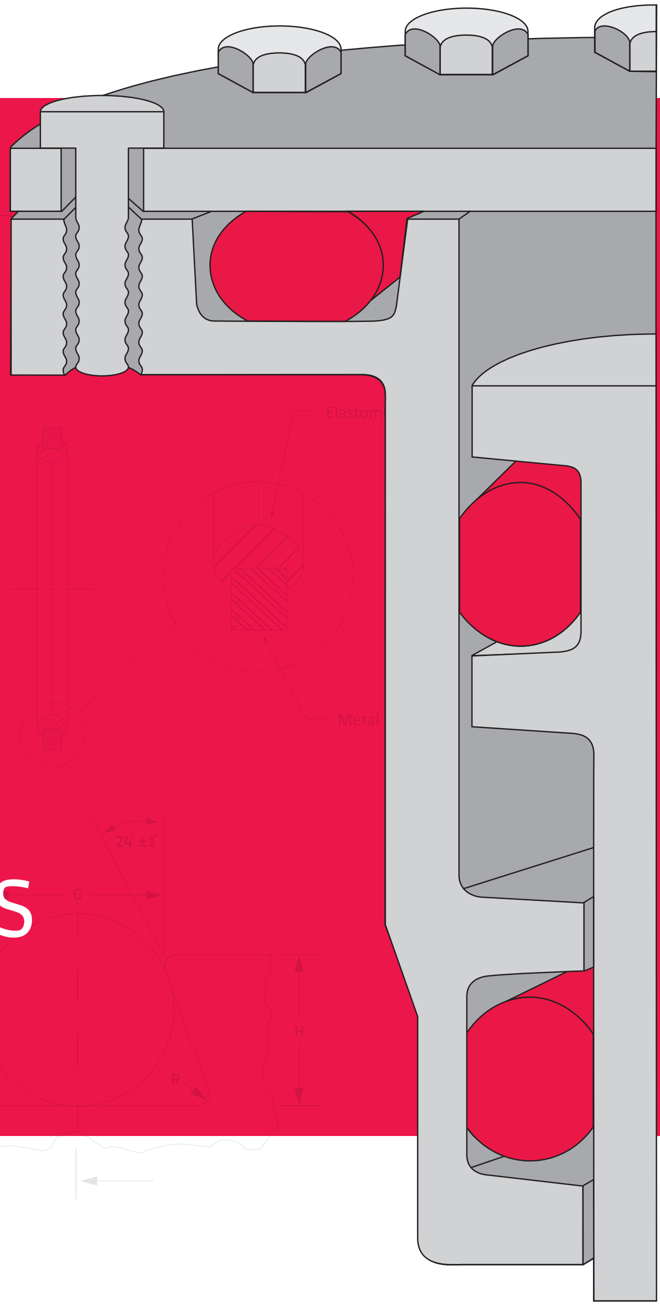
Seal Design Guide

O-Ring Basics



Apple Rubber

appleruBber.com

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

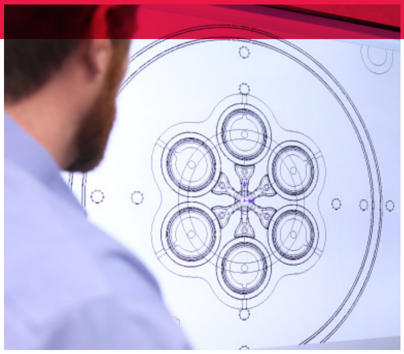
To provide an effective seal, the o-ring's inside diameter (I.D.) must be smaller than the piston groove diameter, so that the o-ring is slightly stretched, fitting snugly in the groove. This stretch should be between 1%- 5% with 2% as the ideal in most applications. A stretch greater than 5% is not 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:

$$\text{O-RING I.D.} = \frac{\text{Groove Diameter}}{\underset{(1\% - 5\%)}{\text{\% of stretch desired} + 1}}$$

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.

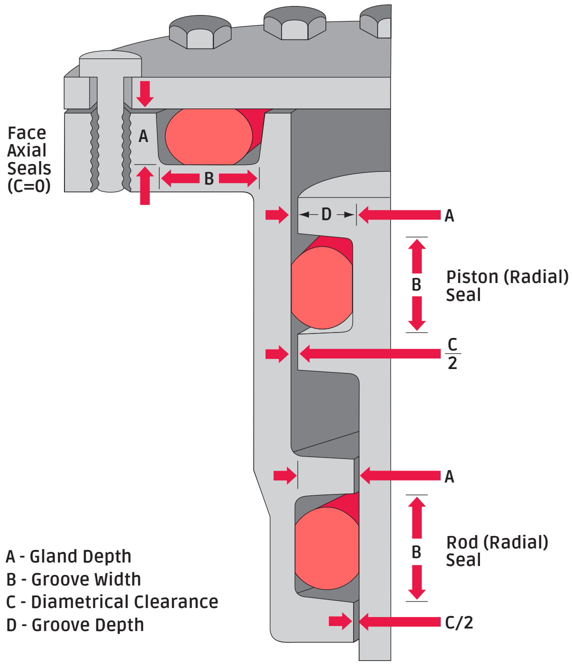


Illustration 3.1, Common Applications

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

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

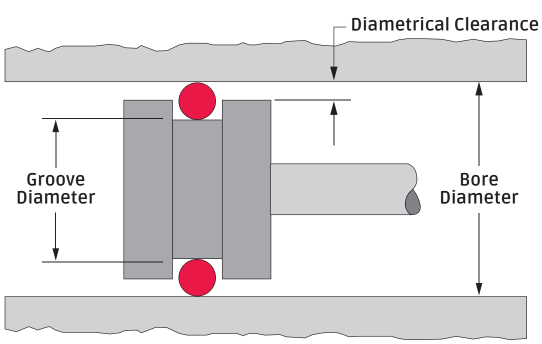


Illustration 3.2, Radial Seal

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

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

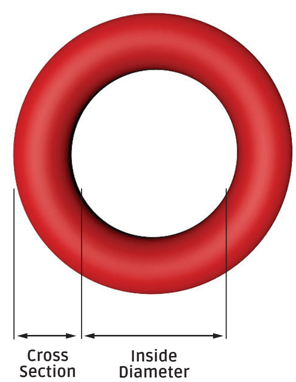


Illustration 3.3, O-ring Profile

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.

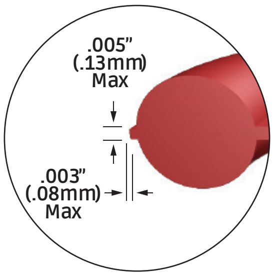


Illustration 3.4, O-ring Profile

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.