

Chapter C12

Kalsi Seal breakout torque



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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 www.kalsi.com/seal-handbook.htm.

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A1. Introduction

Breakout torque¹ is the torque required to initiate relative rotation between the shaft and the rotary seal. While breakout torque *may* be an important design consideration in some applications, it is not important in all applications.

The data presented in this chapter is intended as general information and to illustrate trends. Kalsi Engineering (KEI) continues to perform breakout torque tests and collect data under a variety of conditions. Please contact us for the latest testing results that may be most applicable to your application.

The breakout torque of elastomeric seals, including Kalsi Seals, is related to interlocking between the seal and the shaft surface finish (Figure 1). It is also affected by the frictional characteristics of the seal material, running surface finish, the geometry of the dynamic sealing lip, lubricant viscosity, and the contact pressure between the seal and shaft. The contact pressure is a function of seal compression, seal material hardness, and differential pressure. Breakout torque typically increases with:

- Increases in shaft surface finish roughness
- Increased seal compression/contact pressure
- Decreased lubricant viscosity
- Increased differential pressure
- Increased seal hardness
- Increased contact area between the shaft and the seal
- Increased diameter of the shaft²
- Elapsed time since installation or rotation (until a steady state squeeze film thickness is reached)

Breakout torque is lower at the time of installation, or right after rotation, because of lubricant trapped in the interface between the rotary seal and the shaft. As time passes, the compressive force of the seal squeezes lubricant from the interface, and the seal increasingly interlocks with the shaft surface finish, increasing breakout torque. Maximum steady state breakout torque values occur when the compressive load of the seal is unable to squeeze any additional lubricant from the interface of the seal and shaft.

¹ Sometimes written as "*break out torque*" or "*break-out torque*".

² Shaft diameter has a squared effect on breakout torque. For example, a 0.600" diameter shaft will have 1.78 times the breakout torque of a 0.450" shaft, if all other factors are equal.

When low viscosity lubricants such as hydraulic fluids are used, initial breakout torque can be minimized if a higher viscosity lubricant is applied to the seal ID and shaft OD at the time of assembly³. Testing shows that the maximum breakout torque decreases after rotary use. This phenomenon has been observed in the restart of rotary tests, and is attributed to a combination of seal/shaft burnishing and compression set of the elastomer. The burnishing reduces and or rounds off the peaks found on the shaft surface finish. This reduces the amount of interlocking between the seal and the shaft. Compression set reduces the compressive load of the seal.

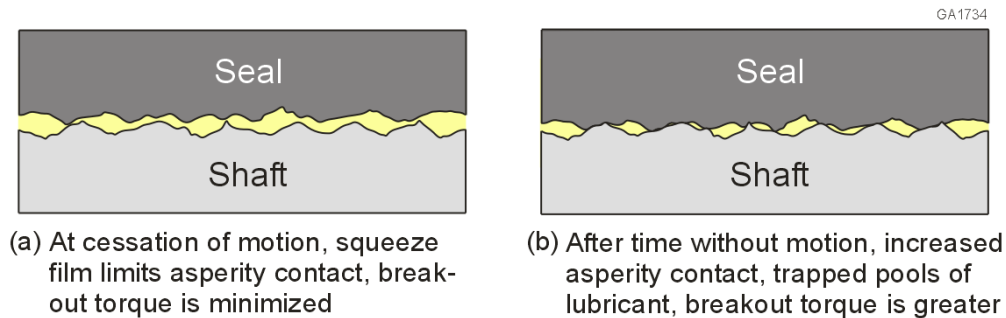


Figure 1

Breakout torque increases over time as the compressive load of the seal squeezes lubricant from the interface. Maximum breakout torque occurs when the remaining trapped lubricant pools and asperity contact areas are able to support the compressive load of the seal. Low viscosity lubricants are squeezed out of the interface more than high viscosity lubricants, resulting in a higher maximum breakout torque.

³ Room temperature, 0 psi testing shows a 34% reduction in bounding breakout torque for Wide Footprint Seals when using an ISO 1000 VG lubricant, compared to an ISO 320 VG lubricant. Grease did not reduce breakout torque. Grease is not recommended for use with Kalsi Seals because it reduces seal life in rotary service.

2. Estimating rotary seal torque from test data

Test breakout load, F_{BO} , is calculated by dividing the test breakout torque by the square of the test shaft diameter. This results in units of breakout load per inch of diameter. Dividing F_{BO} by $\pi/2$ gives the breakout load per inch of circumference.

To estimate breakout torque T_S for any given shaft diameter, S , in inches from a test F_{BO} , use Equation 1 below.

