teflon™ has also been shown by DuPont to undergo only slow oxidative attack by 70% nitric acid, under pressure, at 480°F.

EMI SHIELDING

Electromagnetic interference (EMI) is composed of both electric and magnetic components, and either can be the source of interference. Often, it is critical to shield electronic devices from EMI, which is done via either reflection or absorption. By the suspension of conductive fillers such as silver or nickel in the elastomer binder, a compound suited for shielding or grounding is available for service.

TABLE H O-Ring Lubricant Guide

Elastomer	Apple Rubber Material Designation	Applications	Lubricants		
			Optimum	Temperature Range °F	Manufacturer
Nitrile	BN	Hydraulic Oils & Fuels Extreme Service Automotive Vacuum Food Processing	Petrolatum Barium Grease Krytox™ AUT Krytox™ LVP Gel 807	-20 to 180 -20 to 300 -47 to 392 -40 to 200 -40 to 257	Various Various Chemours Co. Chemours Co. Nye Lubricant
Neoprene	CR	Hydraulic Oils Vacuum	Petrolatum Krytox™ LVP	-20 to 180 -40 to 200	Various Chemours Co.
Ethylene-Propylene	EP	Potable Water Medical Fluid Medical Fluid Medical Grease	Gel 880FG Dow 360 MED-361 MED-9011, MED-9021, MED-9031	-40 to +400 -40 to 250 -85 to 400 -85 to 400	Nye Lubricants Dupont NuSil Technology NuSil Technology
Styrene Butadiene	SB	Brake Fluids	Molykote® 4 or 55	-40 to 250	Dupont
Polyurethane	CP	Oils & Fuels Heavy Duty	Petrolatum Barium Grease	-24 to 180 -20 to 300	Various Various
Butyl	BU	Vacuum	Krytox™ LVP	-40 to 200	Chemours Co.
Silicone	SL	General High Temp Medical (dry coating) Medical (dry coating) Medical Fluid Medical Grease	Petrolatum FS 1292 AdCoat® 10-7020 Parylene N MED-460 MED-6731	-20 to 300 -20 to 400 -85 to 350 -85 to 350 -85 to 350 -85 to 350	Various Dow Corning Co. Adelhelm Specialty Coating Systems NuSil Technology NuSil Technology
Fluorosilicone	FS	Oil or Fuel High Temp Medical Fluid Medical Grease	Petrolatum Molykote® 4 or 55 MED-361 MED-9011, MED-9021, MED-9031	-20 to 180 +32 to 350 -85 to 400 -85 to 400	Various Dupont NuSil Technology NuSil Technology
Fluorocarbon	VT	Hydraulic Vacuum & High Temp Aerospace Medical Fluid	Petrolatum Molykote 55 Krytox™ FPG-028 MED-361	-20 to 180 -65 to 400 -99 to 399 -85 to 400	Various Dupont Chemours Co. NuSil Technology

8 Troubleshooting

COMMON REASONS FOR O-RING FAILURE

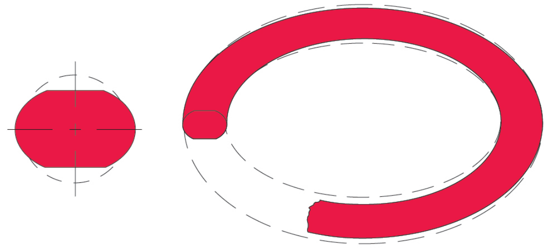
O-Rings typically fail in their applications because of the combined adverse effects of several environmental factors.

The most common causes of o-ring failure have been found to be:

- Improper gland design; allowing for too much or too little compression, not enough room for seal expansion, and tolerance stack-up
- Incorrect o-ring size
- Incompatibility of o-ring elastomer and environmental elements
- Improper o-ring installation
- Inadequate o-ring lubrication

The combination of stresses on the o-ring can be complex and difficult to evaluate. Therefore, it is very important that both the o-ring compound and size be tested in the real environment of its service. The following examples are a classification of the types of o-ring failure that can occur.

COMPRESSION SET



» Failure Pattern

Common to both static and dynamic seals, compression set failure produces flat surfaces on both sides of the o-ring's cross section.

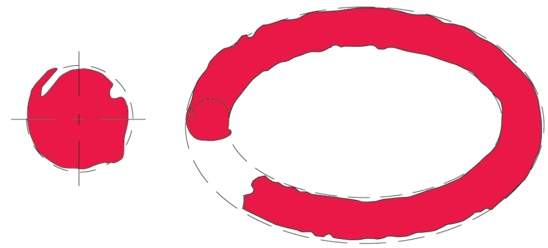
» Problem Sources

- Selection of elastomer with poor compression set properties
- Low heat resistance of material
- Excessive swelling of o-ring material in system fluid
- Too much squeeze to achieve seal
- Incomplete curing (vulcanization) of o-ring material during production
- Operating temperature too high for rubber used

» Suggested Solutions

- Employ a low set elastomer or higher temperature rated material
- Specify an o-ring material that resists both operating and friction generated heat
- Re-check o-ring material compatibility with system chemicals
- Reduce o-ring squeeze if possible
- Inspect incoming o-rings for correct physical properties
- Employ a low-set elastomer or higher temperature rated material

EXTRUSION AND NIBBLING



» Failure Pattern

Typical of high pressure systems, this pattern can be identified by the many small bites (nibbles) taken from the o-ring on the low pressure (downstream) side.

» Problem Sources

- Excessive clearances
- Excessive system pressure
- O-Ring material too soft
- Degradation of o-ring by system fluid
- Irregular clearance gaps caused by eccentricity
- Improper machining of o-ring gland (sharp edges)
- O-ring size too large for gland

» Suggested Solutions

- Decrease gland clearances by machining
- Use back-up rings to prevent extrusion
- Use harder o-ring material
- Re-check elastomer compatibility with system chemicals
- Increase rigidity and improve concentricity of metal components
- Break sharp edges of gland to a minimum radius of .005"
- Install proper size o-ring
- Consider a reinforced composite seal such as rubber-bonded-to-metal

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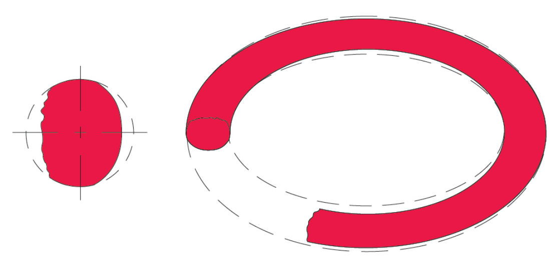
ABRASION



» Failure Pattern

Occurring primarily in dynamic seals involving reciprocating, oscillating, or rotary motion, this failure pattern can be identified by a flattened surface on one side of the o-ring's cross section.

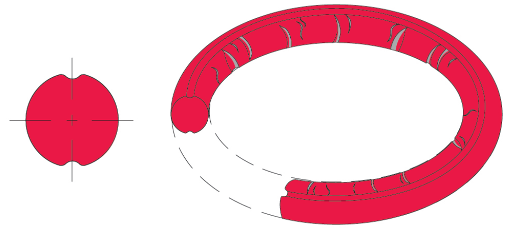
» Problem Sources

- Metal surfaces too rough (acting as an abrasive)
- Metal surfaces too smooth causing inadequate lubrication
- Poor lubrication
- Excessive temperatures
- System contaminated with abrasives

» Suggested Solutions

- Use recommended metal finishes
- Provide adequate lubrication (consider internally-lubed o-rings)
- Check material compatibility with system temperature
- Eliminate abrasive contamination with filters and/or wiper seals
- Consider changing to a more abrasive resistant o-ring material such as carboxylated nitrile or urethane

HEAT HARDENING AND OXIDATION



» Failure Pattern

Seen in both static and dynamic seals, the surface of the o-ring appears pitted and/or cracked, often accompanied by the flatness of high compression set.

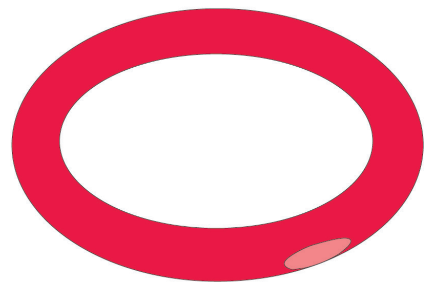
» Problem Sources

- Excessive temperature causing elastomer hardening
- Evaporation of plasticizers
- Cracking from oxidation

» Suggested Solutions

- Specify high temperature o-ring materials with antioxidants
- Lower the operating temperature

INSTALLATION DAMAGE



» Failure Pattern

Occurring in both static and dynamic seals, this failure mode is marked by short cuts, notches, skinned or peripherally peeled surface.

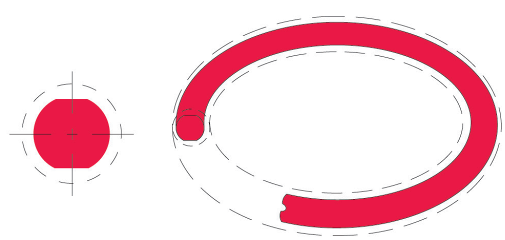
» Problem Sources

- Sharp edges on mating components of the o-ring gland
- Sharp threads over which the o-ring must pass during assembly
- Insufficient lead-in chamfer
- Oversize o-ring ID on piston
- Undersize o-ring ID on rod
- Twisting or pinching of o-ring during installation
- No o-ring lubrication during installation
- Low tear resistant elastomers such as Silicone

» Suggested Solutions

- Break all sharp edges
- Cover threads with tubes or tape during o-ring installation
- Provide a 15-20° lead-in chamfer
- Install correctly sized o-rings and use lubrication during assembly

PLASTICIZER EXTRACTION



» Failure Pattern

Occurring in both static and dynamic seals, primarily in fuel system service, this failure pattern is marked by loss of physical volume.

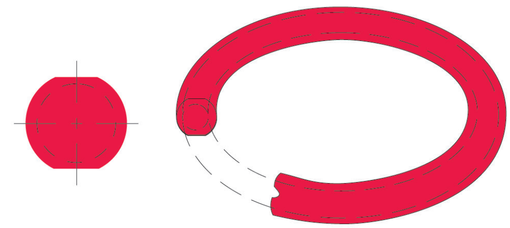
» Problem Sources

- Extraction of plasticizer by system chemicals
- High temperature volitizes rubber plasticizer and outgasses

» Suggested Solutions

- Employ chemically compatible o-ring material
- See Chemical Compatibility Table (Section 6)
- Use high temperature plasticizers
- Use plasticizers that are not soluble in system chemicals

EXCESSIVE SWELL



» Failure Pattern

Easily identified by a marked increase in seal dimensions and occurring in both static and dynamic situations. Results in a reduction of physical properties and can result in improper sizing between seal and gland. Dynamic applications are especially prone in that friction accelerates seal failure.

