O-Ring
Design Guide

K.C. Seals Inc.

O-Ring Gland Design Guidelines

Important factors involved when selecting which O-ring to use

The cross-section of the O-ring can be the most important factor involved when designing your housing details. The tables below describe some of the advantages when opting for a smaller cross-section in comparison to a large cross-section.

Advantages of Smaller Cross-Section

- More compact
- Lighter Weight
- Less expensive-especially for higher cost elastomers like FKM or Fluorosilicone
- Less machining required for machined grooves since grooves are smaller
- More resistant to explosive decompression

Advantages of Larger Cross-Section

- Less prone to compression set
- Less volume swell in liquid-on percentage basis
- Allows for larger tolerances while still maintaining acceptable compression squeeze and compression ratio over full stack-up range.
- Less prone to leakage due to contamination-dirt, lint, scratches, etc.

ID/OD Interference

The ID or OD of the O-ring should be chosen to minimize the potential for installation damage and to minimize wear during use. This can be accomplished by adhering to the following guidelines.

- For piston gland seals the ID of the O-ring should be smaller than the OD of the gland so that the installed O-ring is always slightly stretched. As with all O-ring design calculations, this should be checked at the maximum and minimum stack-up conditions
- For rod gland seals the OD of the O-ring should be slightly larger than the ID of the gland so there is always some interference.
- For external pressure face seals the ID of the O-ring should be slightly smaller than the gland inner diameter (Gland ID) so when the pressure is applied, the O-ring is already where it would be as a result of pressure
- For internal pressure face seals the OD of the O-ring should be slightly larger than the gland outer diameter (gland OD) so when the pressure is applied, the O-ring is already where it would be as a result of the pressure.

Piston Gland Seal

Interference = $\frac{OD - Gland\ \emptyset}{OD}$

Max = 5% Min = 0%

Rod Gland Seal

Interference = $\frac{OD - Gland\ \emptyset}{OD}$

Max = 2% Min = 0%

External Pressure Face Seal

Interference = $\frac{OD - Gland\ \emptyset}{OD}$

Max = 5% Min = 0%

Internal Pressure Face Seal

Interference = $\frac{OD - Gland\ \emptyset}{OD}$

Max = 3% Min = 0%

Reduction in Cross-Section

Since elastomers are essentially incompressible materials, if the ID of the O-ring is stretched (as a result of the ID interference), the cross-section of the O-ring will decrease. The following equation and tables give the O-ring cross-section that result from the ID interference. The new cross-section should be used for all compression and gland fill calculations.

The impact of OD interference on the O-ring cross-section varies and does not require design considerations.

For reference purposes the equation for the volume of an O-ring is as follows.

O-Ring Volume

Volume = $\frac{\pi^2}{4}$ x CS^2 x [ID + CS]

AS568 Series	Original Cross-Section in Inches	Reduced Cross-Section at % ID Interference (inches)				
***Except for -001, -002 and 003 sizes**		**1%**	**2%**	**3%**	**4%**	**5%**
-0XX*	0.070 inches	.069	.069	.068	.068	.068
-1XX	0.103 inches	.102	.101	.100	.100	.100
-2XX	0.139 inches	.138	.137	.136	.135	.134
-3XX	0.210 inches	.208	.206	.205	.204	.203
-4XX	0.275 inches	.272	.270	.268	.267	.266

Compression Squeeze and Compression Ratio

An elastomer is defined as a synthetic or natural material with the resilience or memory sufficient to return to its original shape after a major or minor distortion. This resilience of elastomers is what makes O-ring work as seals. The design parameters that ensure this resilience is properly used and will probably have the biggest impact on O-ring sealing performance are compression squeeze and compression ratio. This resilience of elastomers is what makes O-rings work as seals.

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Compression Squeeze

Compression squeeze is the difference between the original O-ring cross-section (CS) and the gland height (Height) and is expressed in either inches or millimeters. Since almost all elastomers quickly take a 100% compression set with very light squeeze, it is essential that a minimum compression squeeze of 0.1 mm (0.005 inches) be maintained.