Equation 1, Predicted torque:

$$T_S = S^2 \times F_{BO}$$

Where:

S = Application shaft diameter

T_S = Predicted torque for application shaft diameter of S

F_{BO} = Breakout load from breakout torque test data

For example, from Figure 3 the maximum breakout load of a 2.75" ID (69.85 mm) PN 344-25-11 Standard Width Kalsi Seal was 40.2 lbf/inch (7,040 N/m). If an application required a 5.50" (139.7 mm) seal, the predicted breakout torque for one seal, using Equation 1, would be 1,216 in-lb (137.4 N·m).

$$T_S = (5.50 \text{ inch})^2 \times 40.2 \text{ lbf/inch} = 1,216 \text{ in-lb}$$

or

$$T_S = (0.1397 \text{ m})^2 \times 7,040 \text{ N/m} = 137.4 \text{ N}\cdot\text{m}$$

3. Breakout torque test methodology

The test fixture shown in Figure 2 is used to perform breakout torque testing of rotary seals. Breakout torque testing results are highly sensitive to test setup and the acceleration at the onset of shaft rotation. The greater the acceleration, the higher the measured breakout torque will be. A typical test includes a pair of 2.75" (69.85 mm) diameter Kalsi Seals installed against a tungsten carbide coated sleeve that has a surface finish of 3 μin (0.076 μm) AA across the lay. Torque is applied to the system using an electric motor with a 10:1 gear reducer. The gear reducer provides mechanical advantage, and allows the torque to be slowly and smoothly applied to the seals. An in-line torque cell is used to measure the applied torque. These two features eliminate equipment-associated friction/parasitic torque. A signal conditioner is used to provide a comparative measurement. A data acquisition system is used to capture the

instantaneous maximum breakout torque value. The test lubricant is liberally applied to the ID of the rotary seals and the OD of the sleeve prior to assembly, and the volume between the two Kalsi Seals is filled with the test lubricant. For tests at elevated temperatures, heater bands are applied to the OD of the seal carrier and insulation is placed around a bracket and carrier. For tests at elevated differential pressures, fittings are installed in the carrier and regulated nitrogen pressure is applied to the lubricant. When possible, the initial measurement is taken within one minute of sleeve installation. If this is not possible, such as when a test must be brought to an elevated temperature, the sleeve is rotated several times to introduce a film of oil between the Kalsi Seals and the shaft prior to the first reading.

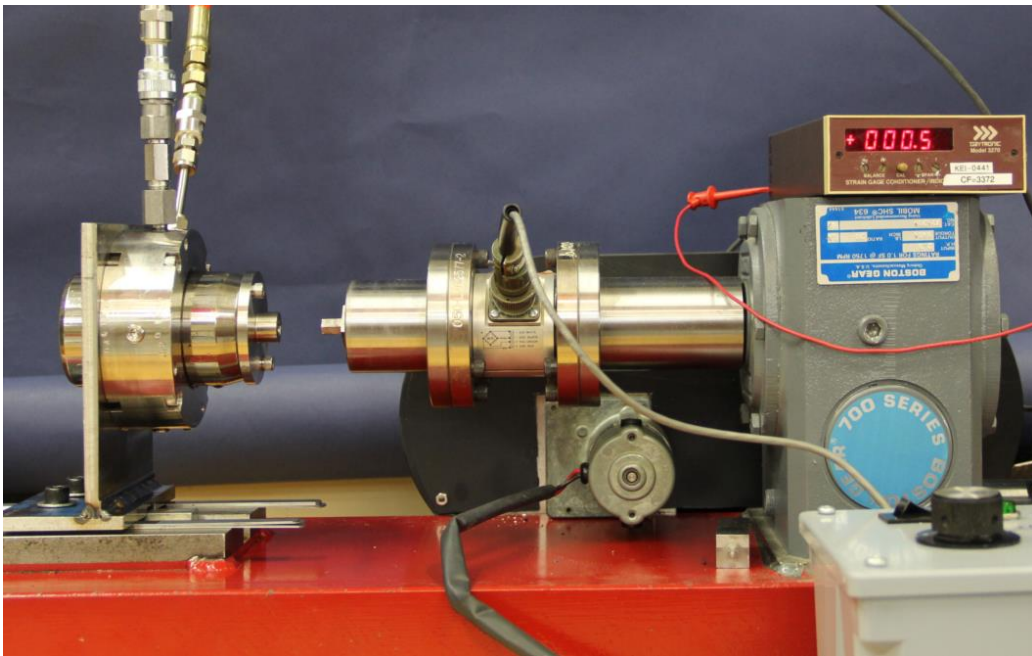


Figure 2

This is the test fixture that is used by Kalsi Engineering to determine the breakout torque of various rotary shaft seal geometries and materials.

The method employed to obtain breakout torque data is based on the elapsed time between measurements. If a reported measurement time is at the 24 hour mark and the next is at the 48 hour mark, an elapsed time of 48 hours occurred between the two measurements. This method closely follows ASTM recommendations.