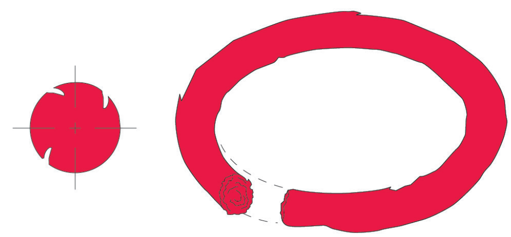
» Problem Sources

- Like a sponge, the seal absorbs the surrounding fluids and swells to the point of malfunction because of incompatibility between seal compound and system environment (i.e. chemical incompatibility, high humidity, etc.)

» Suggested Solutions

- Employ a chemically compatible o-ring material
- See Chemical Compatibility Table (Section 6)

SPIRAL FAILURE



» Failure Pattern

Generally found on long stroke, hydraulic piston seals, the surface of the o-ring exhibits a series of deep, spiral 45 degree angle cuts.

» Problem Sources

- Caused when some segments of the o-ring slide while other segments simultaneously roll
- At a single point on its periphery, the o-ring gets caught on an eccentric component, or against the cylinder wall, causing twisting, the development of 45 degree angle and surface cuts

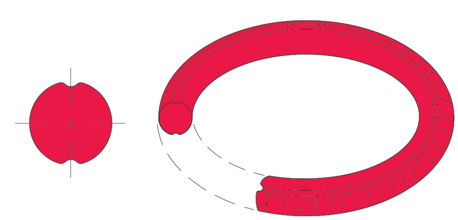
» Contributing Conditions Include

- Eccentric components
- Wide clearance combined with side loads
- Uneven surface finishes
- Inadequate lubrication
- Excessive o-ring material softness
- Too slow stroke speeds

» Suggested Solutions

- Check for out-of-round cylinder bore
- Decrease clearance gap
- Machine metal surfaces to 10-20 micro-inch finish
- Improve lubrication (consider internally-lubed o-rings)
- Increase o-ring material hardness and/or cross section
- Employ anti-extrusion back-up rings

WEATHER OR OZONE CRACKING



» Failure Pattern

Occurring in both static and dynamic seals exposed to atmospheres containing ozone and other air pollutants, this failure mode is marked by the appearance of many small surface cracks perpendicular to the direction of stress.

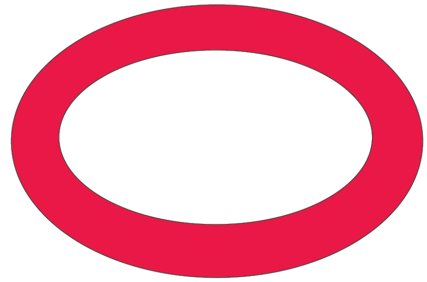
» Problem Sources

- Ozone attack of the polymer chains causing o-ring cracking

» Suggested Solutions

- Employ o-ring elastomers that are resistant to ozone attack
- See "General Properties of O-Ring Elastomers" (Section 6)
- Note: NBR will experience ozone attack when exposed to environmental elements

FAILURE WITHOUT VISIBLE EVIDENCE ON SEAL



» Failure Pattern

Of the various types of seal failure, this is among the hardest to diagnose because the result of the problem is not visible on the o-ring.

» Problem Sources

- Lack of compression
- Tolerance stack-up
- Eccentric components
- Parting lines/flash
- Improper seal/gland volume relationship

» Suggested Solutions

- Maintain recommended compression range for the application
- Identify the amount of stretch as it reduces the o-ring cross section with increased stretch
- Determine the component tolerance stack-up as it directly affects the seal cross section
- Consider maximum component shift in design to ensure that compression is still contained within the recommended compression range
- Avoid parting lines in o-ring grooves as they tend to be areas of flash and mismatch
- Ensure that the o-ring gland volume surpasses the o-ring volume to allow for seal expansion without seal detriment

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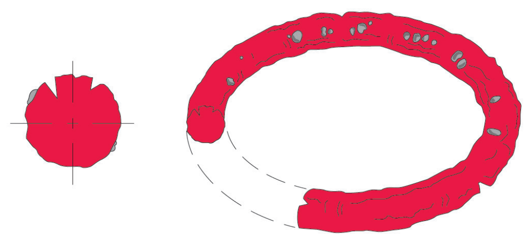
EXPLOSIVE DECOMPRESSION



» Failure Pattern

Marked by random short splits or ruptures going deep into the o-ring's cross section. When the o-ring is first removed, the surface may also be covered with small blisters.

» Problem Sources

- Absorption of gas by o-ring while operating in high pressure conditions
- Subsequent rapid decrease in system pressure traps gas within the o-ring's micropores, causing surface blisters and ruptures as the gas escapes

» Suggested Solutions

- Increase time for decompression
- Increase material hardness to 80-95 durometer range
- Reduce o-ring cross sectional size
- Specify a decompression resistant material, such as HNBR

OTHER PROBLEMS

If you have been unable to diagnose your current problem within the guidelines provided in the preceding pages, please refer to the EAR (Engineering Assistance Request) form at the back of this catalog. Make a copy, complete the form, and fax it to us at (716) 684-8302. You can also find the EAR form on Apple Rubber's Website at applerubber.com which enables you to send your request via the Internet. We will be glad to share our many years of seal experience with you.

9 Sizes and How to Order

HOW TO ORDER APPLE RUBBER O-RINGS

Apple Rubber o-rings and MicrOring™ seals are specified by three characteristics: size, hardness, and material. Prior to seal specification, please check for availability. We add to our tooling list all the time.

» Size

Standards are specified by their AS568 or ISO 3601 dash number. Non-standards are referenced by I.D. and C.S. (cross section). Although we only include the AS568 standard sizes in this guide, Apple Rubber has a vast inventory of non-standard and metric sizes. Visit our website at applerubber.com for more information. And, if you still don't find the size you are looking for, please keep in mind that Apple Rubber provides complete customized work to meet your special needs.

» Hardness

This is specified by a two-digit Shore A durometer number, ranging from 20 (soft) to 90 (hard), depending on the type of elastomer. Our standard durometer is 70 Shore A, except for Viton™ which is 75 Shore A. Standard durometer tolerance is ±5.

» Material

Our standard range of materials is designated by a two-letter abbreviation for each elastomer. See Section 6 for designations and further discussions of materials.

SHRINKAGE SIZE ADJUSTMENT

It is important to note that ALL o-ring materials shrink to some extent during molding. Over time, certain o-ring materials have been identified as possessing similar shrink rates, and are therefore used as o-ring size standards. The nominal o-ring sizes listed in this catalog are based upon a 70 durometer Nitrile. For o-ring materials other than 70 durometer Nitrile, please contact Apple Rubber, as extensive tooling is available for high shrink compounds.

Standard Tolerances for O-Ring Cross Sections

Cross Section	Tolerance (±)
Up to .104	.003
.139	±.004
.210	±.005
.275	±.006
.375	±.008

PROVIDE THE FOLLOWING WHEN ORDERING

- Quantity of o-rings
- Size by AS568 dash number, or I.D. and C.S., if ordering a non-standard
- Material by hardness and two-digit material

» Examples

Standard O-Ring – If ordering 10,000 pieces of an AS568-110 in 70 durometer Silicone your order would read: **10,000 AS568-110 70SL**

Non-Standard – If ordering 25,000 pieces with an internal diameter of .144" and a cross section of .025" 70 durometer Buna-N your order would read: **25,000 .144 I.D. x .025 C.S. 70BN**

HOW TO ORDER CUSTOM PARTS

For assistance with seal design, prototypes and production orders on custom parts, please contact an Apple Rubber team member or fill out an Engineering Assistance Request (EAR) on our website for custom orders and help from our engineers.

TO PLACE ORDERS OR QUOTATIONS

Phone: (716) 684-6560
Fax: (716) 684-8302
E-mail: info@applerubber.com
Online: applerubber.com

For complete list of o-ring seal sizes, please use the

TOLERANCES FOR CUSTOM MOLDED PARTS

The following tables illustrate different levels of tolerance control for all elastomeric parts. However, these standard tables do not take into account specific design concerns such as allowable flash. For assistance, please contact Apple Rubber for specific recommendations.

» RMA Designation "A1" HIgh Precision

Drawing designation “A1” is the tightest tolerance classification and indicates a high precision product. Such products require expensive molds, fewer cavities per mold, costly in-process controls and inspection procedures. It is desirable that the exact method of measurement be agreed upon between rubber manufacturer and customer, as errors in measurement may be large in relation to the tolerance.

» RMA Designation "A2" Precision

Drawing Designation “A2” tolerances indicate a precision product. Molds must be precision machined and kept in good repair. While measurement methods may be simpler than with Drawing Designation “A1", careful inspection will usually be required.

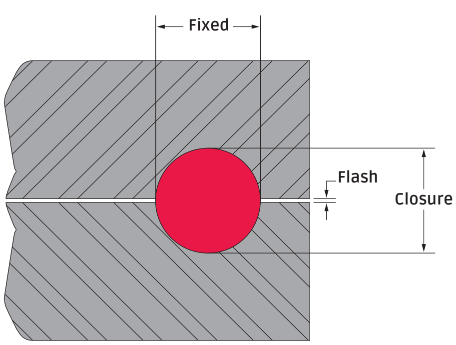


Illustration 9.1

Fixed – Dimensions not affected by flash thickness variation
Closure – Dimensions affected by flash thickness variation

“A1” High Precision

Size (Inches) Above Incl.	Fixed	Closure
0-.40	±.004	±.005
.40-.63	±.005	±.006
.63-1.00	±.006	±.008
1.00-1.60	±.008	±.010
1.60-2.50	±.010	±.013
2.50-4.00	±.013	±.016
4.00-6.30	±.016	±.020

Size (Millimeters) Above Incl.	Fixed	Closure
0-10	±.10	.13
10-16	.13	.16
16-25	.16	.20
25-40	.20	.25
40-63	.25	.32
63-100	.32	.40
100-160	.40	.50

“A2” Precision

Size (Inches) Above Incl.	Fixed	Closure
0-.40	±.006	±.008
.40-.63	±.008	±.010
.63-1.00	±.010	±.013
1.00-1.60	±.013	±.016
1.60-2.50	±.016	±.020
2.50-4.00	±.020	±.025
4.00-6.30	±.025	±.032
6.30 & over multiply by	.004%	.005

Size (Millimeters) Above Incl.	Fixed	Closure
0-10	±.16	.20
10-16	.20	.25
16-25	.25	.32
25-40	.32	.40
40-63	.40	.50
63-100	.50	.63
100-160	.63	.80
160 & over multiply by	.004	.005

