

Chapter D3

The seal installation path



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Individual chapters of the Kalsi Seals Handbook™ are periodically updated. To determine if a newer revision of this chapter exists, please visit <https://www.kalsi.com/seal-handbook/>.

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1. Shaft chamfer fundamentals

As with many types of seals, a Kalsi Seal™ is typically first inserted into a groove in a seal housing, and then installed onto a shaft. Elastomeric Kalsi Seals are harder to damage during installation, compared to plastic seals. Because Kalsi Seals® are sometimes installed exclusion edge first, they can be easier to damage during installation, compared to an O-ring. Even O-rings can be damaged during assembly if no installation chamfer is present (Figure 15).

An installation chamfer, which gradually compresses the seal during installation, is required for proper installation of a Kalsi Seal (Figure 1). In corrosive applications such as oilfield mud motors, rotary steerable tools, and other drilling equipment, consider coating the chamfer for corrosion resistance, to avoid corrosion related seal contamination (Figure 8).

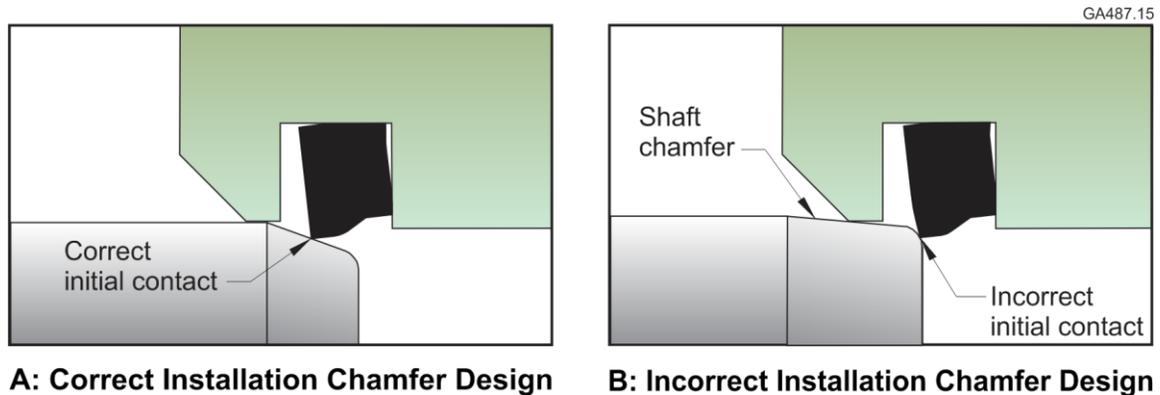


Figure 1
Installation chamfer design

Initial contact between the seal and the shaft must occur on the installation chamfer to avoid damaging the seal, as shown at A. If initial contact misses the chamfer, as shown at B, the seal may roll or become damaged. With a properly designed chamfer, the seal can be installed exclusion edge first (as shown) or hydrodynamic edge first.

The installation chamfer is ordinarily part of the shaft, but as an option it can be incorporated as part of a ring-shaped seal installation tool (Figure 2), provided that the tool is adequately centered by the shaft during seal installation. Such tools must be carefully handled and adequately maintained to avoid corrosion, contaminants, nicks, burrs, etc. that could damage the rotary seal.

It is critically important that initial contact between the seal and the shaft occurs on the chamfer, as shown on the left-hand side of Figure 1. If the seal is inadvertently forced

against a shaft shoulder during installation, as shown on the right-hand side of Figure 1, a portion of the seal may roll (Figure 3) or become damaged, resulting in impaired performance.

The installation chamfer should be designed to penetrate well past the leading edge of the dynamic sealing lip. Since some amount of angular misalignment is inevitable during assembly, the initial penetration should be great enough to ensure that the seal cannot inadvertently twist off the chamfer as installation force is applied.

Manual assembly is only suited to relatively small equipment components that are easily handled and aligned. Mechanical assistance should be used whenever heavy, cumbersome parts or large diameter seals are involved. Hydraulic presses or simple thread driven presses are both suitable. The seal hardware, the mechanic's skill, or the installation fixture must provide adequate alignment to ensure that initial seal contact takes place on the installation chamfer.