4. Effects of seal geometry on breakout torque

For the purpose of breakout torque, most Kalsi Seals can be placed in four categories: Standard Width, Wide Footprint, Extra Wide, and Axially Constrained. The relative torque comparison of Wide Footprint and Standard Width seals, lubricated with an ISO 28 VG lubricant at room temperature, is shown in Figure 3. The Standard Width seals are tested with ~7.8% compression and the Wide Footprint Seals are tested with ~9.1% compression. The elapsed time is 168 hours. Tests with standard width seals and 28 VG lubricants show that the breakout torque at 24 hours and 2,187 hours are approximately the same. Based on this, 168-hour elapsed time is sufficient to achieve steady state breakout torque with this lubricant. The results presented are bounding values from a limited number of repeat tests.

The breakout torque of Wide Footprint Kalsi Seals tends to be higher than that of Standard Width Kalsi Seals. This is a result of the wider dynamic interface and larger seal contact area with the shaft—and in certain cases, more installed compression. While the width of the dynamic interface of Axially Constrained (462 Series) Kalsi Seals is similar to that of the Standard Width Kalsi Seal, the breakout torque tends to be higher due to higher contact loads resulting from the axial constraint of the seal.

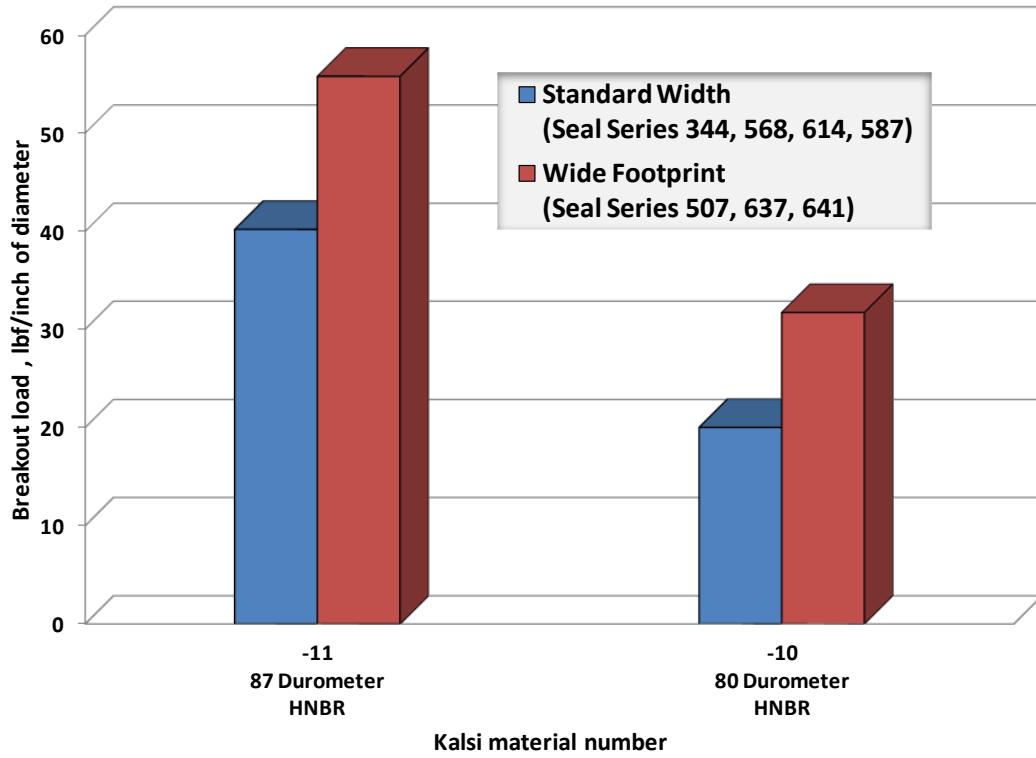


Figure 3

Room temperature breakout load, F_{BO} , of various 2.75" (69.85 mm) ID Kalsi Seal geometries at 0 psi using Aeroshell 560 lubricant.

5. Effects of lubricant viscosity on breakout torque

Low lubricant viscosity causes higher breakout torque. This viscosity effect is made evident in Figure 4. Figure 4 shows the room temperature breakout load at 0 psi for 87 Durometer HNBR (KEI -11 material) Wide Footprint, and Standard Width Kalsi Seals lubricated with ISO 28, 320, and 680 VG lubricants.