Standard AS568 Size O-Rings

AS568 No.	Nominal Reference			Actual Dimensions	
	I.D.	O.D.	Width	I.D. Tol.	W. Tol.
-001	1/32	3/32	1/32	.029 ± .004	.040 ± .003
-001 1/2	1/16	1/8	1/32	.070 ± .004	.040 ± .003
-002	3/64	9/64	3/64	.042 ± .004	.050 ± .003
-003	1/16	3/16	1/16	.056 ± .004	.060 ± .003
-004	5/64	13/64	1/16	.070 ± .005	.070 ± .003
-005	3/32	7/32	1/16	.101 ± .005	.070 ± .003
-006	1/8	1/4	1/16	.114 ± .005	.070 ± .003
-007	5/32	9/32	1/16	.145 ± .005	.070 ± .003
-008	3/16	5/16	1/16	.176 ± .005	.070 ± .003
-009	7/32	11/32	1/16	.208 ± .005	.070 ± .003
-010	1/4	3/8	1/16	.239 ± .005	.070 ± .003
-011	5/16	7/16	1/16	.301 ± .005	.070 ± .003
-012	3/8	1/2	1/16	.364 ± .005	.070 ± .003
-013	7/16	9/16	1/16	.426 ± .005	.070 ± .003
-014	1/2	5/8	1/16	.489 ± .005	.070 ± .003
-015	9/16	11/16	1/16	.551 ± .007	.070 ± .003
-016	5/8	3/4	1/16	.614 ± .009	.070 ± .003
-017	11/16	13/16	1/16	.676 ± .009	.070 ± .003
-018	3/4	7/8	1/16	.739 ± .009	.070 ± .003
-019	13/16	15/16	1/16	.801 ± .009	.070 ± .003
-020	7/8	1	1/16	.864 ± .009	.070 ± .003
-021	15/16	1 1/16	1/16	.926 ± .009	.070 ± .003
-022	1	1 1/8	1/16	.989 ± .010	.070 ± .003
-023	1 1/16	1 3/16	1/16	1.051 ± .010	.070 ± .003
-024	1 1/8	1 1/4	1/16	1.114 ± .010	.070 ± .003
-025	1 3/16	1 5/16	1/16	1.176 ± .011	.070 ± .003
-026	1 1/4	1 3/8	1/16	1.239 ± .011	.070 ± .003
-027	1 5/16	1 7/16	1/16	1.301 ± .011	.070 ± .003
-028	1 3/8	1 1/2	1/16	1.364 ± .013	.070 ± .003
-029	1 1/2	1 5/8	1/16	1.489 ± .013	.070 ± .003
-030	1 5/8	1 3/4	1/16	1.614 ± .013	.070 ± .003
-031	1 3/4	1 7/8	1/16	1.739 ± .015	.070 ± .003
-032	1 7/8	2	1/16	1.864 ± .015	.070 ± .003
-033	2	2 1/8	1/16	1.989 ± .018	.070 ± .003
-034	2 1/8	2 1/4	1/16	2.114 ± .018	.070 ± .003
-035	2 1/4	2 3/8	1/16	2.239 ± .018	.070 ± .003
-036	2 3/8	2 1/2	1/16	2.364 ± .018	.070 ± .003
-037	2 1/2	2 5/8	1/16	2.489 ± .018	.070 ± .003
-038	2 5/8	2 3/4	1/16	2.614 ± .020	.070 ± .003
-039	2 3/4	2 7/8	1/16	2.739 ± .020	.070 ± .003
-040	2 7/8	3	1/16	2.864 ± .020	.070 ± .003
-041	3	3 1/8	1/16	2.989 ± .024	.070 ± .003
-042	3 1/4	3 3/8	1/16	3.239 ± .024	.070 ± .003
-043	3 1/2	3 5/8	1/16	3.489 ± .024	.070 ± .003
-044	3 3/4	3 7/8	1/16	3.739 ± .027	.070 ± .003
-045	4	4 1/8	1/16	3.989 ± .027	.070 ± .003
-046	4 1/4	4 3/8	1/16	4.239 ± .030	.070 ± .003
-047	4 1/2	4 5/8	1/16	4.489 ± .030	.070 ± .003

AS568 No.	Nominal Reference			Actual Dimensions	
	I.D.	O.D.	Width	I.D. Tol.	W. Tol.
-048	4 3/4	4 7/8	1/16	4.739 ± .030	.070 ± .003
-049	5	5 1/8	1/16	4.989 ± .037	.070 ± .003
-050	5 1/4	5 3/8	1/16	5.239 ± .037	.070 ± .003
-102	1/16	1/4	3/32	.049 ± .005	.103 ± .003
-103	3/32	9/32	3/32	.081 ± .005	.103 ± .003
-104	1/8	5/16	3/32	.112 ± .005	.103 ± .003
-105	5/32	11/32	3/32	.143 ± .005	.103 ± .003
-106	3/16	3/8	3/32	.174 ± .005	.103 ± .003
-107	7/32	13/32	3/32	.206 ± .005	.103 ± .003
-108	1/4	7/16	3/32	.237 ± .005	.103 ± .003
-109	5/16	1/2	3/32	.299 ± .005	.103 ± .003
-110	3/8	9/16	3/32	.362 ± .005	.103 ± .003
-111	7/16	5/8	3/32	.424 ± .005	.103 ± .003
-112	1/2	11/16	3/32	.487 ± .005	.103 ± .003
-113	9/16	3/4	3/32	.549 ± .007	.103 ± .003
-114	5/8	13/16	3/32	.612 ± .009	.103 ± .003
-115	11/16	7/8	3/32	.674 ± .009	.103 ± .003
-116	3/4	15/16	3/32	.737 ± .009	.103 ± .003
-117	13/16	1	3/32	.799 ± .010	.103 ± .003
-118	7/8	1 1/16	3/32	.862 ± .010	.103 ± .003
-119	15/16	1 1/8	3/32	.924 ± .010	.103 ± .003
-120	1	1 3/16	3/32	.987 ± .010	.103 ± .003
-121	1 1/16	1 1/4	3/32	1.049 ± .010	.103 ± .003
-122	1 1/8	1 5/16	3/32	1.112 ± .010	.103 ± .003
-123	1 3/16	1 3/8	3/32	1.174 ± .012	.103 ± .003
-124	1 1/4	1 7/16	3/32	1.237 ± .012	.103 ± .003
-125	1 5/16	1 1/2	3/32	1.299 ± .012	.103 ± .003
-126	1 3/8	1 9/16	3/32	1.362 ± .012	.103 ± .003
-127	1 7/16	1 5/8	3/32	1.424 ± .012	.103 ± .003
-128	1 1/2	1 11/16	3/32	1.487 ± .012	.103 ± .003
-129	1 9/16	1 3/4	3/32	1.549 ± .015	.103 ± .003
-130	1 5/8	1 13/16	3/32	1.612 ± .015	.103 ± .003
-131	1 11/16	1 7/8	3/32	1.674 ± .015	.103 ± .003
-132	1 3/4	1 15/16	3/32	1.737 ± .015	.103 ± .003
-133	1 13/16	2	3/32	1.799 ± .015	.103 ± .003
-134	1 7/8	2 1/16	3/32	1.862 ± .015	.103 ± .003
-135	1 15/16	2 1/8	3/32	1.925 ± .017	.103 ± .003
-136	2	2 3/16	3/32	1.987 ± .017	.103 ± .003
-137	2 1/16	2 1/4	3/32	2.050 ± .017	.103 ± .003
-138	2 1/8	2 5/16	3/32	2.112 ± .017	.103 ± .003
-139	2 3/16	2 3/8	3/32	2.175 ± .017	.103 ± .003
-140	2 1/4	2 7/16	3/32	2.237 ± .017	.103 ± .003
-141	2 5/16	2 1/2	3/32	2.300 ± .020	.103 ± .003
-142	2 3/8	2 9/16	3/32	2.362 ± .020	.103 ± .003
-143	2 7/16	2 5/8	3/32	2.425 ± .020	.103 ± .003
-144	2 1/2	2 11/16	3/32	2.487 ± .020	.103 ± .003
-145	2 9/16	2 3/4	3/32	2.550 ± .020	.103 ± .003

Many more o-ring sizes available, visit us online for our full listing.

Standard AS568 Size O-Rings

AS568 No.	Nominal Reference			Actual Dimensions	
	I.D.	O.D.	Width	I.D. Tol.	W. Tol.
-146	2 5/8	2 13/16	3/32	2.612 ± .020	.103 ± .003
-147	2 11/16	2 7/8	3/32	2.675 ± .022	.103 ± .003
-148	2 3/4	2 15/16	3/32	2.737 ± .022	.103 ± .003
-149	2 13/16	3	3/32	2.800 ± .022	.103 ± .003
-150	2 7/8	3 1/16	3/32	2.862 ± .022	.103 ± .003
-151	3	3 3/16	3/32	2.987 ± .024	.103 ± .003
-152	3 1/4	3 7/16	3/32	3.237 ± .024	.103 ± .003
-153	3 1/2	3 11/16	3/32	3.487 ± .024	.103 ± .003
-154	3 3/4	3 15/16	3/32	3.737 ± .028	.103 ± .003
-155	4	4 3/16	3/32	3.987 ± .028	.103 ± .003
-156	4 1/4	4 7/16	3/32	4.237 ± .030	.103 ± .003
-157	4 1/2	4 11/16	3/32	4.487 ± .030	.103 ± .003
-158	4 3/4	4 15/16	3/32	4.737 ± .030	.103 ± .003
-159	5	5 3/16	3/32	4.987 ± .035	.103 ± .003
-160	5 1/4	5 7/16	3/32	5.237 ± .035	.103 ± .003
-161	5 1/2	5 11/16	3/32	5.487 ± .035	.103 ± .003
-162	5 3/4	5 15/16	3/32	5.737 ± .035	.103 ± .003
-163	6	6 3/16	3/32	5.987 ± .035	.103 ± .003
-164	6 1/4	6 7/16	3/32	6.237 ± .040	.103 ± .003
-165	6 1/2	6 11/16	3/32	6.487 ± .040	.103 ± .003
-166	6 3/4	6 15/16	3/32	6.737 ± .040	.103 ± .003
-167	7	7 3/16	3/32	6.987 ± .040	.103 ± .003
-168	7 1/4	7 7/16	3/32	7.237 ± .045	.103 ± .003
-169	7 1/2	7 11/16	3/32	7.487 ± .045	.103 ± .003
-170	7 3/4	7 15/16	3/32	7.737 ± .045	.103 ± .003
-171	8	8 3/16	3/32	7.987 ± .045	.103 ± .003
-172	8 1/4	8 7/16	3/32	8.237 ± .050	.103 ± .003
-173	8 1/2	8 11/16	3/32	8.487 ± .050	.103 ± .003
-174	8 3/4	8 15/16	3/32	8.737 ± .050	.103 ± .003
-175	9	9 3/16	3/32	8.987 ± .050	.103 ± .003
-176	9 1/4	9 7/16	3/32	9.237 ± .055	.103 ± .003
-177	9 1/2	9 11/16	3/32	9.487 ± .055	.103 ± .003
-178	9 3/4	9 15/16	3/32	9.737 ± .055	.103 ± .003
-201	3/16	7/16	1/8	.171 ± .005	.139 ± .004
-202	1/4	1/2	1/8	.234 ± .005	.139 ± .004
-203	5/16	9/16	1/8	.296 ± .005	.139 ± .004
-204	3/8	5/8	1/8	.359 ± .005	.139 ± .004
-205	7/16	11/16	1/8	.421 ± .005	.139 ± .004
-206	1/2	3/4	1/8	.484 ± .005	.139 ± .004
-207	9/16	13/16	1/8	.546 ± .007	.139 ± .004
-208	5/8	7/8	1/8	.609 ± .009	.139 ± .004
-209	11/16	15/16	1/8	.671 ± .009	.139 ± .004
-210	3/4	1	1/8	.734 ± .010	.139 ± .004
-211	13/16	1 1/16	1/8	.796 ± .010	.139 ± .004
-212	7/8	1 1/8	1/8	.859 ± .010	.139 ± .004
-213	15/16	1 3/16	1/8	.921 ± .010	.139 ± .004
-214	1	1 1/4	1/8	.984 ± .010	.139 ± .004
-215	1 1/16	1 5/16	1/8	1.046 ± .010	.139 ± .004