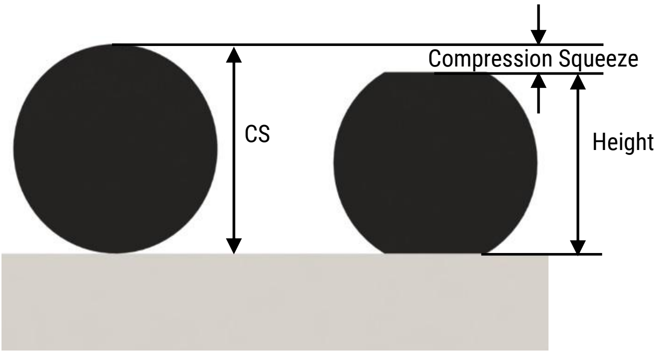


Figure 2.1: Important measurements in relation to compression squeeze

Compression Squeeze

Squeeze = CS – Height

Recommended Minimum Value

Squeeze > 0.1 mm (0.005 in)

Compression Ratio

The compression ratio recommendations seen below are for **Static** sealing applications only. When dealing with dynamic sealing applications you would want to use tighter tolerances on the mating components, as well as target a compression ratio range in the lower half of the static sealing recommended range (5% to 20%). A smaller compression squeeze is recommended die to friction and wear considerations.

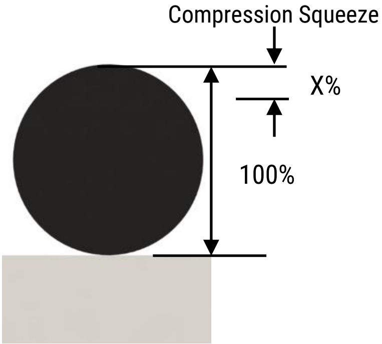


Figure 2.2: Important measurements in relation to compression ratio

$$\textbf{Ratio} = \frac{\textit{Compression Squeeze}}{CS} \times 100$$

Recommended Value

See Below

Compression Ratio Recommendations

Rod or Piston O-ring seal

Min: 5% Target: 20% Max: 30%

Static Axial O-ring Seal

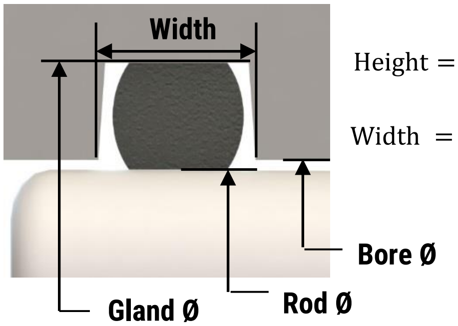
Min: 10% Target: 25% Max: 35%

Gland Dimension Calculations

Although each physical arrangement is different, each involves the O-ring being captured in a rectangular gland which has two sets of opposing surfaces. The first set of opposing surfaces is sealing surfaces, in that the distance between them, the gland height, is less than the O-ring cross-section (CS) so that the installed O-ring is compressed resulting in a sealing force.

The second set of opposing surfaces is containing surfaces, in that the distance between them, the gland width, is larger than the O-ring cross-section so that they only serve to keep the O-ring in place.

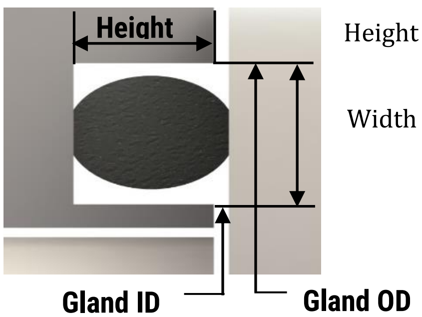
Gland height and width are used for compression and fill calculations. The formulas for calculating these gland dimensions for piston glands, rod glands and face seals are shown on the next page.