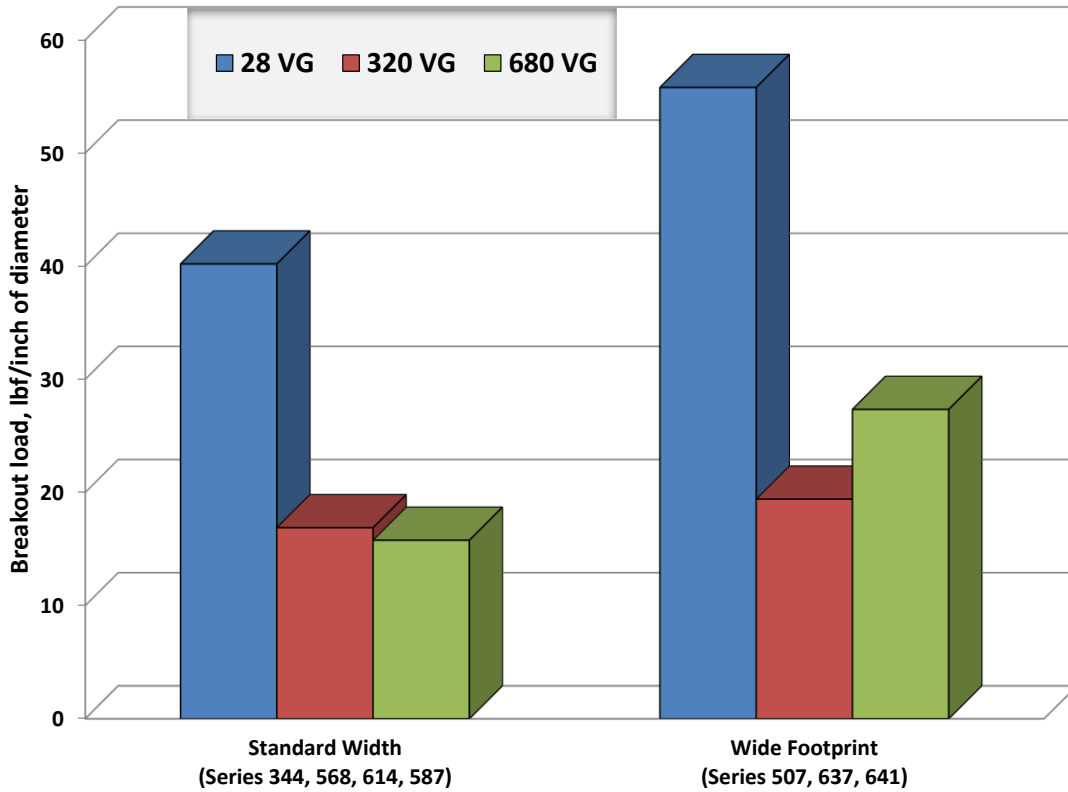


Figure 4

Room temperature breakout load, F_{BO} , of various 87 Durometer HNBR (-11) 2.75" (69.85 mm) ID Kalsi Seal geometries at 0 psi using various viscosity grade lubricants.

6. Effect of differential pressure on breakout torque

The impact of differential pressure, as a single factor, significantly affects the breakout torque of a Kalsi Seal. Since an elastomer behaves as an incompressible fluid, differential pressure across a seal directly increases the contact load in the seal-to-shaft interface.

The mechanisms described in this section, and the illustrated data, are for differential pressure acting across a Kalsi Seal. They in no way describe the effect of the hydrostatic pressure found in the downhole oilfield environment.

Figure 5 shows the effect of differential pressure on breakout load. The increase in breakout load is nearly linear with the increase in differential pressure.