AS568 No.	Nominal Reference			Actual Dimensions	
	I.D.	O.D.	Width	I.D. Tol.	W. Tol.
-216	1 1/8	1 3/8	1/8	1.109 ± .012	.139 ± .004
-217	1 3/16	1 7/16	1/8	1.171 ± .012	.139 ± .004
-218	1 1/4	1 1/2	1/8	1.234 ± .012	.139 ± .004
-219	1 5/16	1 9/16	1/8	1.296 ± .012	.139 ± .004
-220	1 3/8	1 5/8	1/8	1.359 ± .012	.139 ± .004
-221	1 7/16	1 11/16	1/8	1.421 ± .012	.139 ± .004
-222	1 1/2	1 3/4	1/8	1.484 ± .015	.139 ± .004
-223	1 5/8	1 7/8	1/8	1.609 ± .015	.139 ± .004
-224	1 3/4	2	1/8	1.734 ± .015	.139 ± .004
-225	1 7/8	2 1/8	1/8	1.859 ± .018	.139 ± .004
-226	2	2 1/4	1/8	1.984 ± .018	.139 ± .004
-227	2 1/8	2 3/8	1/8	2.109 ± .018	.139 ± .004
-228	2 1/4	2 1/2	1/8	2.234 ± .020	.139 ± .004
-229	2 3/8	2 5/8	1/8	2.359 ± .020	.139 ± .004
-230	2 1/2	2 3/4	1/8	2.484 ± .020	.139 ± .004
-231	2 5/8	2 7/8	1/8	2.609 ± .020	.139 ± .004
-232	2 3/4	3	1/8	2.734 ± .024	.139 ± .004
-233	2 7/8	3 1/8	1/8	2.859 ± .024	.139 ± .004
-234	3	3 1/4	1/8	2.984 ± .024	.139 ± .004
-235	3 1/8	3 3/8	1/8	3.109 ± .024	.139 ± .004
-236	3 1/4	3 1/2	1/8	3.234 ± .024	.139 ± .004
-237	3 3/8	3 5/8	1/8	3.359 ± .024	.139 ± .004
-238	3 1/2	3 3/4	1/8	3.484 ± .024	.139 ± .004
-239	3 5/8	3 7/8	1/8	3.609 ± .028	.139 ± .004
-240	3 3/4	4	1/8	3.734 ± .028	.139 ± .004
-241	3 7/8	4 1/8	1/8	3.859 ± .028	.139 ± .004
-242	4	4 1/4	1/8	3.984 ± .028	.139 ± .004
-243	4 1/8	4 3/8	1/8	4.109 ± .028	.139 ± .004
-244	4 1/4	4 1/2	1/8	4.234 ± .030	.139 ± .004
-245	4 3/8	4 5/8	1/8	4.359 ± .030	.139 ± .004
-246	4 1/2	4 3/4	1/8	4.484 ± .030	.139 ± .004
-247	4 5/8	4 7/8	1/8	4.609 ± .030	.139 ± .004
-248	4 3/4	5	1/8	4.734 ± .030	.139 ± .004
-249	4 7/8	5 1/8	1/8	4.859 ± .035	.139 ± .004
-250	5	5 1/4	1/8	4.984 ± .035	.139 ± .004
-251	5 1/8	5 3/8	1/8	5.109 ± .035	.139 ± .004
-252	5 1/4	5 1/2	1/8	5.234 ± .035	.139 ± .004
-253	5 3/8	5 5/8	1/8	5.359 ± .035	.139 ± .004
-254	5 1/2	5 3/4	1/8	5.484 ± .035	.139 ± .004
-255	5 5/8	5 7/8	1/8	5.609 ± .035	.139 ± .004
-256	5 3/4	6	1/8	5.734 ± .035	.139 ± .004
-257	5 7/8	6 1/8	1/8	5.859 ± .035	.139 ± .004
-258	6	6 1/4	1/8	5.984 ± .035	.139 ± .004
-259	6 1/4	6 1/2	1/8	6.234 ± .040	.139 ± .004
-260	6 1/2	6 3/4	1/8	6.484 ± .040	.139 ± .004
-261	6 3/4	7	1/8	6.734 ± .040	.139 ± .004
-262	7	7 1/4	1/8	6.984 ± .040	.139 ± .004

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Standard AS568 Size O-Rings

AS568 No.	Nominal Reference			Actual Dimensions	
	I.D.	O.D.	Width	I.D. Tol.	W. Tol.
-263	7 1/4	7 1/2	1/8	7.234 ± .045	.139 ± .004
-264	7 1/2	7 3/4	1/8	7.484 ± .045	.139 ± .004
-265	7 3/4	8	1/8	7.734 ± .045	.139 ± .004
-266	8	8 1/4	1/8	7.984 ± .045	.139 ± .004
-267	8 1/4	8 1/2	1/8	8.234 ± .050	.139 ± .004
-268	8 1/2	8 3/4	1/8	8.484 ± .050	.139 ± .004
-269	8 3/4	9	1/8	8.734 ± .050	.139 ± .004
-270	9	9 1/4	1/8	8.984 ± .050	.139 ± .004
-271	9 1/4	9 1/2	1/8	9.234 ± .055	.139 ± .004
-272	9 1/2	9 3/4	1/8	9.484 ± .055	.139 ± .004
-273	9 3/4	10	1/8	9.734 ± .055	.139 ± .004
-274	10	10 1/4	1/8	9.984 ± .055	.139 ± .004
-275	10 1/2	10 3/4	1/8	10.484 ± .055	.139 ± .004
-276	11	11 1/4	1/8	10.984 ± .065	.139 ± .004
-277	11 1/2	11 3/4	1/8	11.484 ± .065	.139 ± .004
-278	12	12 1/4	1/8	11.984 ± .065	.139 ± .004
-279	13	13 1/4	1/8	12.984 ± .065	.139 ± .004
-280	14	14 1/4	1/8	13.984 ± .065	.139 ± .004
-281	15	15 1/4	1/8	14.984 ± .065	.139 ± .004
-282	16	16 1/4	1/8	15.955 ± .075	.139 ± .004
-283	17	17 1/4	1/8	16.955 ± .080	.139 ± .004
-284	18	18 1/4	1/8	17.955 ± .085	.139 ± .004
-309	7/16	13/16	3/16	.412 ± .005	.210 ± .005
-310	1/2	7/8	3/16	.475 ± .005	.210 ± .005
-311	9/16	15/16	3/16	.537 ± .007	.210 ± .005
-312	5/8	1	3/16	.600 ± .009	.210 ± .005
-313	11/16	1 1/16	3/16	.662 ± .009	.210 ± .005
-314	3/4	1 1/8	3/16	.725 ± .010	.210 ± .005
-315	13/16	1 3/16	3/16	.787 ± .010	.210 ± .005
-316	7/8	1 1/4	3/16	.850 ± .010	.210 ± .005
-317	15/16	1 5/16	3/16	.912 ± .010	.210 ± .005
-318	1	1 3/8	3/16	.975 ± .010	.210 ± .005
-319	1 1/16	1 7/16	3/16	1.037 ± .010	.210 ± .005
-320	1 1/8	1 1/2	3/16	1.100 ± .012	.210 ± .005
-321	1 3/16	1 9/16	3/16	1.162 ± .012	.210 ± .005
-322	1 1/4	1 5/8	3/16	1.225 ± .012	.210 ± .005
-323	1 5/16	1 11/16	3/16	1.287 ± .012	.210 ± .005
-324	1 3/8	1 3/4	3/16	1.350 ± .012	.210 ± .005
-325	1 1/2	1 7/8	3/16	1.475 ± .015	.210 ± .005
-326	1 5/8	2	3/16	1.600 ± .015	.210 ± .005
-327	1 3/4	2 1/8	3/16	1.725 ± .015	.210 ± .005
-328	1 7/8	2 1/4	3/16	1.850 ± .015	.210 ± .005
-329	2	2 3/8	3/16	1.975 ± .018	.210 ± .005
-330	2 1/8	2 1/2	3/16	2.100 ± .018	.210 ± .005
-331	2 1/4	2 5/8	3/16	2.225 ± .018	.210 ± .005
-332	2 3/8	2 3/4	3/16	2.350 ± .018	.210 ± .005
-333	2 1/2	2 7/8	3/16	2.475 ± .020	.210 ± .005
-334	2 5/8	3	3/16	2.600 ± .020	.210 ± .005

