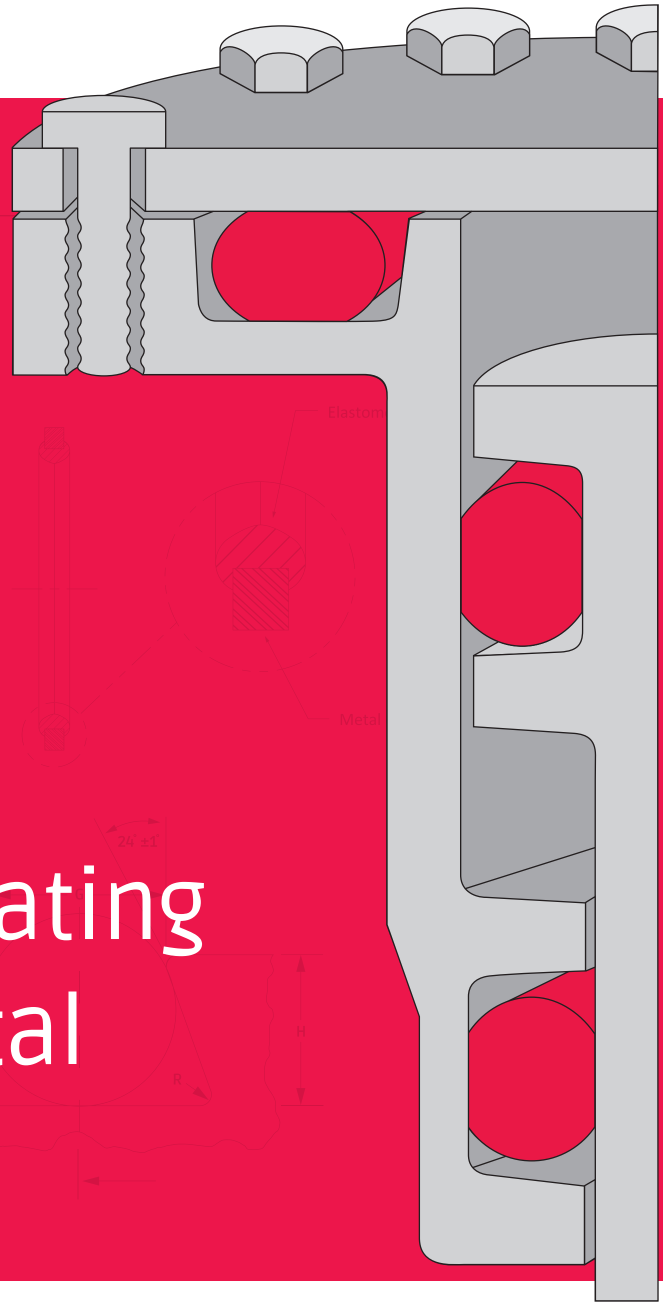
Seal Design Guide

Critical Operating Environmental Factors



Apple Rubber™

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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