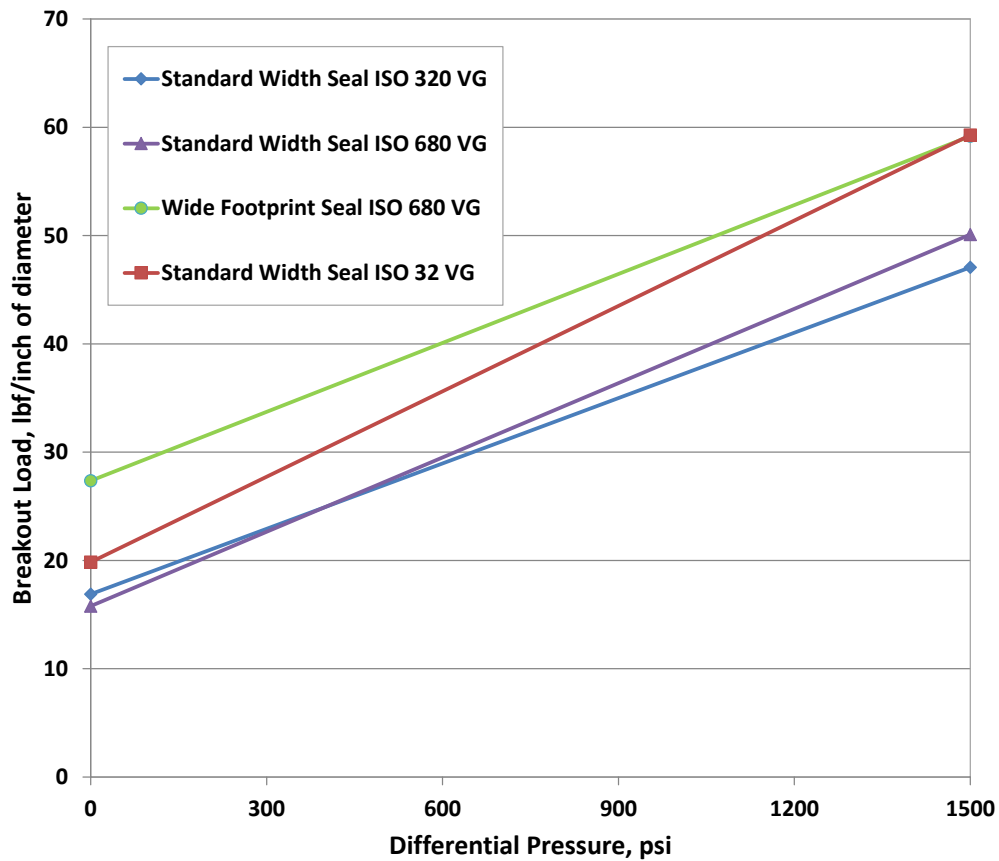


Figure 5

Room temperature breakout load, F_{BO} , of 2.75" (69.85 mm) ID Wide Footprint and standard width Kalsi Seals in 87 Durometer HNBR (-11) material with various lubricant viscosities and differential pressures

7. Geometry selection for reduced breakout torque

Methods exist to reduce the breakout torque of Kalsi Seals. Some of the methods have advantages and disadvantages based on application specifics.

Seal construction methods to reduce breakout torque

Filled (555 Series) Kalsi Seals (Figure 6) achieve lowered breakout torque by employing a deep environment-end groove that is filled with a low durometer material to reduce interfacial contact pressure. While this geometry does provide greatly reduced breakout torque, it does not adequately exclude abrasives when exposed directly to drilling muds. It does effectively exclude comparatively less abrasive environments such as road dust and sea water slurries in submerged dredge pumps. It should be noted that in addition to lower breakout torque, this geometry also has very low running torque.

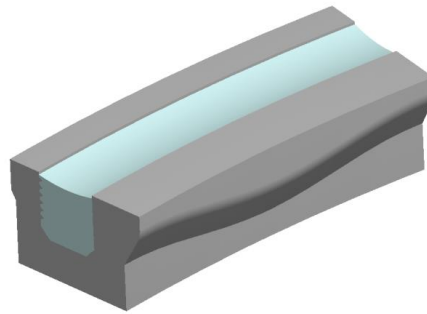


Figure 6
Filled Seals

The Filled Kalsi Seal features a soft energizer and hydrodynamic interfacial lubrication that significantly reduce torque and seal-generated heat. The seals are used to retain lubricant in high speed applications such as submerged dredge pumps and oilfield cement pumps.

Increased radial cross section to reduce breakout torque

It is possible to reduce breakout torque through the use of larger radial cross section Kalsi Seals.⁴ A certain amount of initial dimensional compression is required to accommodate shaft runout, manufacturing tolerances, assembly misalignment and material compression set. When the same amount of *dimensional* compression used in a smaller radial cross section seal is used with a larger radial cross section seal, the contact load is reduced. This is analogous to compressing a short spring and a longer spring equal linear distances. More force is required to deflect the shorter spring than the

⁴ Rotary shaft seals with larger radial cross-sections also have less chance of circumferential slippage relative to the seal groove.

longer spring. Reduction in the contact load will reduce breakout torque. The reduction in load is more than the reduction in percent compression, and the proportionality constant changes with cross-section and seal diameter. For a conservative estimate, assume the reduction in breakout load to be the same as the reduction in compression.

8. Rotary seal material selection for reduced breakout torque

In addition to the modulus of a material, the formulation of the material influences breakout torque. Figure 8 shows the room temperature breakout load for 0.335" (8.51 mm) radial cross-section, 2.75" (69.85 mm) diameter Standard Width Kalsi Seals, of various materials, tested with a 28 VG lubricant without differential pressure. The elapsed time is sufficient to achieve steady state breakout torque for this lubricant. The results presented are bounding values from a limited number of repeat tests.

As seen in Figure 8, the -106 Dual Durometer material has the lowest breakout load. Kalsi Seals using the Dual Durometer construction (Figure 7) achieve lowered breakout torque by employing a relatively soft energizing static lip material with a comparatively harder inner lip. The soft energizer reduces interfacial contact pressure while the hard dynamic lip material reduces interlocking with the shaft surface finish. The greatest torque reduction is achieved by selecting the softest energizer and hardest inner lip combination that is suitable for the application.