Chamfers of 30° or less, with a surface finish of $32 \mu\text{in}$ ($0.8 \mu\text{m}$) AA or less, are typically recommended for elastomeric seals. Chamfer angles as steep as 40° have been used on occasion for elastomeric seals but increase seal installation force (see Figure 7). Chamfers up to 20° have been used for Plastic Lined SealsTM, but 15° or less is preferred.

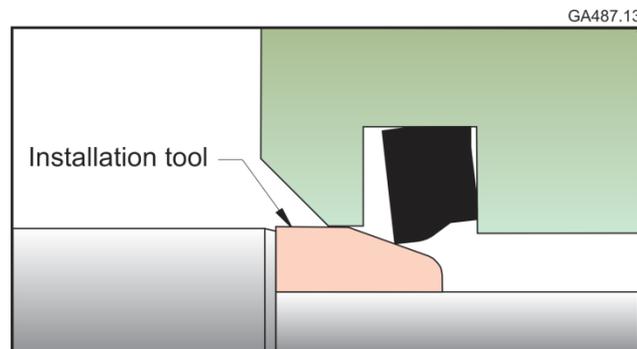


Figure 2

Example of a shaft seal installation tool

In this illustration, a centrifugal pump shaft requires a large shoulder to mate with the impeller. As a result, a seal installation tool is required to avoid damaging the Kalsi Seal during assembly.



Figure 3

An improper installation chamfer can cause local seal rolling during assembly

Other reasons for locally rolled portions of a rotary seal

In addition to the chamfer-induced rolling described above, there are other reasons that a local portion of a seal can become twisted.

Technicians can inadvertently leave a portion of the seal twisted during installation into the housing groove, which results in the same appearance as Figure 3. Installation of elastomeric seals – particularly small diameter seals – requires a certain amount of torsional twisting of the seal cross-section prior to insertion into the groove. It is the technician's job to make sure that all the seal is untwisted and tucked into the groove before the seal is installed onto the shaft. Train your technicians to inspect the seal immediately after installation into the groove, to make sure that none of the seal remains twisted.

When diagnosing twisted seals, remember that a technician might leave a portion of the seal twisted in either direction, but contact with a shaft shoulder during installation can twist the seal in only one direction.

Another cause of a locally twisted section of a used rotary seal is locally severe extrusion damage. Pressure continues to feed more seal material into the extrusion gap, to be consumed by the extrusion mechanism. This pressure feeding phenomenon can cause a local portion of the seal to be twisted. This twisting mechanism is usually identifiable by the typical signature left by extrusion damage. When such pressure-driven seal twisting is encountered, try to determine what is causing the extrusion damage to be more severe at a particular location. Such locally accelerated damage can sometimes be tracked to factors such as grossly eccentric extrusion gaps, local damage to the extrusion gap corner, seal overheating due to metal-to-metal contact, inadequate cooling, or excessive surface speed.