AS568 No.	Nominal Reference			Actual Dimensions	
	I.D.	O.D.	Width	I.D. Tol.	W. Tol.
-335	2 3/4	3 1/8	3/16	2.725 ± .020	.210 ± .005
-336	2 7/8	3 1/4	3/16	2.850 ± .020	.210 ± .005
-337	3	3 3/8	3/16	2.975 ± .024	.210 ± .005
-338	3 1/8	3 1/2	3/16	3.100 ± .024	.210 ± .005
-339	3 1/4	3 5/8	3/16	3.225 ± .024	.210 ± .005
-340	3 3/8	3 3/4	3/16	3.350 ± .024	.210 ± .005
-341	3 1/2	3 7/8	3/16	3.475 ± .024	.210 ± .005
-342	3 5/8	4	3/16	3.600 ± .028	.210 ± .005
-343	3 3/4	4 1/8	3/16	3.725 ± .028	.210 ± .005
-344	3 7/8	4 1/4	3/16	3.850 ± .028	.210 ± .005
-345	4	4 3/8	3/16	3.975 ± .028	.210 ± .005
-346	4 1/8	4 1/2	3/16	4.100 ± .028	.210 ± .005
-347	4 1/4	4 5/8	3/16	4.225 ± .030	.210 ± .005
-348	4 3/8	4 3/4	3/16	4.350 ± .030	.210 ± .005
-349	4 1/2	4 7/8	3/16	4.475 ± .030	.210 ± .005
-350	4 5/8	5	3/16	4.600 ± .030	.210 ± .005
-351	4 3/4	5 1/8	3/16	4.725 ± .030	.210 ± .005
-352	4 7/8	5 1/4	3/16	4.850 ± .030	.210 ± .005
-353	5	5 3/8	3/16	4.975 ± .037	.210 ± .005
-354	5 1/8	5 1/2	3/16	5.100 ± .037	.210 ± .005
-355	5 1/4	5 5/8	3/16	5.225 ± .037	.210 ± .005
-356	5 3/8	5 3/4	3/16	5.350 ± .037	.210 ± .005
-357	5 1/2	5 7/8	3/16	5.475 ± .037	.210 ± .005
-358	5 5/8	6	3/16	5.600 ± .037	.210 ± .005
-359	5 3/4	6 1/8	3/16	5.725 ± .037	.210 ± .005
-360	5 7/8	6 1/4	3/16	5.850 ± .037	.210 ± .005
-361	6	6 3/8	3/16	5.975 ± .037	.210 ± .005
-362	6 1/4	6 5/8	3/16	6.225 ± .040	.210 ± .005
-363	6 1/2	6 7/8	3/16	6.475 ± .040	.210 ± .005
-364	6 3/4	7 1/8	3/16	6.725 ± .040	.210 ± .005
-365	7	7 3/8	3/16	6.975 ± .040	.210 ± .005
-366	7 1/4	7 5/8	3/16	7.225 ± .045	.210 ± .005
-367	7 1/2	7 7/8	3/16	7.475 ± .045	.210 ± .005
-368	7 3/4	8 1/8	3/16	7.725 ± .045	.210 ± .005
-369	8	8 3/8	3/16	7.975 ± .045	.210 ± .005
-370	8 1/4	8 5/8	3/16	8.225 ± .050	.210 ± .005
-371	8 1/2	8 7/8	3/16	8.475 ± .050	.210 ± .005
-372	8 3/4	9 1/8	3/16	8.725 ± .050	.210 ± .005
-373	9	9 3/8	3/16	8.975 ± .050	.210 ± .005
-374	9 1/4	9 5/8	3/16	9.225 ± .055	.210 ± .005
-375	9 1/2	9 7/8	3/16	9.475 ± .055	.210 ± .005
-376	9 3/4	10 1/8	3/16	9.725 ± .055	.210 ± .005
-377	10	10 3/8	3/16	9.975 ± .055	.210 ± .005
-378	10 1/2	10 7/8	3/16	10.475 ± .060	.210 ± .005
-379	11	11 3/8	3/16	10.975 ± .060	.210 ± .005
-380	11 1/2	11 7/8	3/16	11.475 ± .065	.210 ± .005
-381	12	12 3/8	3/16	11.975 ± .065	.210 ± .005

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Standard AS568 Size O-Rings

AS568 No.	Nominal Reference			Actual Dimensions	
	I.D.	O.D.	Width	I.D. Tol.	W. Tol.
-382	13	13 3/8	3/16	12.975 ± .065	.210 ± .005
-383	14	14 3/8	3/16	13.975 ± .070	.210 ± .005
-384	15	15 3/8	3/16	14.975 ± .070	.210 ± .005
-385	16	16 3/8	3/16	15.955 ± .075	.210 ± .005
-386	17	17 3/8	3/16	16.955 ± .080	.210 ± .005
-387	18	18 3/8	3/16	17.955 ± .085	.210 ± .005
-388	19	19 3/8	3/16	18.955 ± .090	.210 ± .005
-389	20	20 3/8	3/16	19.955 ± .095	.210 ± .005
-390	21	21 3/8	3/16	20.955 ± .095	.210 ± .005
-391	22	22 3/8	3/16	21.955 ± .100	.210 ± .005
-392	23	23 3/8	3/16	22.940 ± .105	.210 ± .005
-393	24	24 3/8	3/16	23.940 ± .110	.210 ± .005
-394	25	25 3/8	3/16	24.940 ± .115	.210 ± .005
-395	26	26 3/8	3/16	25.940 ± .120	.210 ± .005
-425	4 1/2	5	1/4	4.475 ± .033	.275 ± .006
-426	4 5/8	5 1/8	1/4	4.600 ± .033	.275 ± .006
-427	4 3/4	5 1/4	1/4	4.725 ± .033	.275 ± .006
-428	4 7/8	5 3/8	1/4	4.850 ± .033	.275 ± .006
-429	5	5 1/2	1/4	4.975 ± .037	.275 ± .006
-430	5 1/8	5 5/8	1/4	5.100 ± .037	.275 ± .006
-431	5 1/4	5 3/4	1/4	5.225 ± .037	.275 ± .006
-432	5 3/8	5 7/8	1/4	5.350 ± .037	.275 ± .006
-433	5 1/2	6	1/4	5.475 ± .037	.275 ± .006
-434	5 5/8	6 1/8	1/4	5.600 ± .037	.275 ± .006
-435	5 3/4	6 1/4	1/4	5.725 ± .037	.275 ± .006
-436	5 7/8	6 3/8	1/4	5.850 ± .037	.275 ± .006
-437	6	6 1/2	1/4	5.975 ± .037	.275 ± .006
-438	6 1/4	6 3/4	1/4	6.225 ± .040	.275 ± .006
-439	6 1/2	7	1/4	6.475 ± .040	.275 ± .006
-440	6 3/4	7 1/4	1/4	6.725 ± .040	.275 ± .006
-441	7	7 1/2	1/4	6.975 ± .040	.275 ± .006
-442	7 1/4	7 3/4	1/4	7.225 ± .045	.275 ± .006
-443	7 1/2	8	1/4	7.475 ± .045	.275 ± .006
-444	7 3/4	8 1/4	1/4	7.725 ± .045	.275 ± .006
-445	8	8 1/2	1/4	7.975 ± .045	.275 ± .006

AS568 No.	Nominal Reference			Actual Dimensions	
	I.D.	O.D.	Width	I.D. Tol.	W. Tol.
-446	8 1/2	9	1/4	8.475 ± .055	.275 ± .006
-447	9	9 1/2	1/4	8.975 ± .055	.275 ± .006
-448	9 1/2	10	1/4	9.475 ± .055	.275 ± .006
-449	10	10 1/2	1/4	9.975 ± .055	.275 ± .006
-450	10 1/2	11	1/4	10.475 ± .060	.275 ± .006
-451	11	11 1/2	1/4	10.975 ± .060	.275 ± .006
-452	11 1/2	12	1/4	11.475 ± .060	.275 ± .006
-453	12	12 1/2	1/4	11.975 ± .060	.275 ± .006
-454	12 1/2	13	1/4	12.475 ± .060	.275 ± .006
-455	13	13 1/2	1/4	12.975 ± .060	.275 ± .006
-456	13 1/2	14	1/4	13.475 ± .070	.275 ± .006
-457	14	14 1/2	1/4	13.975 ± .070	.275 ± .006
-458	14 1/4	15	1/4	14.475 ± .070	.275 ± .006
-459	15	15 1/2	1/4	14.975 ± .070	.275 ± .006
-460	15 1/2	16	1/4	15.475 ± .070	.275 ± .006
-461	16	16 1/2	1/4	15.955 ± .075	.275 ± .006
-462	16 1/2	17	1/4	16.455 ± .075	.275 ± .006
-463	17	17 1/2	1/4	16.955 ± .080	.275 ± .006
-464	17 1/2	18	1/4	17.455 ± .085	.275 ± .006
-465	18	18 1/2	1/4	17.955 ± .085	.275 ± .006
-466	18 1/2	19	1/4	18.455 ± .085	.275 ± .006
-467	19	19 1/2	1/4	18.955 ± .090	.275 ± .006
-468	19 1/2	20	1/4	19.455 ± .090	.275 ± .006
-469	20	20 1/2	1/4	19.955 ± .090	.275 ± .006
-470	21	21 1/2	1/4	20.955 ± .090	.275 ± .006
-471	22	22 1/2	1/4	21.955 ± .100	.275 ± .006
-472	23	23 1/2	1/4	22.940 ± .105	.275 ± .006
-473	24	24 1/2	1/4	23.940 ± .110	.275 ± .006
-474	25	25 1/2	1/4	24.940 ± .115	.275 ± .006
-475	26	26 1/2	1/4	25.940 ± .120	.275 ± .006

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Standard O-Rings for Boss Gaskets for Straight Thread Tube Fittings

AS568 No.	Tube Size (O.D.) Fractional	Actual Dimensions	
		I.D. Tol.	W. Tol.
-901	3/32	.185 ±.005	.056 ±.003
-902	1/8	.239 ±.005	.064 ±.003
-903	3/16	.301 ±.005	.064 ±.003
-904	1/4	.351 ±.005	.072 ±.003
-905	5/16	.414 ±.005	.072 ±.003
-906	3/8	.468 ±.005	.078 ±.003
-907	7/16	.530 ±.007	.082 ±.003
-908	1/2	.644 ±.009	.087 ±.003
-909	9/16	.706 ±.009	.097 ±.003
-910	5/8	.755 ±.009	.097 ±.003
-911	11/16	.863 ±.009	.116 ±.004
-912	3/4	.924 ±.009	.116 ±.004
-913	13/16	.986 ±.010	.116 ±.004
-914	7/8	1.047 ±.010	.116 ±.004
-916	1	1.171 ±.010	.116 ±.004
-918	1 1/8	1.355 ±.012	.116 ±.004
-920	1 1/4	1.475 ±.014	.118 ±.004
-924	1 1/2	1.720 ±.014	.118 ±.004
-928	1 3/4	2.090 ±.018	.118 ±.004
-932	2	2.337 ±.018	.118 ±.004

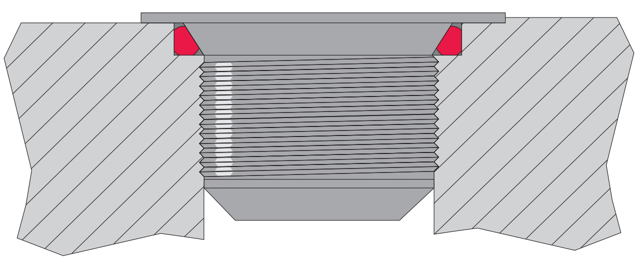


Illustration 9.2, O-rings for Straight Thread Tube Fitting Bosses

This class of o-rings is primarily utilized in hydraulic tubing and fittings up to 3000 psi. A straight thread, not tapered, is used so that the o-ring seals under compression. Because of their use in primarily high pressure applications, these seals are normally supplied in 90 durometer material.