The Dual Durometer method of construction can be used with most types of solid cross-section Kalsi Seals, but is not compatible with Axially Constrained Kalsi Seals. While the use of the Dual Durometer construction can reduce breakout torque, the construction was initially designed for high differential pressure service. Rotary testing has shown, for extreme material hardness combinations, higher differential pressure is required for Dual Durometer Kalsi Seals to exclude abrasives as well as single modulus Kalsi Seals.



Figure 7
Dual Durometer Seals

The composite construction of the Dual Durometer seal consists of an outer material that is softer than the inner material, to reduce interfacial contact pressure. This reduces torque and seal generated heat, and improves extrusion resistance.

Kalsi Engineering has performed breakout torque tests on a variety of seal series and material combinations used in applications that are sensitive to breakout torque. There are likely hardness combinations that result in lower breakout torque. For a complete description of seal materials offered by Kalsi Engineering, see Section B of this handbook.

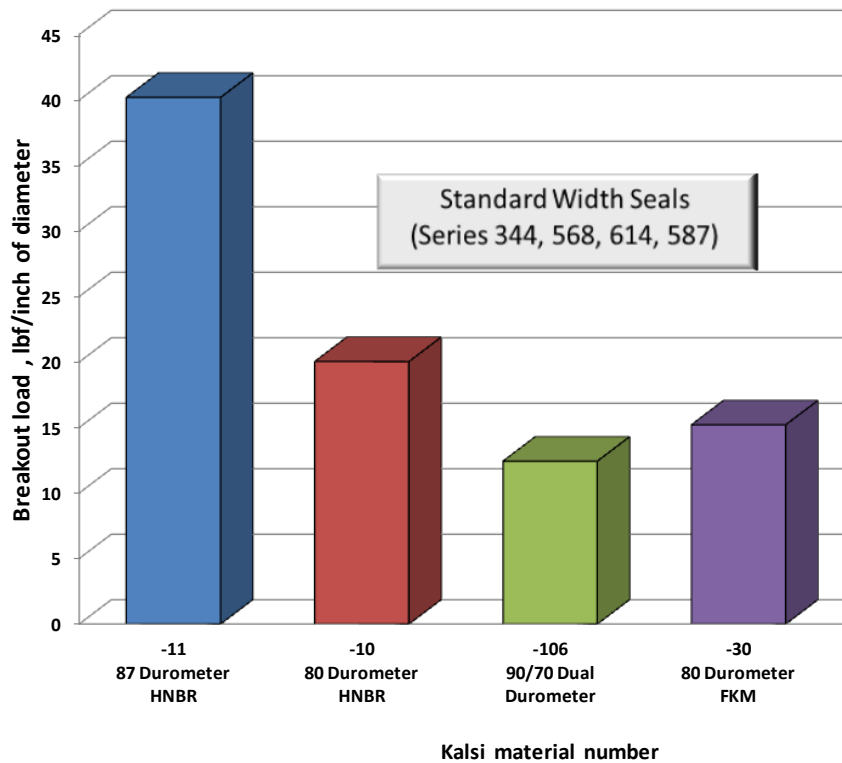


Figure 8

Room temperature breakout load, F_{BO} , of 2.75" (69.85 mm) ID, 0.335" (8.51 mm) radial cross-section, standard width Kalsi Seals of various materials with Aeroshell 560 lubricant at 0 psi.

9. Use of Kalsi Seal Low Friction (LF) surface treatment

Kalsi Engineering has a Low Friction (LF) surface treatment to reduce breakout torque of HNBR seals. This treatment can be combined with the other methods that reduce breakout torque to achieve the lowest breakout torque.

This treatment is applied to fully cured Kalsi Seals. The LF treatment is not a surface coating. The treatment penetrates and chemically alters the elastomer. Breakout load testing, shown in Figure 9, has shown that this treatment is highly effective at reducing the breakout torque of HNBR materials.