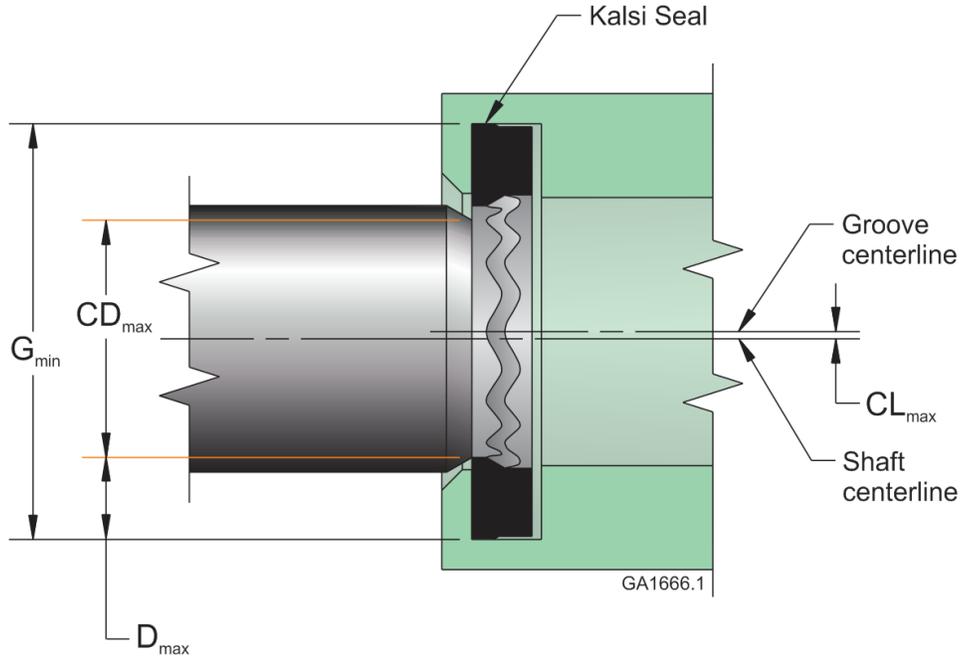


Figure 4

Variables for calculating seal installation chamfer size for a well guided assembly

2. Designing an installation chamfer for a well guided assembly

The variables that control the design of a chamfer for a mechanically guided assembly, or assembly by a skilled mechanic, are shown in Figure 4. The maximum chamfer diameter CD_{max} can be determined by the following equation:

Equation 1, Maximum chamfer diameter for a well guided assembly:

$$CD_{max} = G_{min} - 2 \times D_{max} - 2 \times CL_{max}$$

Where:

- CL_{max} = Maximum lateral offset of the installation chamfer relative to the seal groove that is possible during shaft insertion, taking all factors into account, such as chamfer machining eccentricity, the mechanic's estimated manual alignment accuracy, and/or the mechanical alignment accuracy provided by an alignment tool or by the fit of the seal carrier to the shaft.
- CD_{max} = Maximum installation chamfer diameter.
- D_{max} = Maximum seal radial depth (see [website](#)).
- G_{min} = Minimum groove diameter.

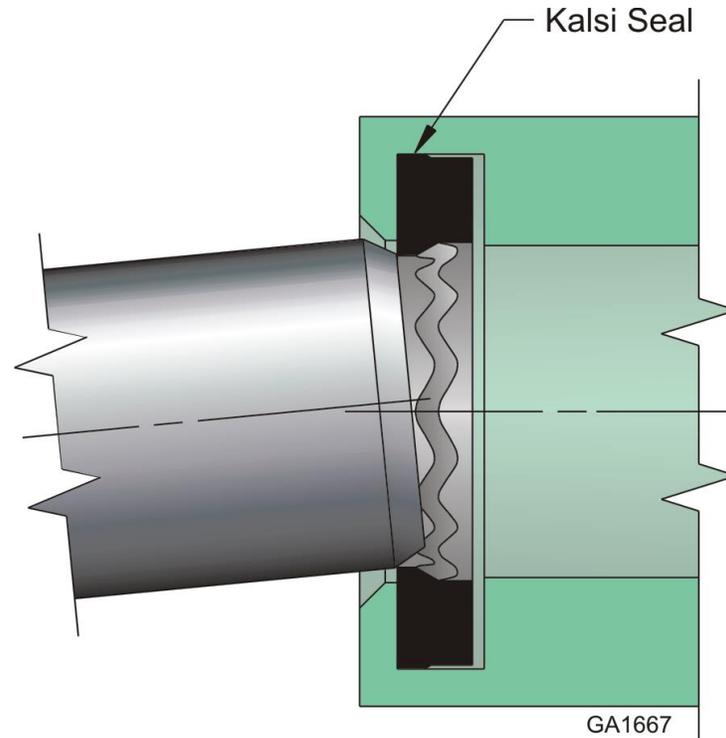


Figure 5
Example of a poorly guided assembly

3. Designing an installation chamfer for a poorly guided assembly

When a shaft may be poorly guided at the time of assembly (Figure 5), or may be installed by an unskilled mechanic, the chamfer should be designed so that it cannot damage the seal even if the shaft is grossly crooked relative to the seal at the time of insertion.

One way to accomplish this is to design the chamfer graphically (Figure 6) by:

1. Drawing the rectangular outline of the shaft.
2. Sketch the chamfer at the desired angle.
3. Sketch a radius as shown in Figure 6, making the radius of the circle equal to $G_{\min} - 2 \times D_{\max}$.
4. The intersection of the radius and the sketched chamfer line graphically represents the maximum allowable chamfer size CD_{\max} for the angle that was used to draw the chamfer.