10 Glossary of Terms

Abrasion Resistance
The ability of a rubber compound to resist surface wear by mechanical action.

Accelerator
A chemical compound that speeds up the vulcanization of natural or synthetic rubbers.

Air Checks / Traps
Surface markings or depressions resulting from the trapping of air between the rubber surfaces being cured and the mold or press surface.

Ambient Temperature
The temperature of the environment surrounding a particular object.

Aliphatic
A major group of organic compounds characterized by the presence of straight chain arrangements of carbon atoms. The three subgroups that comprise aliphatic hydrocarbons are: paraffins (alkanes), olefins (alkenes), and acetylenes (alkynes).

AMS
Aerospace Material Specification.

AN
Abbreviation for Air Force-Navy (specifications).

Aniline Point
The lowest temperature at which equal parts of aniline and a test liquid (such as oil) will uniformly mix or blend. The aniline point of oil is a measure of aromaticity (the amount of unsaturated hydrocarbons present). The lower the aniline point, the more unsaturants are present and the higher the potential for swelling certain rubber compounds.

Antioxidant
Any organic compound that slows the process of oxidation.

Antiozonant
Any substance that slows the severe oxidizing effect of ozone on elastomers. Exposure to ozone typically causes surface cracking in many rubbers.

Aromatic
A major group of unsaturated cyclic hydrocarbons containing one or more rings. A typical aromatic compound is benzene, which has a six carbon ring, containing three double bonds.

AS568
Aerospace Standard Uniform Dash Numbering System for o-rings. All military standard (MS) drawings currently use this system. This standard periodically changes so check for the latest revision.

ASTM
American Society for Testing and Materials.

Axial Seal
Squeezed, like a gasket, on both the top and bottom surfaces of the seal's cross section. A face seal.

Back-Up Ring
A washer-like device of a relatively hard, tough material installed in the gland on the downstream side of the seal to prevent seal extrusion into the diametrical gap while under pressure.

Bench Test
A laboratory test approximating product service conditions.

Bending Modulus
The measure of applied force required to bend a material a given distance around a specified radius. A measure of material elasticity (stiffness).

Bleeding
A film or beads formed by such compound components as plasticizers that have migrated to the surface of rubber products because of incompatibility with the base elastomer and/or the compound ingredients.

Blemish
A surface mark or deformity.

Blisters
A raised spot on the seal's surface created by an internal void, or air-filled pocket.

Bloom
A milky surface discoloration caused by the migration of certain compound components (such as antiozonants) to the rubber's surface after molding or storage. The waxy film serves as a protective coating shielding the part from oxidation. This discoloration does not adversely affect material performance.

Bond
The mechanical or chemical force that holds an elastomer to some other object. Mechanical bonding includes component interference and no molecular cross bridging between the elastomer and substrate, whereas chemical bonding involves contact adhesives with heat and pressure to adhere an elastomer to a primed surface.

Break-Out
The force required to overcome initial seal to gland surface adhesion, when part movement is intermittent. A common term used to describe one form of friction.

Brittleness
Tendency to crack upon physical deformation at low temperature.

Coefficient of Thermal Expansion
Value used to determine the amount of linear dimensional change for a particular elastomer, which is temperature dependent.

Cold Flexibility
Flexibility following elastomer exposure to a specified low temperature for a specified period of time.

Cold Flow
A term describing the tendency of certain materials to continue to deform or "creep" under constant sealing pressure (compressive load).

Cold Resistant
Capable of low temperature operation without loss of serviceability.

Composite Seal
Combines the sealing performance of elastomers with the physical properties of the bonded material (i.e. metal, plastic, etc.).

Compound
An elastomeric material resulting from the combination of a number of individual chemical ingredients into a batch mix. Further processing of the thoroughly mixed ingredients, to induce cross linking of polymer chains (vulcanization), results in the creation of a useful rubber-like product.

Compression Modulus
The ratio of applied compressive force (stress) to the resulting deformation of the test material (strain). Compressive strain is expressed as a fraction of the original height or thickness of the test specimen in the direction of the applied force.

Compression Set
The amount by which an elastomeric material fails to return to its original size after release from a constant compressive load.

Copolymer
An elastomer (polymer) resulting from the chemical combination of two dissimilar monomers. For example, Buna N from Butadiene and Acrylonitrile.

Cracking
Sharp breaks or fissures in rubber surfaces resulting from excessive strain or exposure to adverse environmental factors.

Creep
The progressive relaxation of an elastomeric material under constant sealing pressure (compressive load). Also known as cold flow.

Cross Section
A seal cut at right angles to the mold parting line. Also known as width.

Cure
Another term for "vulcanization" of compounded and molded rubber (green stock), resulting in the chemical bonding (cross linking) of polymer chains and the accompanying creation of useful elastomeric products. Curing typically occurs in the presence of sulfur and an accelerator, under pressure, at elevated temperature.

Cure Date
O-Ring molding date. A product code of 2Q19, for example indicates a cure date of the second quarter (2Q) of 2019 (19).

Curing Temperature
The temperature of vulcanization.

Cylinder
Chamber in which a piston is driven.

Deflash
A process of removing unwanted, excess material (flash) from a finished product.

Degassing
Intentional, controlled outgassing of the volatile (evaporative) components of elastomeric materials.

Diametrical Clearance
The gap between the two mating metal surfaces forming a gland's internal cavity. Through slight oversizing and accompanying "squeeze," the o-ring seals this gap to prevent system leakage.

Durometer
A measure of the hardness of a rubber compound. In a Shore A scale, the resultant numerical rating of hardness runs from lower numbered (30 or 40) softer materials to higher numbered (80 to 90) harder materials. Usually designated with a +/-5 tolerance.

Dynamic Seal
Any application involving reciprocating, rotating, or oscillating motion relative to the seal.

Elasticity
The tendency of a material to return to its original shape after deformation.

Elastomer
A general term used to describe both natural and synthetic polymers possessing the resilience required to return to approximate original shape after major or minor distortion.

Elongation
Generally referred to in terms of tensile (pull apart) testing, elongation is the increase in length of a test specimen, expressed as a percentage of its original (unstretched) length relative to a given load at the breakpoint.

Extrusion
The forced extension of part of the seal into the diametrical clearance gap of the gland, caused by excessive system pressure.

Face Seal
Squeezed, like a gasket, on both the top and bottom surfaces of the seal's cross section. An axial seal.

FDA
Food and Drug Administration is a U.S. government agency that regulates the ingredients in rubber compounds that are intended for use in food and medical applications.

Filler
A finely divided material used to reinforce or modify elastomer physical properties, impart certain processing properties, or reduce cost. Typical examples are carbon black, clays, calcium carbonates and silicas.

Flash
Excess rubber around a molded part due to cavity overflow and/or parting line of molded surfaces.

Flex Resistance
The ability of an elastomeric product to resist the stress of constant bending.

Flow Lines
Molded article surface imperfections caused by failure of the rubber stock to blend with itself during the molding operation.

Fluid
A liquid or gas.

Friction (Break-Out)
Friction developed in dynamic seal situations during machine startup. When machine operation is irregular, o-rings tend to conform (adhere) to the microfine grooves of surrounding glandular surfaces, requiring extra initial force to break them out of these microfine grooves.

Friction (Running)
A force which resists objects already in motion.

Gasket
A static (stationary) sealing device used to retain fluids under pressure or to seal out foreign matter.

Gland
Complete cavity into which the seal is installed. Includes a machined groove and mating metal surfaces.

Groove
The machined glandular recess into which the seal is fitted.

Hardness
Resistance of rubber to forced distortion as measured by the indentor point of a durometer gauge.

Hardness, Shore A
Durometer reading in degrees of rubber hardness as measured on a Shore A gauge. Scale is 0-100, with higher numbers indicating greater hardness.

Hermetic Seal
An airtight seal.

I.D.
The inside or hole diameter of an o-ring.

ISO
International Organization for Standardization – model for quality assurance in design, development, production, installation and servicing.

Leakage Rate
The rate at which a fluid (either gas or liquid) passes a barrier.

Life Test
A laboratory test of the amount and duration of product resistance to a set of destructive forces or conditions. Used to compare the relative performance capabilities of various product designs.

LIM
"Liquid Injection Molding" is a closed manufacturing process. Using LSR in an injection molding machine is an example.

Low Temperature Flexibility
The ability of an elastomeric product to be flexed or bent at low temperatures without cracking.

LSR
"Liquid Silicone Rubber" is composed of a two-component, low viscosity, heat-curable rubber system.

Memory
Ability of an elastomeric material to return to its original size and shape after deformation.

MIL
Abbreviation for Military.

MIL STD
Military Standard.

Mismatch
Unequal o-ring cross-sectional radii caused by dimensional differences in the mold cavity.

Modulus
The tensile stress force in psi required to produce a specified increase in material length (usually 100% elongation).

Modulus of Elasticity
One of several measurements of stiffness or resistance to deformation.

Mold
Typically made from steel. Product is formed within machined cavity.

Mold Cavity
Hollow space of the mold within which the uncured rubber compound is shaped and cured to the desired finished product form.

Mold Finish
The surface roughness of the mold which imparts the desired surface quality to the finished molded product.

Mold Marks
Slight irregularities in the surface of molded articles caused by mold machining marks, or damage to the mold itself.

Mold Release
A lubricant used to assist in the removal of rubber products from the mold.

MS
Abbreviation for Military Standard.

Nominal Dimension
The mean dimension of a molded article, from which small dimensional (plus and minus) deviations are allowed as manufacturing tolerances.

Non-Fill
A molding condition where the rubber fails to completely fill the mold cavity, resulting in an incomplete part.

Occlusion
The mechanical entrapment of gases, liquids or solids within the folds of a substance.

O.D.
The outside diameter of an o-ring. A dimensional reference.

Off Register
Eccentric o-ring cross-sectional radii caused by lateral shift of one mold cavity relative to the other.

Oil Resistant
Ability of vulcanized rubber to resist swelling and other detrimental effects of exposure to various oils.

O-Ring
A doughnut-shaped object, or torus, that functions as a seal, blocking the passage of liquids or gases, by being compressed between the two mating surfaces comprising the walls of the cavity (gland) into which the ring is installed.