$$\text{Height} = \frac{\text{Gland } \emptyset - \text{Rod } \emptyset}{2}$$

$$\text{Width} = \text{Width}$$

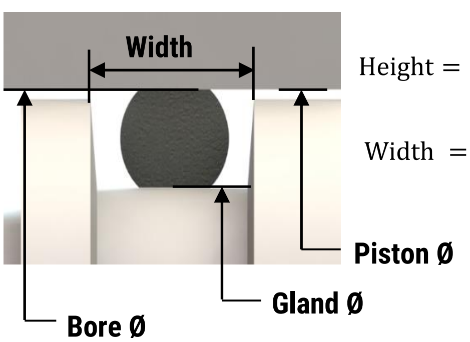
Figure 2.3: Rod Gland Seal important measurements and calculation.



$$\text{Height} = \frac{\text{Bore } \emptyset - \text{Gland}\emptyset}{2}$$

$$\text{Width} = \text{Width}$$

Figure 2.5: Face Gland Seal important measurements and calculation.



$$\text{Height} = \frac{\text{Bore } \emptyset - \text{Gland}\emptyset}{2}$$

$$\text{Width} = \text{Width}$$

Figure 2.4: Piston Gland Seal measurements and calculation.

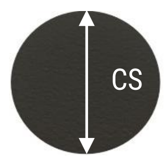
Note: There has been a recent trend to increase the amount of interference to a nominal value in the range 20 to 25%, particularly for face seal arrangements. Keep in mind; most design standards are for the regular materials in general purpose applications. Some materials, such as perfluoroelastomers, require special consideration as the high temperatures of operation and low strength at high temperature mean that care is required to avoid overstressing the material and interference is normally recommended to be limited to 13–15% maximum.

Gland Fill

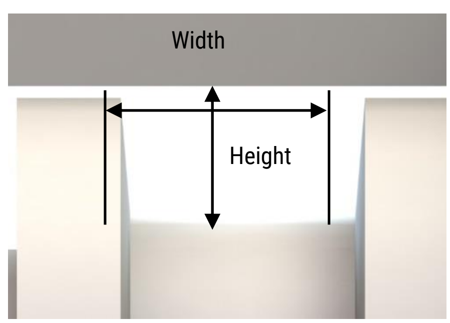
The volume percentage of the gland that is occupied by an O-ring is called gland fill. The cross-section of the gland and CS of O-ring are used to calculate the gland fill.

O-Ring Cross-Sectional Area

O-ring CSA = $\pi \times \frac{CS}{2}^2$



Gland CSA = Height x Width



The following target gland fill recommendations take into account several hardware and O-ring related factors including but not limited to thermal expansion, volume swell due to fluid exposure and the effect of tolerance stack-ups.

Recommended Values:

Minimum: 50%   Target Minimum: 65%

Target 75%   Target Maximum 85%

Additional Groove Details

Once the geometric arrangement and dimension for the O-ring gland have been determined, the following details must be observed for correct sealing function.

Groove Wall Angle

The wall angle of gland need to be in range from 0° to 5°.

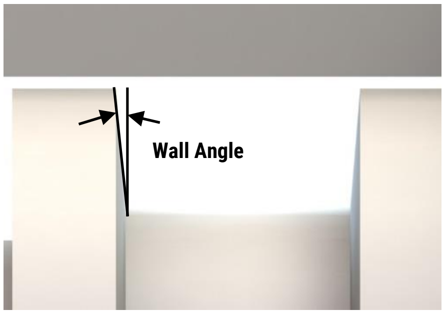


Figure 2.7: Example of groove wall

Transition Radii

The transition from the piston, bore or face to the groove edge and from the groove edge to the groove bottom must be slightly rounded as shown. Radii recommendations follow on the table.