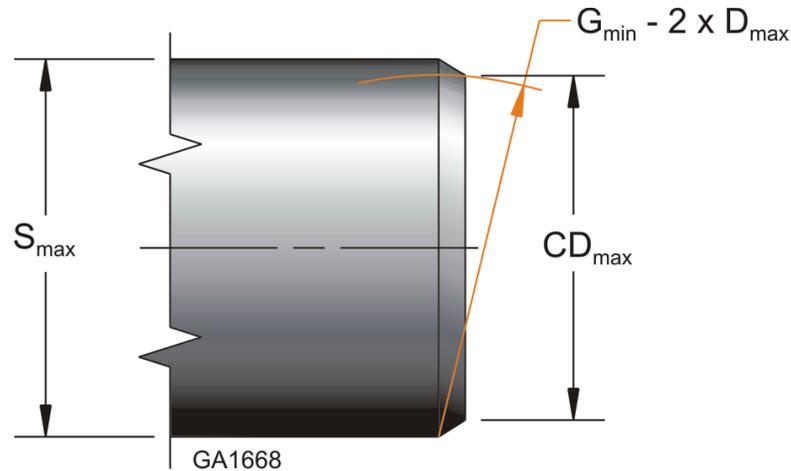


Figure 6

Variables for calculating the seal installation chamfer for a poorly guided assembly

4. Seal installation force

The seal installation path must be lubricated to minimize installation force and prevent seal damage. The lubricant used in the equipment being assembled can also be used to lubricate the shaft and the I.D. of the rotary seals during assembly. If the machinery uses a low viscosity lubricant, however, a higher viscosity installation lubricant can advantageously be used to reduce installation force, initial seal breakout torque, and circumferential seal slippage with respect to the groove.

More installation force is required as seal diameter, chamfer angle, and seal hardness increase, and as lubricant viscosity decreases. More force is also required when seals are installed exclusion edge first. Figure 7 shows installation force test results for a wide variety of conditions using solid cross-section elastomeric seals with a standard lip width. These tests were performed with higher than normal seal compression but represent the best available data. The test results show trends associated with chamfer angle and the viscosity of the seal installation lubricant. Filled, Grooved and Dual Durometer Kalsi Seals™ require less installation force than comparable solid cross section Kalsi Seals.

