



Kalrez[®] perfluoroelastomer
parts

From DuPont Performance Elastomers

Seal Design Considerations Using Kalrez[®] Parts

Kalrez[®] perfluoroelastomer parts are primarily used in fluid sealing environments. In order to achieve optimum performance levels, it is essential to pay close attention to seal design parameters, especially as they relate to the mechanical properties of Kalrez[®]. In many cases, Kalrez[®] can be substituted for seals made from other elastomers with no change in standard practice for design and installation methods.

The sealing performance of an elastomer is a function of the stability of the material in the seal environment, the mechanical properties of the elastomer, and the mechanical design of the seal installation. Kalrez[®] is an exceptionally stable material that is serviceable in most chemical environments up to 260–316°C (500–600°F). The following sections discuss some design considerations when working with Kalrez[®].

General Gland Design

Kalrez[®] O-rings, in standard compounds, are manufactured to conform to the dimensions and tolerances specified in AS-568A, “Aerospace Size Standard for O-Rings.” Therefore, groove dimensions for static and dynamic seals should conform to those generally suggested for O-rings using this standard. Metric size O-rings are also available. Thermal expansion of Kalrez[®] seals must also be considered, especially at higher temperatures. Groove width should allow for the use of backup rings where appropriate. Surface finish of the gland should be at least 32 µin for both static and dynamic seals. If gases are being sealed, a surface finish of at least 16 µin is suggested.

Many factors affect seal design considerations, and these can be critical to the successful use of elastomer seal components. In general, the elastomer seals are the weakest mechanical member of a seal. Thus, the elastomer is usually the first member to fail if designs do not adequately deal with material limitations. The three properties of most concern are thermal expansion, extrusion, and compression set.

Gland Design Utilizing Kalrez[®]

O-Ring Compression

Experience with Kalrez[®] seals has shown that an installed compression (ambient temperature) of 12–18% is recommended for maximum seal life. Excessive compression on the O-ring seal may result in cracking, splitting, or extrusion of the O-ring, especially if the O-ring is exposed to high temperatures where thermal expansion is a major factor.

At temperatures below 0°C (32°F), it may be necessary to apply additional compression to the O-ring. An installed compression of 15–21% is suggested for these lower temperature applications. However, this higher compression may cause problems if the O-ring is cycled between very low and very high temperatures (>149°C [>300°F]); an approximate engineering balance must be reached.

O-Ring Stretch

For proper sealing and extended seal life, an installed stretch of 1–3% is generally suggested, with a maximum stretch of 5%. Too little stretch and the O-ring may not seat properly. Too much stretch and the O-ring may break or suffer premature failure due to high internal stresses (Gow-Joule Effect).

Thermal Expansion

The linear coefficient of thermal expansion for Kalrez® is $3.2 \times 10^{-4}/^{\circ}\text{C}$ ($1.7 \times 10^{-4}/^{\circ}\text{F}$) for the temperature range of 25–250°C (77–482°F). This translates to a volume expansion for Kalrez® that is approximately 75% greater than that for fluoroelastomers. This extra expansion must be considered when designing seals for higher temperatures. Otherwise, premature seal failure could result.

When designing a seal, it is generally suggested that a standard groove design be used as a starting point. In many cases, the groove may be adequate for Kalrez®. However, if the groove volume is insufficient at higher temperatures, thermal expansion will result in either extrusion of the seal through the clearance gap or circumferential splitting of the seal (usually along the parting line) if it can not extrude. In either case, it is necessary to increase the groove volume to accommodate the thermal expansion.

The following table shows the approximate linear and volumetric expansion that occurs as the seal is heated from room temperature.