Oscillating Seal
Most commonly used in faucet valves, in this application the inner or outer member of the gland moves in an arc around the axis of a shaft. Movement is limited to a few turns in one direction and a few turns in the return direction (i.e. faucet on, faucet off).

Outgassing
Primarily occurring in vacuum situations, the volatile (evaporative) components of some rubber compounds may become vaporized in the vacuum and released (outgassed) by the compound into the surrounding environment.

Oxidation
The reaction of oxygen with a rubber compound, typically resulting in surface cracking of the rubber material. As oxidation involves the transfer of electrons, reduction in the physical strength of elastomers may also occur from exposure to the oxidizing agent.

Ozone Resistance
The ability of vulcanized rubber to withstand cracking and physical deterioration from exposure to ozone, a more active oxidizing agent than oxygen itself.

Permanent Set
The deformation remaining in a rubber specimen following both stress and relaxation over a period of time.

Permeability
The rate of gas flow through a particular rubber material.

Plasticizer
A chemical agent added to the rubber compound batch mix to soften the elastomer for processing, as well as to improve physical properties of the compound product (i.e., increase elongation, reduce hardness, improve tack).

Polymer
A long molecular chain material formed by the chemical combination of many similarly structured, small molecular units.

Post Cure
A second step in the vulcanization of certain elastomers, used to drive off residual decomposition products resulting from initial vulcanization.

QS 9000
Quality System model, used in conjunction with the ISO 9000 standard, for the automotive industry.

Radial Seal
Compression is applied perpendicular to the seal centerline.

Reciprocating Seal
Seals used in moving piston and rod situations.

Reinforcing Agent
Fillers, such as Carbon Black, added to the elastomeric batch mix to improve such physical properties as tensile strength.

Resilience
The capability of returning to original size and shape after deformation.

RMA
Rubber Manufacturer’s Association.

RMS
Root Mean Square. A measure of surface roughness typically applied to the machining of metal gland and shaft surfaces. RMS stands for the square root of the sum of the squares of micro-inch deviation from true flat.

Rotary Seal
Seals for rotating shafts, with the turning shaft protruding through the I.D. (hole) of the o-ring.

Rubber
A common name for both naturally occurring and synthetically made elastomers.

Rubber, Natural
A natural product of the juices of certain tropical plants (latex), improved through heat treating with sulfur (vulcanization).

Rubber, Synthetic
Man-made elastomers such as Nitrile, Fluorocarbon, Silicone, etc.

Running Friction
A force which resists objects already in motion.

Runout (Shaft)
Same as gyration. When expressed in inches along, or accompanied by abbreviation “TIR” (total indicator reading), it refers to twice the radical distance between shaft axis and axis of rotation.

SAE
Society of Automotive Engineers.

Scorching
Premature curing of compounded rubber stock during processing or storage, with the potential for adversely affecting material flow and plasticity during subsequent shaping and curing processes.

Seal
Any device used to prevent the passage of a fluid (gas or liquid) or fine particles.

Shelf-Aging
The potential degradation of seal performance capabilities due to exposure of seal elastomers to stressful environmental factors during storage. Proper packaging and storage conditions help to avoid this problem.

Shore A Hardness
Durometer reading in degrees of rubber hardness as measured on a Shore A gauge. Scale is 0-100, with higher numbers indicating greater hardness.

Shrinkage
(1) All rubber materials shrink to some extent during molding. This is normal and should be taken into consideration (by individual polymer shrink rates) when designing rubber parts. (2) Decreased seal volume due to exposure to adverse environmental factors. Can be an indication of plasticizer extraction from system chemicals.

Size, Actual
Actual dimensions of a molded article (including manufacturing tolerances).

Size, Nominal
Basic dimensions of a part from which plus and minus tolerances are developed to account for the range of actual dimensions expected during manufacturing.

Specific Gravity
The weight of a given volume of any substance compared with the weight of an equal volume of water. Specific Gravity is used as a comparison tool to determine the relative density of seal materials, helping to identify base polymers and certain compounds.

Spiral Failure
Generally found on long stroke, hydraulic piston seals, spiral failure results when certain segments of the o-ring slide, while other segments simultaneously roll. At a single point on its periphery, the o-ring gets caught on an eccentric component, or against the cylinder wall, causing twisting and development of 45 degree angle, surface cuts.

Sprue Marks
Raised or recessed marks on the surface of a molded rubber part created by the removal of extra cured material left at the inlet (gate) of the mold by the sprue (pouring nozzle) of the molding machine.

Squeeze
Compression of the o-ring between the two mating surfaces comprising the walls of the cavity or “gland” into which the seal is installed. Squeeze may be either of two types: Axial- squeezed on the top and bottom o-ring surfaces, as in face seals. Radial- squeezed on the inner and outer o-ring surfaces, as in piston or rod seals. Squeeze helps to assure a leak-resistant seal.

Stack Up Tolerance
The summation of sealing system tolerances.

Static Seal
A gasket type application where the seal is contained within two non-moving gland walls, as in face seals.

Strain
Deformation per specified area unit of material due to applied force (stress).

Stress
Applied force per specified area unit of material.

Swell
Increased seal volume caused by exposure to adverse operating conditions, such as exposure to oils, fluids, heat, and the like.

Tear Resistance
Resistance to the growth of a cut in the seal when tension is applied.

Temperature Range
The working range marked by the limits of minimum and maximum operating temperatures for effective seal performance.

Tensile Strength
Pull-apart strength. A measure of the compound’s strength when stretched to the breaking point.

Terpolymer
A polymer resulting from the chemical combination of three monomers.

Thermal Expansion
Linear or volumetric expansion caused by temperature increases.

Thermoplastics
Polymeric materials that soften and can be re-formed when heated, returning to original properties when cooled.

Thermoset
Elastomers that undergo a permanent chemical crosslinking of molecules when processed, heated and molded, and therefore cannot be reprocessed.

TIR (Total Indicator Reading)
A measurement of roundness with relationship to a centerline and expressed in total diametric deviation.

Torque
A turning or twisting force, generally associated with the rotation of a shaft.

Torsional Strength
Ability of a seal to withstand damage due to twisting.

TPE
Thermoplastic Elastomer combines the rubber-like performance of elastomers with the processing advantages of plastic. Scrap material can be recycled without significant loss in physical properties, unlike thermoset materials.

Trim
Removal of excess material (flash) from a molded rubber article.

Trim Cut
Damage to the molded article by trimming too close.

Under-Cure
A condition where rubber has not been cured enough, exhibiting poor physical properties and/or tackiness.

Ultimate Elongation
The % of specimen stretching at the point of breaking. Generally referred to in tensile testing.

Viscosity
Resistance to flow.

Voids
Empty pockets where not intended.

Volume Change
Increase or decrease in the size of a specimen expressed as a percentage of original volume. Generally associated with immersion of elastomer samples in various chemical agents.

Volume Swell
A term generally used to describe the increase in physical size of a specimen immersed in a particular chemical agent.

Vulcanization
The heat induced cross linking (curing) of polymer chains, converting basic visco-elastic liquids into three-dimensional networks of flexible, elastomeric chains (the molded rubber product).

Weathering
The tendency of some o-ring seals to surface crack upon exposure to atmospheres containing ozone and other pollutants.

Width
1. The cross-sectional diameter of an o-ring.
2. One half the difference between the I.D. and O.D. of the ring.

11 Technical Summary

RULES OF THUMB SUMMARY

- A stretch greater than 5% on the o-ring I.D. is not recommended because it can lead to a loss of seal compression. (Section 3, page 10)
- A Groove depth is the machined depth into one surface, whereas a Gland depth consists of the groove depth plus diametrical clearance and is used to calculate seal compression. (Section 3, page 10)
- To create seal squeeze, the gland depth must be less than the seal cross section. (Section 3, page 11)
- Static applications are more tolerant of material and design limitations than dynamic applications. (Section 3, page 12)
- The maximum volume of the o-ring should never surpass the minimum volume of the gland. (Section 3, page 12)
- For a static crush seal application, it is recommended that the o-ring volume does not exceed 95% of the gland void. (Section 4, page 15)
- For reciprocating seals – passing o-rings over ports is not recommended. Nibbling and premature wear and seal failure will result. (Section 4, page 17)
- The closer the application is to room temperature, the longer an o-ring can be expected to effectively seal. (Section 4, page 17)
- Avoid using graphite-loaded compounds with stainless steel, as they tend to pit the stainless steel surface over time. (Section 4, page 18)
- Before installation, make sure to lightly coat the o-ring with a lubricant that is compatible with the o-ring material, as well as with system chemicals. (Section 4, page 19)
- When using only one back-up ring, be sure to install it on the low pressure side of the o-ring. (Section 5, page 58)
- Static seal cross sections are generally compressed from 10% to 40%, whereas Dynamic seals are from 10% to only 30%. (Section 5, page 60)
- When it is said that an elastomer is good for an application it is meant that some compounds which include that material are acceptable, not all. For instance, some compounds of EP are good for brake fluid applications, but most are not acceptable. (Section 6, page 66)
- Material cost does not correlate with performance, it depends on the application. (Section 6, page 70)
- You must test all seals in their actual environment because every application is unique. (Section 6, page 71)
- Do not use a lubricant composed of the same material as the o-ring because “like” will dissolve “like.” For example, a silicone lubricant should not be used with a silicone o-ring. (Section 7, page 85)
- Resistance of elastomers to chemical attack is greatly reduced at elevated temperatures. (Section 7, page 86)

FORMULAS

$$\text{Maximum \% Compression} = \left[1 - \left[\frac{\left(\dfrac{\text{Min Bore Diameter} - \text{Max Goove Diameter}}{2}\right)}{\text{Max O-Ring CS}}\right]\right] \cdot 100$$

$$\text{Minimum \% Compression} = \left[1 - \left[\frac{\left(\dfrac{\text{Max Bore Diameter} - \text{Min Goove Diameter}}{2}\right)}{\text{Min O-Ring CS}}\right]\right] \cdot 100$$

$$\text{Maximum \% O-Ring CS} = \left[\frac{\left(\dfrac{\text{Min Bore Diameter} - \text{Max Goove Diameter}}{2}\right)}{1 - \left(\dfrac{\text{Maximum \% Compression}}{100}\right)}\right] - \text{O-Ring CS Tolerance}$$

$$\text{Minimum \% O-Ring CS} = \left[\frac{\left(\dfrac{\text{Max Bore Diameter} - \text{Min Goove Diameter}}{2}\right)}{1 - \left(\dfrac{\text{Minimum \% Compression}}{100}\right)}\right] + \text{O-Ring CS Tolerance}$$

$$\text{\% Stretch} = \left(\frac{\text{Goove Diameter}}{\text{O-Ring ID}} - 1\right) \cdot 100$$

$$\text{O-Ring CS Reduced Due to Stretch (calculated)} = \text{O-Ring CS} - \left[\text{O-Ring CS}\left(1 - \frac{10}{\sqrt{100 + \text{\% Stretch}}}\right)\right]$$

The calculated value assumes the o-ring volume does not change and the cross-section remains round when stretched.