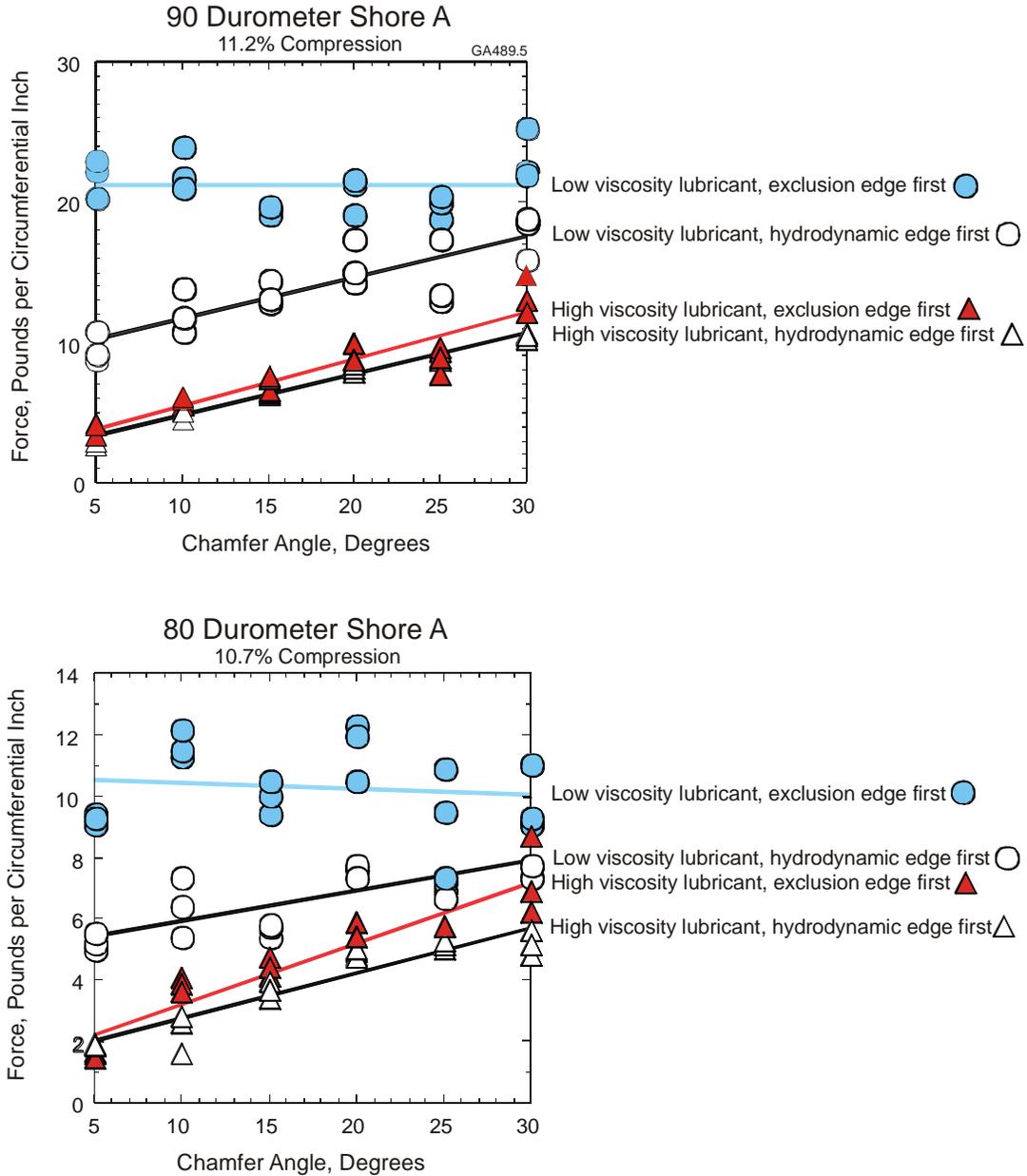


Figure 7

Seal installation force versus chamfer angle

These graphs show the room temperature installation force of 0.335" (8.51 mm) standard lip width solid cross-section elastomeric seals at higher than normal compression. The "low viscosity" lubricant was an ISO 32 viscosity grade, and the "high viscosity" lubricant was an ISO 1,500 viscosity grade.

Seals that are installed hydrodynamic edge first tend to capture a temporary lubricant film in the seal to shaft interface as they are pushed down the shaft. Seals that are installed exclusion edge first tend to scrape oil off the shaft as they are pushed along, leaving the

seal to shaft interface relatively dry. This has implications when two seals are installed onto the same shaft surface, because the second seal encounters a relatively dry shaft surface. This situation can be alleviated to a degree by introducing lubricant between the seals after the seals engage the shaft but before sliding the seals to their final axial locations. Although it may be relatively easy to slide a seal exclusion edge first down a shaft, reversing directions and pulling the seal off the shaft (before rotation occurs) will be more difficult because the seal to shaft interface is relatively dry. Likewise, initial breakout torque is greater if a seal has been installed exclusion edge first. (A special seal surface treatment is available on a custom basis to reduce seal breakout torque.)

5. Other seal installation path considerations

The seal installation path and running surface must be smooth and free of nicks, burrs, corrosion, contaminants, and wear patterns that could damage or contaminate the seal during installation or operation. If exposed to a corrosive environment, the seal installation path, including the installation chamfer, should be plated or treated for corrosion resistance. Figure 8 shows what can happen to an uncoated steel chamfer in oilwell downhole service.



Figure 8

To avoid seal contamination, provide corrosion protection

This un-plated installation chamfer for a mud motor seal was severely corroded by exposure to drilling mud. Any reuse of the shaft will result in seal contamination by the corrosion.

Any threads along the seal installation path should be recessed enough to avoid compressing the seal during installation (Figure 9). Radial holes and grooves along the installation path should be recessed or well chamfered (Figures 9 and 11) to avoid cutting the seal. The severity of damage that can result due to the lack of a proper installation path is illustrated in Figure 15. Keyways should be incorporated at relief diameters, rather than at the diameter the seal engages (Figure 12). If this is not practical, bevel the end of the keyway and radius the external corners (Figure 12).