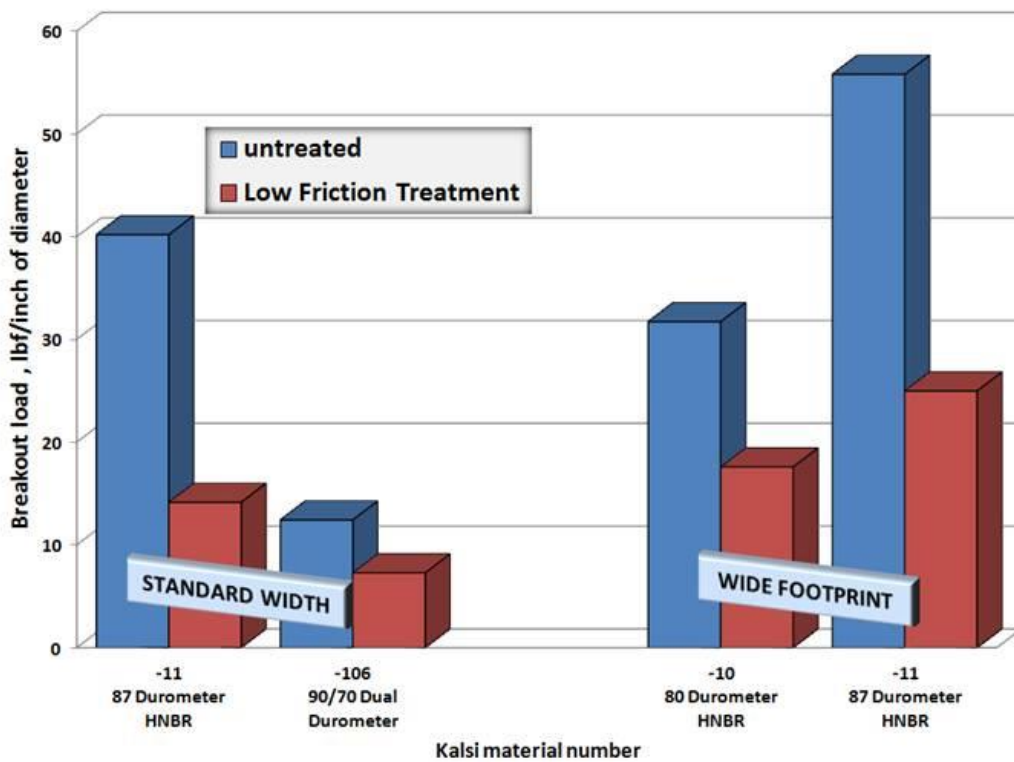


Figure 9

Room temperature breakout load, FBO, of LF treated and untreated 2.75" (69.85 mm) Kalsi Seals using Aeroshell 560 lubricant at 0 psi.

Testing for other performance characteristics

Testing was also performed to evaluate the effect of the low friction treatment on compression set and dynamic running torque, and to evaluate breakout torque after prolonged rotary operation. In these tests the treatment was shown to be robust and have no negative effect on compression set. In our testing of treated rotary seals, breakout torque did not increase after prolonged rotary operation and repeated starts and stops.

The impact of the low friction treatment on seal slippage

Rotary testing indicates that an all-over low friction treatment reduces the tendency for seals to slip circumferentially relative to the gland. This advantage can be increased by masking the static lip during application of the low friction treatment, however the all-over treatment is much more economical.

How to obtain seals with the low friction treatment

The low friction treatment can be applied to any newly manufactured⁵ HNBR Kalsi Seal as a special order item, if appropriate lead time is available. To specify an all-over low friction treatment, add the designator “-LF” to the end of the part number. To specify masking of the static lip during application of the treatment, add the designator “-LFM” to the end of the part number. Contact our sales personnel for pricing and lead time.

10. Plastic-lined Enhanced Lubrication Kalsi Seals

Certain types of Enhanced Lubrication Seals are available with plastic linings that have better high pressure extrusion resistance than rubber. Based on initial testing, such plastic linings also have much lower breakout friction, compared to treated and untreated rubber.

At the time of this writing, only a limited amount of comparative breakout torque testing has been performed. This testing, shown in Figures 10 and 11, has been performed at 1,000 psi. As the sealing diameter decreases, the plastic liner hoop strength increases, resulting in lower contact load between the seal and shaft and therefore lower breakout torque. Conducting the tests with 1,000 psi acting on the seal reduces the influence that the hoop strength of the plastic liner has on breakout torque making this data more accurate when estimating the breakout load for larger diameter seals.

⁵ The low friction treatment is **not** suitable for inventory that has already been packaged.