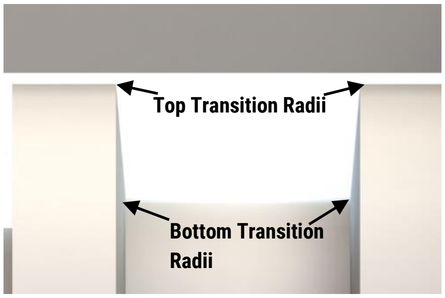


Figure 2.8: Example of Transition Radii

Table of Radii recommendations:

Gland Depth Range (mm)	Top Transition Radii (mm)	Bottom Transition Radii (mm)
1.0 to 2.0	0.1	0.3
2.0 to 3.0	0.2	0.3
3.0 to 4.0	0.2	0.5
4.0 to 5.0	0.2	0.6
5.0 to 6.0	0.2	0.6
6.0 to 8.0	0.2	0.8
8.0 to 10.0	0.2	1.0
10.0 to 12.0	0.2	1.0
12.0 to 15.0	0.2	1.2

Gland Depth Range (inch)	Top Transition Radii (inch)	Bottom Transition Radii (inch)
0.04 to 0.08	0.004	0.012
0.08 to 0.12	0.008	0.012
0.12 to 0.16	0.008	0.020
0.16 to 0.2	0.008	0.024
0.2 to 0.24	0.008	0.024
0.24 to 0.31	0.008	0.031
0.31 to 0.39	0.008	0.039

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0.39 to 0.47	0.008	0.039
0.47 to 0.59	0.008	0.047

Surface Finish

The surface finish of the sealing surfaces and the sides of the gland should be controlled as shown.

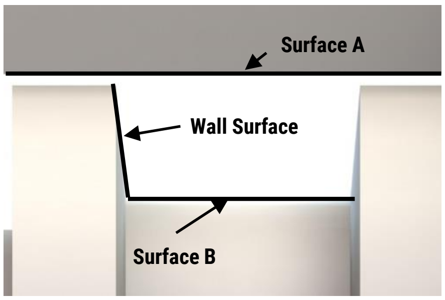

Figure 2.9: Surface Finish measurements

Constant Pressure Application Recommended Surface Values				
		Surface A	**Surface B**	**Wall Surface**
Max Ra	**µin** **µm**	1.6 64	3.2 128	6.3 256
Max Rz	**µin** **µm**	6.3 256	10.0 400	12.5 500
Max Rmax	**µin** **µm**	10.0 400	12.5 500	16.0 640

Pulsating Pressure Application Recommended Surface Values				
		Surface A	**Surface B**	**Wall Surface**
Max Ra	**µin** **µm**	0.8 32	1.6 64	3.2 128
Max Rz	**µin** **µm**	1.6 64	3.2 128	6.3 252
Max Rmax	**µin** **µm**	3.2 128	6.3 252	10.0 400

Extrusion Gap

Extrusion gap is a concern for radial seals where there is a gap between the piston and the bore for a male gland seal or between the rod and the bore for a female gland seal. Extrusion is not a concern for face seals where the metal parts to be sealed are typically in line-to-line contact. The concern is that at higher pressure, especially for softer O-ring elastomers, the O-ring can be forced by the pressure into the small gap between the piston or rod and the bore. Unless the bore and the piston or rod are ensured to remain concentric by the hardware, we have to assume that all of the gap possible can shift to on side.

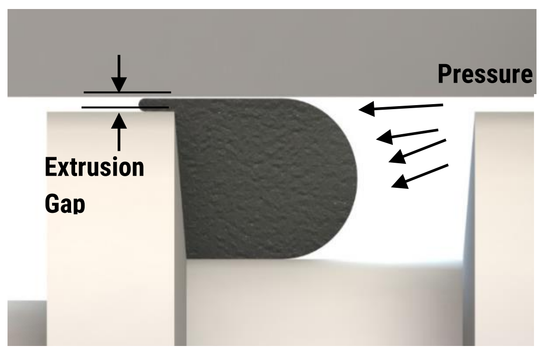

Figure 2.10: Example of Extrusion Gap

Note: The usual course of action to prevent extrusion is to incorporate a Back-up Ring, which can come in a variety of profiles and materials. For more information please view our Back-up Ring Design Guide or contact a member of our team at sales@kcseals.ca or 403-531-2690.