Avoid installing the compressed seal over long sections of the shaft that are machined to the sealing diameter (Figure 13), because such sections may become damaged or contaminated, and in turn may cause seal installation damage or contamination. Preferably, such sections of the shaft are undercut so they are not in contact with the seal during seal installation (dashed lines on Figure 13). Similarly, there should be a step change in shaft diameter between the sealing surface and the bearing mounting surface, so that installation of the bearing races does not damage the sealing surface.

For installation paths where contact with sharp features such as threads, holes, and grooves cannot be avoided, cover the features with tape or a thin sleeve (Figure 10) during installation. Be aware that tape wrap has undesirable attributes – the wrapping process is slow, the quality of seal protection depends on the quality of the wrapping job, and detrimental adhesive transfer to the seal is possible. Beware that thin sleeves (Figure 10) may not hold up well to abuse in a production setting.

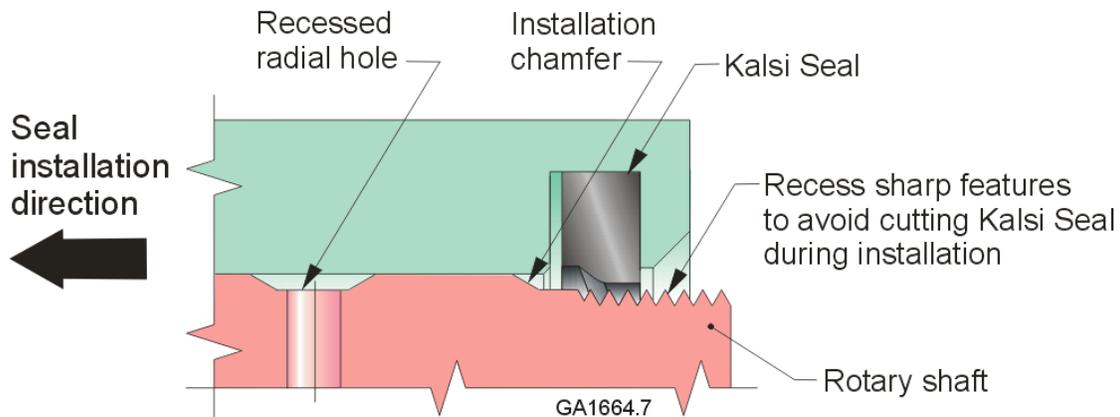


Figure 9

Recess sharp features to avoid cutting the seal during installation

To prevent damaging the Kalsi Seal during installation, sharp features, such as the threads and radial hole shown here, should be recessed to avoid compressing and damaging the seal. Radial holes along the installation path are a common feature in hydraulic swivels and rotary valve actuators.