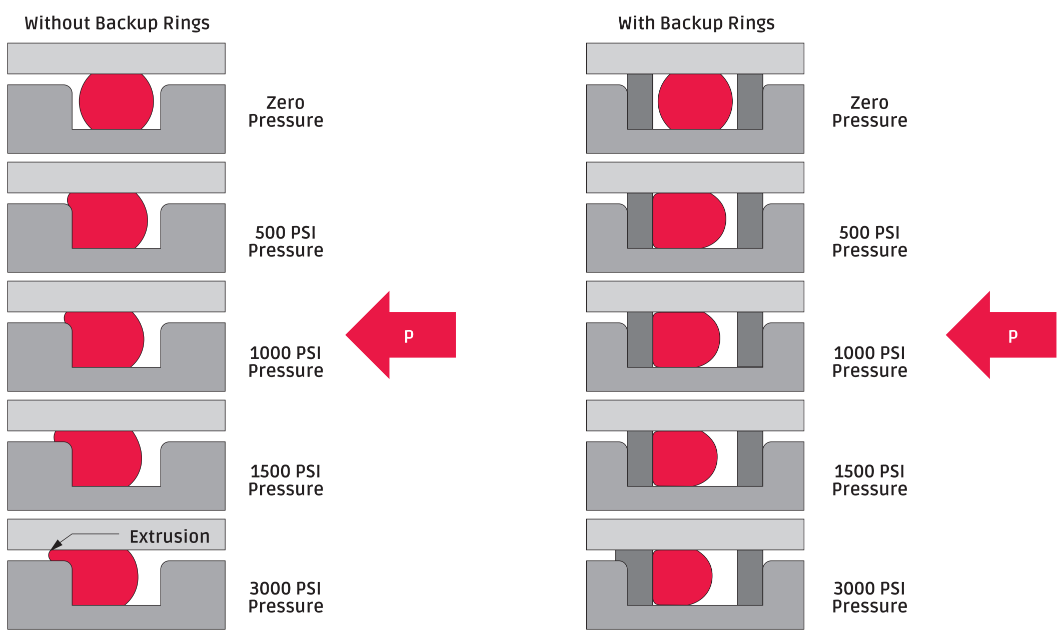

Illustration 5.1, Effect of Pressure

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.

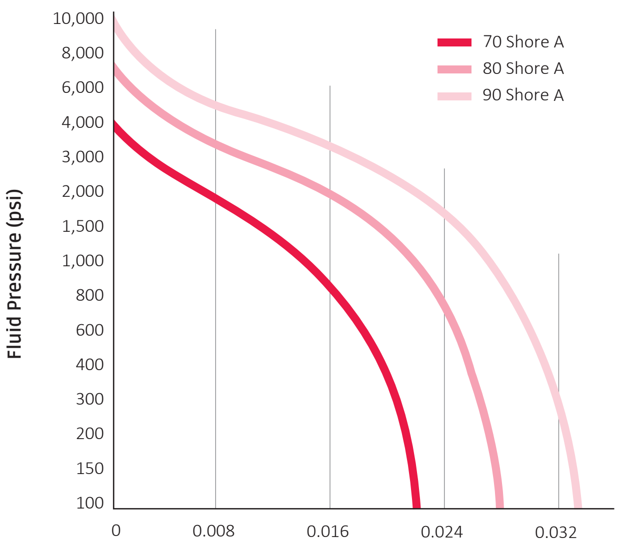

Illustration 5.2, Extrusion Limit

» 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.

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

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.