Diametrical clearance

The following table indicates the maximum recommended total diametric clearance for a given system pressure or hardness values between those listed in the table, either interpolated to determine the value or use the next higher pressure and the next lower durometer

Pressure	Extrusion Gap (in) based on Hardness (Durometer)			
(PSI)	60	70	80	90
500	0.010”	0.015”	0.020”	0.025”
750	0.005”	0.011”	0.016”	0.023”
1000	0.002”	0.008”	0.012”	0.018”
1250	0.001”	0.004”	0.009”	0.015”
1500	consult KC	0.002”	0.007”	0.012”

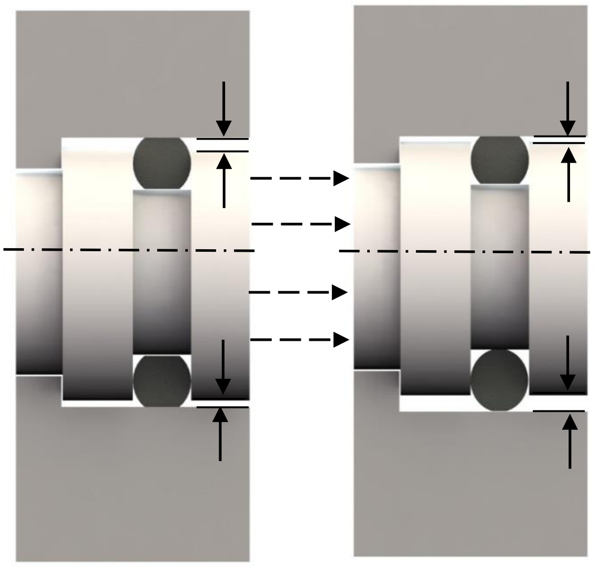

Figure 2.11: Concentricity and Diametric Clearance

Installation

Installation chamfer

A perfectly designed O-ring seal is of little use if the O-ring is damaged during installation. To prevent damage for male gland and female gland seals, a 15° chamfer on the bore or rod is recommended. The chamfer must be long enough to ensure that the O-ring sees only the chamfer when it is installed. Face seals do not require installation chamfers.

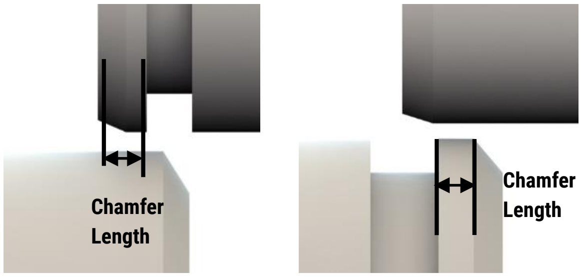

Figure 2.12: Example of Chamfer Length and Extrusion Gap

O-ring Cross Section		Chamfer Length	
Inches	MM	Inches	MM
0.070	1.78	0.083	2.10
0.103	2.62	0.122	3.10
0.139	3.53	0.157	4.00
0.210	5.33	0.236	6.00
0.275	6.99	0.283	7.20

General Installation Guidelines

- The O-ring must not be stretched beyond its elongation limit.
- Edges must be burr-free and all radii and angles should be applied smoothly.
- Dust, dirt, metal chips and other foreign material should be removed prior to installation of the O-ring.
- Tips of screws and installation housing for other sealing and guiding elements

should be covered by an assembly sleeve.

- A suitable lubricant should be applied to the assembly surfaces and/or the O-rings.
- All installation tools (mandrels, sleeves, etc.) should be made of a soft material and not have any sharp edges.
- The O-ring should not be rolled over assembly surfaces.
- Ensure that O-ring is not twisted during installation into the groove.

Some applications benefit from the use of an internally lubricated elastomer. Internal lubrication is typically accomplished in one of two ways.

- A Lubricant (typically an oil or wax) that is somewhat incompatible with the elastomer is added to the elastomer during compounding. The incompatibility causes the lubricant to “bloom” to the surface of the molded part over time, thus providing longer-term lubrication.
- A non-blooming lubricant, such as MoS2 or PTFE, is added during compounding to provide even longer-term lubrication.