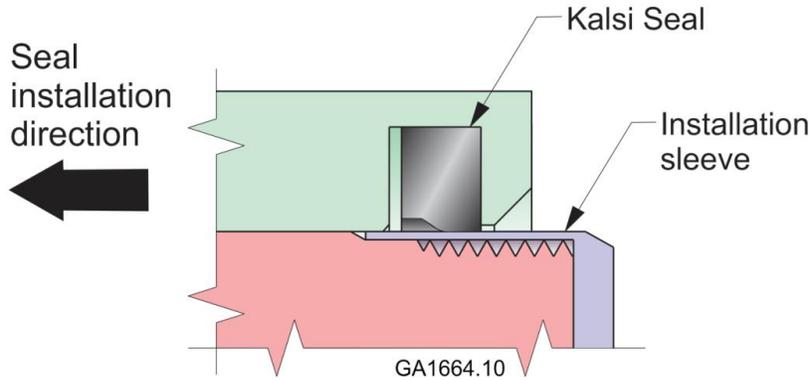


Figure 10

A seal installation sleeve protects the seal during assembly

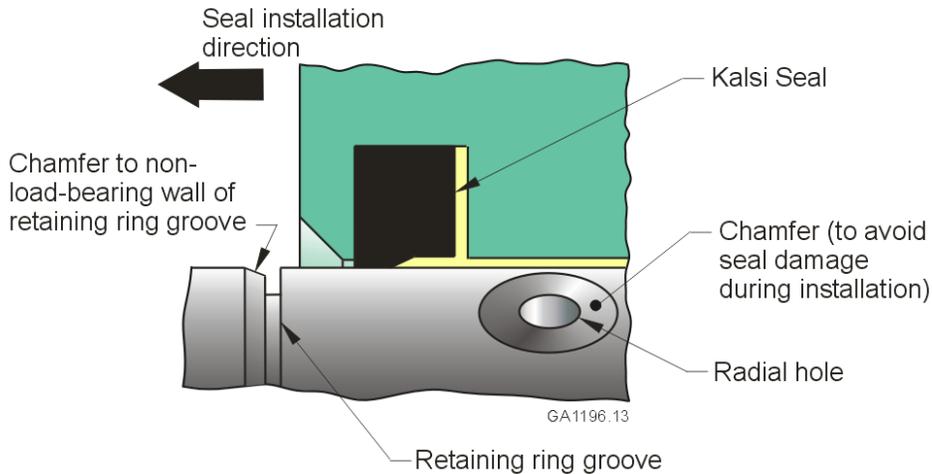


Figure 11

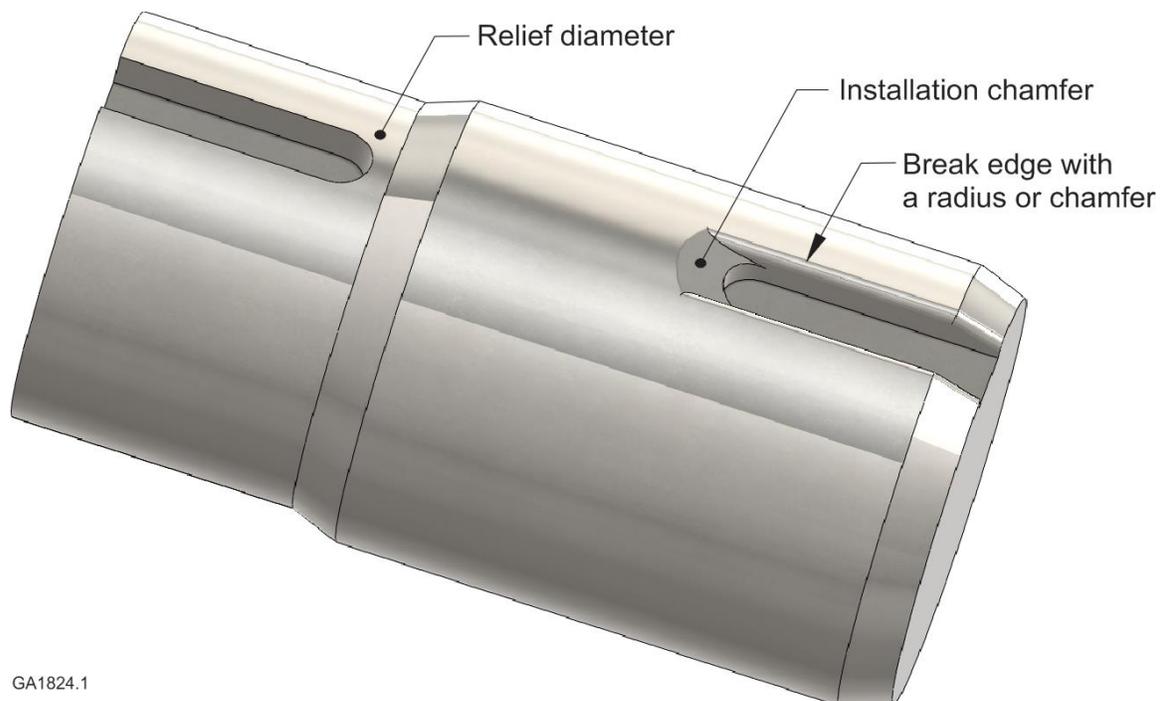
Other methods to prevent seal damage during installation

As an alternative to using an annular groove to recess radial holes, the mouth of the holes can be locally chamfered to avoid cutting the rotary seal during installation, as shown here. In some cases, the non-load bearing wall of a retaining ring groove can be chamfered to permit seal installation, however seal damage is likely to occur during disassembly.