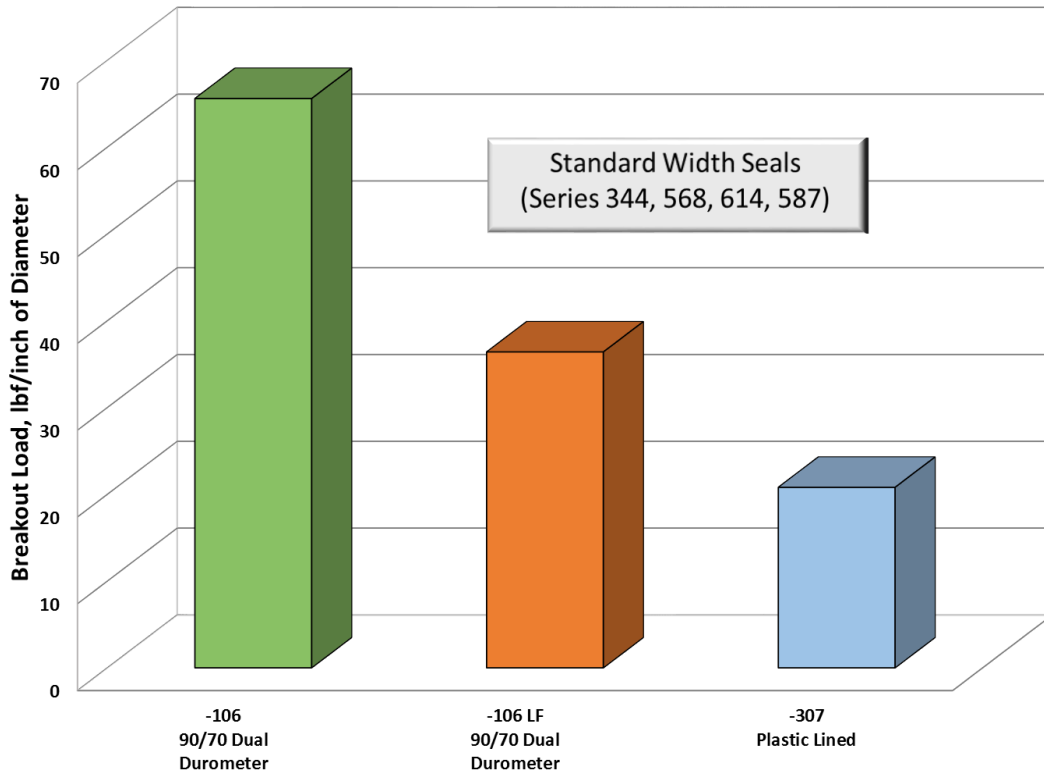


Figure 10

Room temperature breakout load, F_{BO} , of 2.75" (69.85 mm) ID, 0.335" (8.51 mm) radial cross-section, standard width Kalsi Seals of various materials with Aeroshell 560 lubricant at 1,000 psi (6.89 mPa)

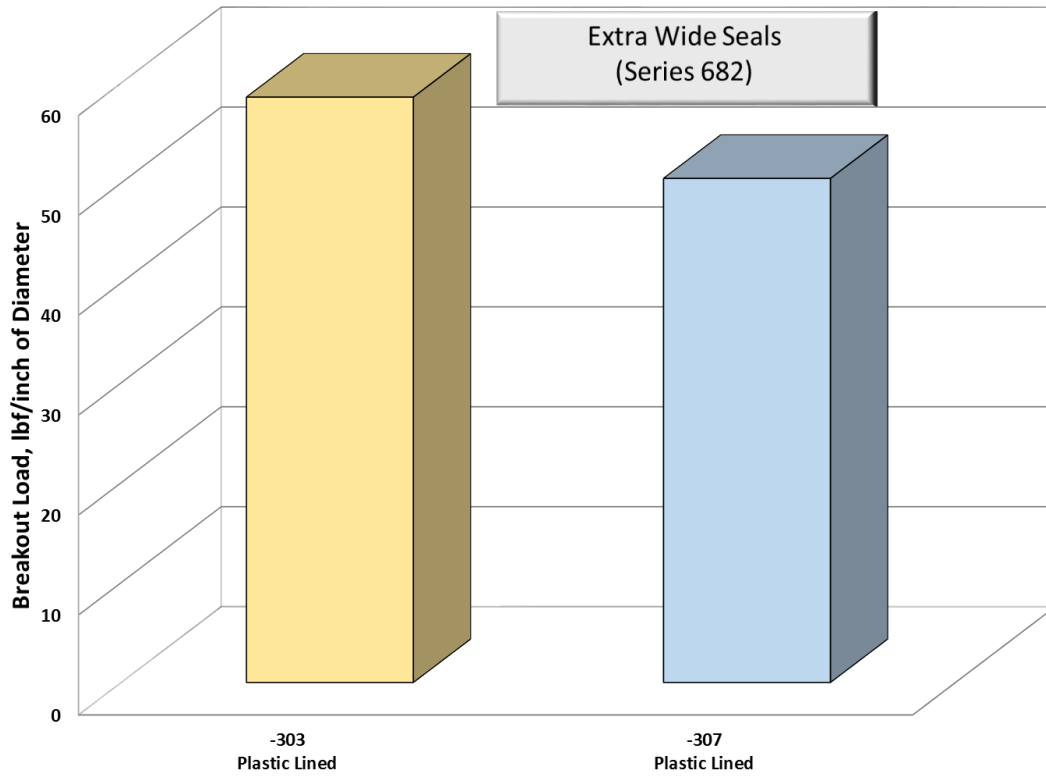


Figure 11

Room temperature breakout load, F_{BO} , of 2.75" (69.85 mm) ID, 0.335" (8.51 mm) radial cross-section, Extra Wide Plastic Lined Kalsi Seals of various materials with Aeroshell 560 lubricant at 1,000 psi (6.89 mPa)