Operating Temperature		% Expansion	
°C	°F	Linear	Volumetric
25	77	0.0	0.0
38	100	0.4	1.3
93	200	2.2	6.7
149	300	4.0	12.4
204	400	5.7	18.2
260	500	7.5	24.3
316	600	9.3	30.6

O-Ring Installation

Lubrication

The use of a lubricant during installation of an elastomer seal can minimize abrasion and cutting. In general, a light lubricant film applied to the O-ring is all that is required. Because Kalrez® is used in severe environments, the lubricant should be resistant to breakdown by carbonization in the environment. In many cases, the fluid being sealed may be used to lubricate the seal. Fluorinated oil, such as Krytox®, or powdered graphite may also be used. Even though an elastomer seal has been lubricated, care should still be taken when installing the seal to minimize the chance of damage to the elastomer.

Stretch

The elongation at break ranges from 120–170% for most Kalrez® compounds. The Kalrez® Physical Properties and Compound Comparison chart has elongation at break for the Kalrez® compounds. Care must be taken when installing the O-ring to prevent exceeding this limit and breaking the O-ring. In general, stretching the O-ring during installation should be limited to 50% of the elongation at break, even on a localized basis. For difficult installations, the O-rings can be softened by immersion in hot water. Appropriate installation fixtures should be used to prevent damage to the seals.

Other Design Considerations

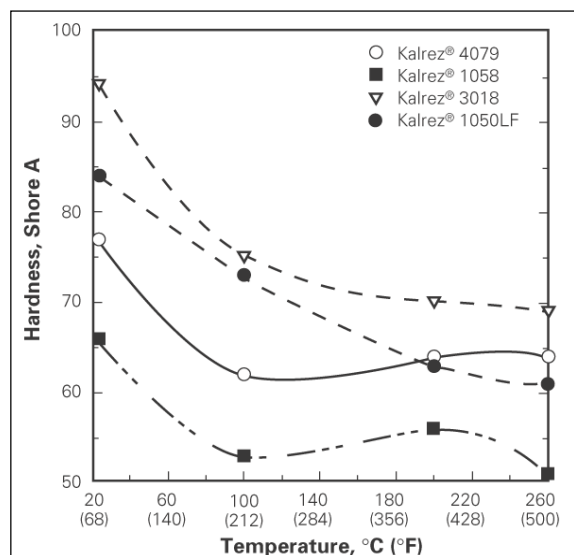
Extrusion

Extrusion of an elastomeric seal is a function of the operating temperature, the mechanical properties of the elastomer at that temperature, the clearance gap and the operating pressure. Because the elastomer is usually the weakest component of a seal assembly, failure by extrusion is an indication that the seal design does not adequately address the mechanical properties of the elastomer.

Under the effect of pressure, elastomer seals deform and tend to extrude through any seal gaps. Some extrusion helps to maintain an effective seal. However, if the extrusion is excessive, the seal will fail. An increase in the temperature, pressure, or clearance gap will increase the severity of the extrusion.

In many instances, parts made of Kalrez® perfluoroelastomer are used at very high temperatures because it is the only elastomer that is thermally stable at those temperatures. At high temperatures, Kalrez® softens and there is some decrease in mechanical properties. This decrease in properties can aggravate the extrusion phenomenon. *Figure 1* shows the decrease of hardness of several Kalrez® compounds with an increase in temperature. Therefore, extrusion may occur at higher temperatures while not occurring at lower temperatures.

Figure 1. Kalrez® Pellets: Hardness vs. Temperature (per ASTM 1415)



Even at moderate pressures (<1000 psi) and temperatures (149°C [300°F]), backup rings are an option to reduce stress on the elastomer and improve service life. Because the O-ring will deform under load and conform to the shape of the groove, high stresses can result in the O-ring at the corners of the groove. To help relieve these stresses, it is suggested to radius break the gland edges. If the stresses exceed the tensile limit of the material, the O-ring may develop localized splits. If this occurs, it is suggested that a contoured backup ring be installed on the downstream pressure side of the seal. The backup ring should be made from a material compatible with the process environment, and the groove dimensions should be increased to accommodate the backup ring and seal.