***NOTE:** All formulas assume concentricity and most apply to a Piston configuration.

FORMULAS

Maximum O-Ring Volume $= \frac{\pi^2}{4}$ [(Max O-Ring ID + Max O-Ring CS) • Max O-Ring CS²]

$$\text{Maximum O-Ring Volume} = \frac{\pi^2}{4}\left[(\text{Max O-Ring ID} + \text{Max O-Ring CS}) \cdot \text{Max O-Ring CS}^2\right]$$

$$\text{Minimum Gland Volume} = \frac{\pi}{4}\left[(\text{Min Bore Diameter}^2 - \text{Max Groove Diameter}^2) \cdot \text{Min Groove Width}\right]$$

$$\text{Minimum Groove Width} = \frac{\pi \cdot \left(\frac{\text{Max O-Ring CS}^2}{4}\right) \cdot \left[\left(\frac{\%\ \text{Void}}{100}\right) + 1\right]}{\left(\frac{\text{Min Bore Diameter} - \text{Max Goove Diameter}}{2}\right)}$$

***NOTE:** The value "% Void" is typically a minimum of 10%.

CONVERSTION TABLE

Length	1 mm = 0.039 in. 1 m = 3.281 ft.	1 in = 25.4 mm 1 ft = 0.305 m
Temperatures	Temp (°C) = 0.56 (°F -32)	Temp (°F) = 1.8 °C +32
Pressure	1 Pa = 1 N / m² = 1.4504 x 10^{-4} psi 1 bar = 10^5 N / m² = 14.5 psi 1 atm = 1.01325 bar = 14.696 psi	1 psi = 6894.8 Pa

$$\frac{\text{ft}}{\text{Min}} = \frac{(\text{rev/min})^* (\text{shaft diameter (inches)})^* \pi}{12}$$

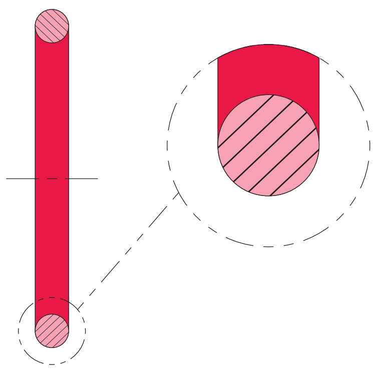
***NOTE:** All formulas assume concentricity and most apply to a Piston configuration.

SEAL GLOSSARY

We have selected the most popular types of seals and given you a basic example of each complete with a brief description of its common use.

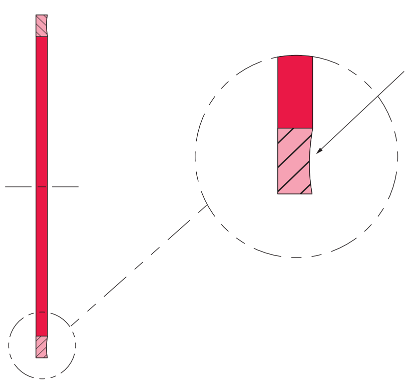
O-Ring

A doughnut-shaped object, or torus, that functions as a seal blocking the passage of liquids or gases. This seal is energized by being compressed between two mating surfaces comprising the walls of the cavity (gland).



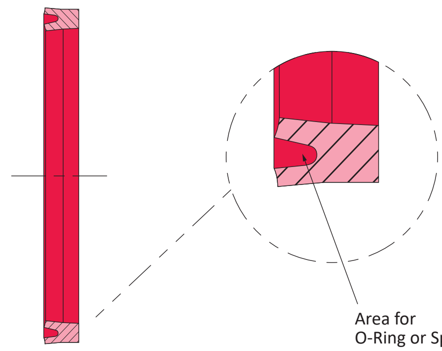
Back-Up Ring

A washer-like device of a relatively hard, tough material installed in the gland on the downstream side of the o-ring to prevent o-ring extrusion into the diametrical gap while under pressure.



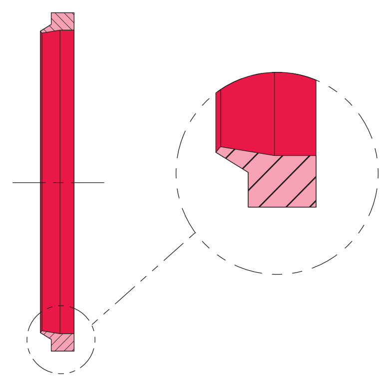
U-Cup

Used extensively throughout the pneumatic and hydraulic industries because of low breakaway force and dynamic friction. Also used for sealing large extrusion gaps. Designed for low speeds/pressures and can be energized with springs or o-rings.



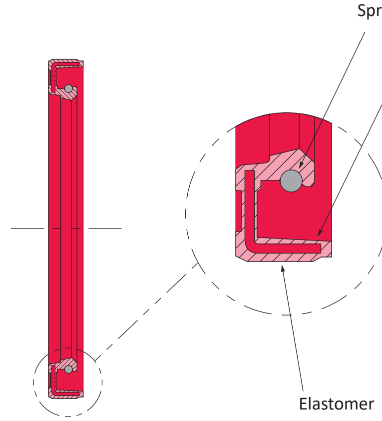
Wiper

Designed to exclude foreign debris from contaminating the sealed system via a long, flexible lip. Should not be considered as the primary seal, only as a secondary seal.



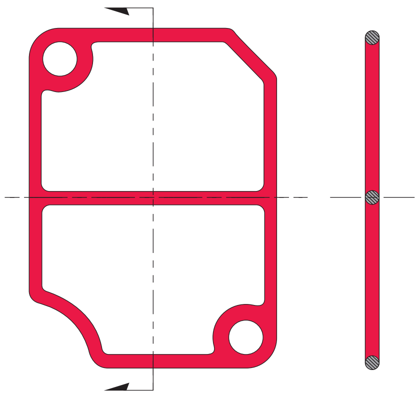
Shaft Seal

Typically employed in engines, pumps, and electric motors. Maximum RPM for effective sealing depends on many factors such as surface speed, shaft finish and hardness, pressure, eccentricity, and lubrication.



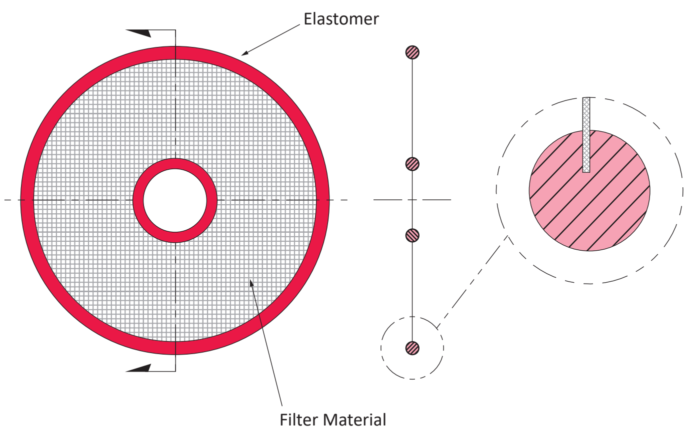
Housing Seal

An alternative to flat gaskets and other gasketing methods for sealing plastic or metal housings. Features round "o-ring" cross section and can be reused after disassembly.



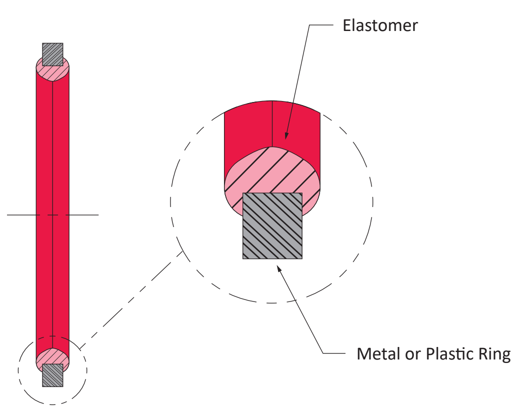
FilterSeal®

Combination of elastomer and fabric that operates as both a seal and a filter.



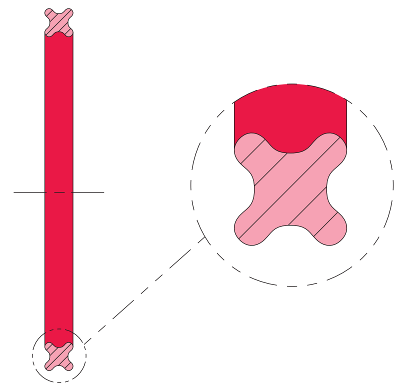
Composite Seal

A seal combining the structural advantages of metal or plastic with the sealing advantages of elastomers.

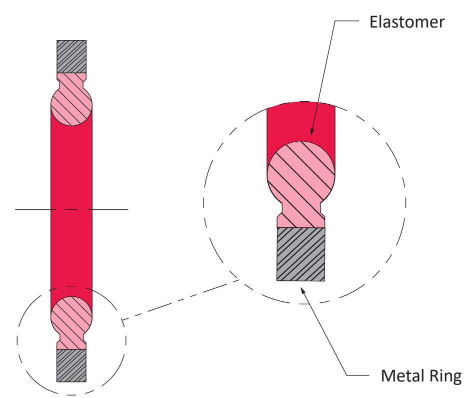


X or Quad-Ring®

A four-lobed profile primarily used in dynamic situations because of reduced friction and increased resistance to spiral failure. The parting line is located away from the sealing surface, unlike o-rings in radial applications.

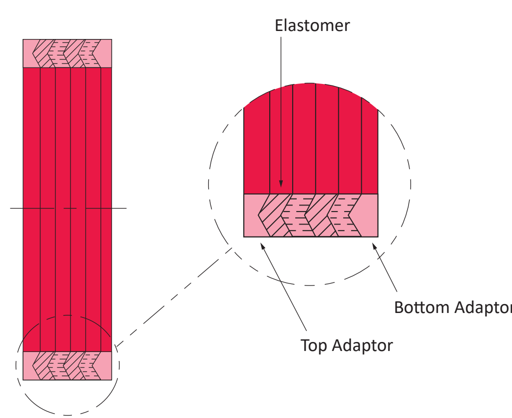


Torque-lok™ Seal



Vee Packing

A set of elastomeric and sometimes non-elastomeric rings which rely on fluid pressure to activate the seal. Primarily used in dynamic applications such as reciprocating shafts.



The adaptors can be elastomeric or non-elastomeric.

12 Index, Bibliography and Trademarks

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310 Erie Street
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P (716) 684-6560
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