An alternate method for installing Kalsi Seals over sharp features, such as grooves, is to incorporate a removable groove wall in the housing (Figure 14). The seal can then be slid across the sharp features before being installed into the groove, which lowers the risk of damaging the seal. After crossing the sharp features, the seal is stuffed into the groove, and the removable groove wall is installed. When using this method, an OD installation

chamfer must be used to facilitate stuffing the seal into the groove (see Figure 14). This chamfer can be either part of the housing, or part of a separate seal installation tool.

If the removable groove wall is on the environment side of the seal, it should be piloted closely to the seal groove bore so that the extrusion gap bore is as concentric with the shaft as possible. It should also be pinned, keyed, or bolted to the housing to prevent rotation.



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Figure 12**Keyways are preferably incorporated on relief diameters**

Keyways are preferably incorporated on relief diameters, as shown at the left of this rotary shaft. If a keyway must be cut into the diameter that a rotary seal engages, the end of the keyway must be chamfered and free of burrs, as shown at the right-hand end of this shaft.

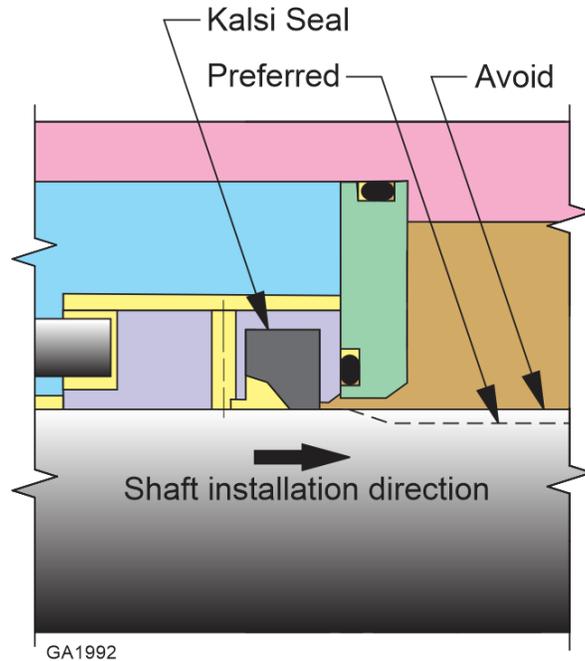


Figure 13

Reduce seal installation damage by relieving shaft diameter

Avoid installing the seal over long sections of the shaft that are machined to match the sealing diameter, because damage or contamination of such sections can harm the seal during assembly. Instead, provide a shaft relief diameter (dashed lines).

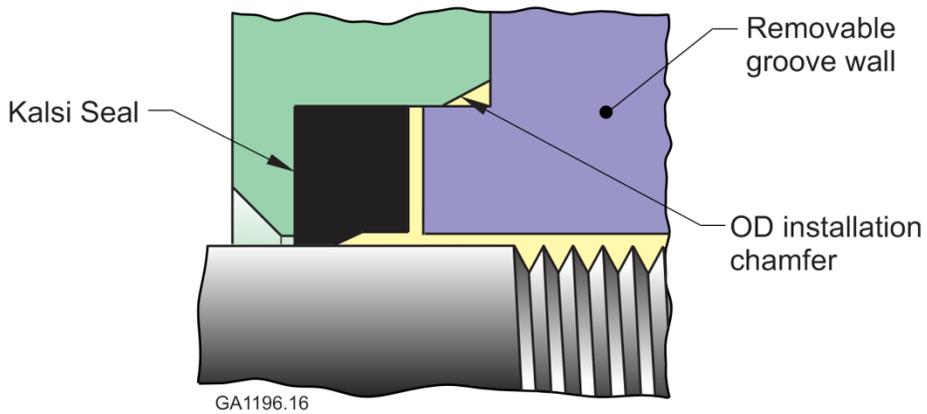


Figure 14

Optional OD seal installation chamfer

If the Kalsi Seal must traverse sharp features on the shaft during installation, such as grooves or threads, the seal can be installed into the groove using an OD installation chamfer.



Figure 15

O-ring damage from crossing an unchamfered groove

This O-ring was damaged from crossing the unchamfered groove of a retaining ring. Similar damage can occur to Kalsi Seals that slide across abrupt features. The result of such damage is seal failure.