To prevent extrusion, it is suggested that:

- Clearance gaps be kept to the minimum achievable, consistent with economical machining process (this would typically be 0.002–0.005 in).
- Contoured anti-extrusion backup rings machined from Teflon® fluoropolymer resin, filled with 25% glass or other materials appropriate for the environment, should be used if reducing the clearance gap is insufficient. **The width of the grooves and seal cavities should be increased to accommodate the increased volume of the backup ring.** Inside corners of the backup ring should be radiused to minimize the potential for cutting the seal or creating areas of high stress.

Compression Set

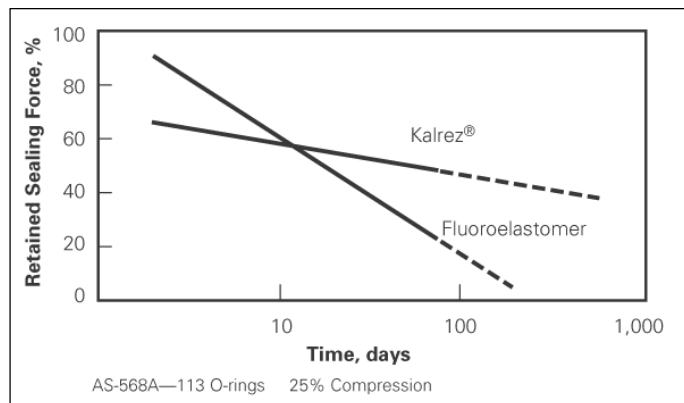
The compression set of Kalrez® may affect seal retention in applications that undergo broad thermal change. When Kalrez® is used continuously as a seal at high temperature, it will assume an equilibrium position and will seal for a long time. As the temperature is reduced, the seal “remembers” its equilibrium position. The physical volume of the seal gets smaller, which, when combined with the established seal equilibrium position, can cause leakage. This may occur even at room temperature, unless a restoring force such as a mechanical spring is imposed on the seal to retain its equilibrium position.

Should leakage occur at a lower temperature, the seal should be allowed to recover dimensionally by raising its temperature before applying any fluid pressure to it. This will permit the seal to recover and once again provide the desired sealing force.

The compression set values for Kalrez® O-rings are sometimes high when compared to some other elastomers. However, experience indicates that the high compression set values are caused primarily by stress relaxation rather than thermal or chemical degradation. Sealing performance tests confirm this.

One test that is very useful in predicting sealing properties is “Stress Relaxation in Compression.” This is commonly referred to as the “Lucas Test.” Simply put, this test measures the amount of sealing force that an elastomer is exerting to maintain a seal. Typically, values are reported as percent retained sealing force. *Figure 2* compares the retained sealing force of perfluoroelastomer and fluoroelastomer O-rings as a function of air aging at 204°C (400°F). *Figure 2* shows the exceptional stability of Kalrez® with time, whereas the fluoroelastomer rapidly loses its ability to maintain a seal.

**Figure 2. Sealing Force Retention (204°C [400°F] Air)
of Perfluoroelastomer and Fluoroelastomer**



Special Application Considerations

High Vacuum Applications

Generally speaking, increasing the compression of an elastomeric seal's cross section has been shown to reduce gas permeation rates. Some of the theories regarding this phenomenon include:

- The gas must travel an increased path length through the elastomer.
- There is a decreased surface area available for gas entry.
- The elastomer is forced "deeper" to negate surface deviations.

The use of vacuum grease has also been shown to reduce gas permeation rates. This approach is only beneficial for lower O-ring compressions, for example initial compressions that are less than 30%.

Increasing O-ring compression for seals exposed to high temperatures may have a negative effect on Kalrez® parts. Due to thermal expansion, excessive compression may result in excessive stress on the O-ring, causing splits and subsequent seal failure.

The standard suggested compression guidelines of 12-18% should be suitable for most applications. Increasing compression to 20-25% may be suitable for some specific high vacuum applications. Face-type seals should be used whenever possible. Minimal clearance, the reduction of surface area exposed, and predictable compression around the circumference are all benefits of this type of design.

Additional Help

For additional help on critical sealing applications please contact your Kalrez® distributor or DuPont Performance Elastomers.

For further information please contact one of the addresses below, or visit us at our website at www.dupontelastomers.com/kalrez

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