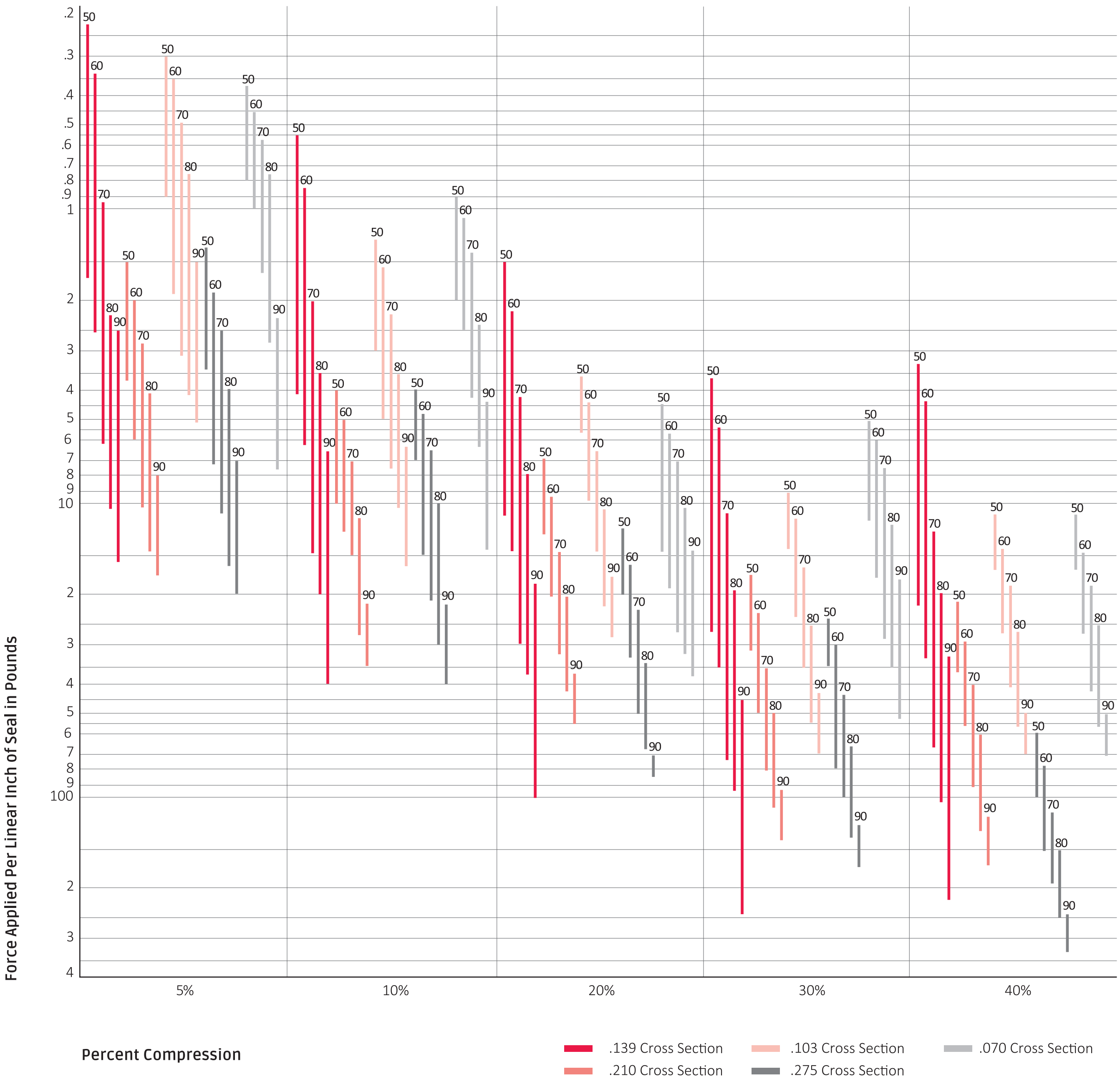

Illustration 5.3, Calculating Seal Compression

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.

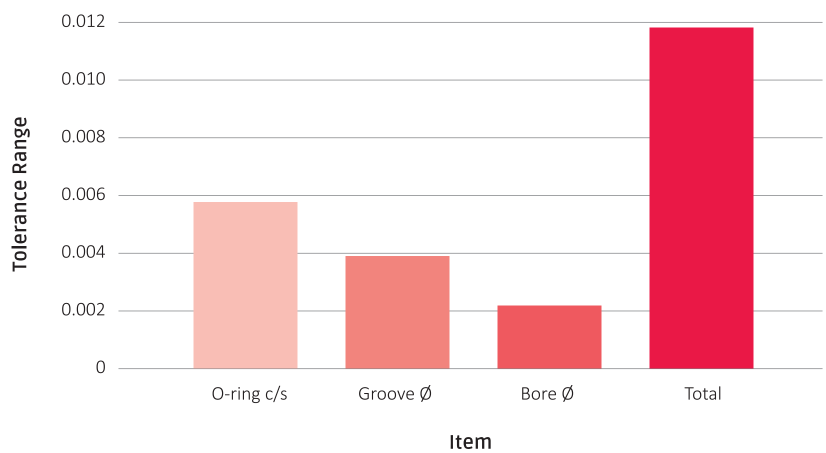

Illustration 5.5, Effects of Tolerance Stack Up