

## Chapter C16

### Plastic lined Kalsi Seals



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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](http://www.kalsi.com/seal-handbook.htm).

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## 1. Higher differential pressure, lower breakout torque

Plastic lined Kalsi-brand rotary seals are high pressure shaft seals that have a plastic layer at the dynamic interface, and an elastomer energizing section forming the seal body. Radial compression of the elastomer loads the dynamic lip against the shaft. This type of seal is directed at increasing high pressure sealing capacity and reducing breakout torque.

We recommend plastic lined Kalsi Seals for use as pressure-retaining rotary seals in extreme pressure oilfield applications that employ lubricant pressure. Examples of such equipment are washpipe assemblies, side entry cement swivels, hydraulic swivels, and rotating control devices (RCDs). Many RCD designs, for example, will benefit from both the added pressure capacity and the reduced breakout torque of plastic lined RCD seals.

As with other Kalsi-brand rotary seals, our plastic lined seals rely on hydrodynamic interfacial lubrication to minimize the wear of the dynamic sealing surfaces. The significant level of hydrodynamic efficiency that is required to lubricate a plastic seal in high differential pressure conditions is achieved by the enhanced lubrication wave pattern, which possesses the necessary hydrodynamic efficiency required to lubricate plastics in high differential pressure sealing conditions.

The use of a plastic liner places a material at the extrusion gap that has a higher modulus of elasticity, compared to elastomers. This increase in modulus promotes high pressure extrusion resistance. The use of a plastic liner also places a material at the shaft that has a lower coefficient of friction than the elastomer that contacts the seal groove. This reduces breakout torque, compared to Kalsi Seals composed entirely of elastomer, and helps to ensure that the seal does not slip circumferentially within the seal groove.



**Figure 1**

### **An early screening test of plastic lined seals at 6,200 psi**

This extra wide plastic lined seal was tested at 6,200 psi and 350 RPM on a 2.75" shaft for 90 hours with an ISO 150 viscosity grade lubricant at ~160°F. The seal is oriented with the exclusion edge up, and is in excellent condition, as was its running mate. As a result of this screening test, we commenced a successful 1,000 hour, 7,500 psi duration test. The seals in both tests used the -303 material combination, and were tested with our patented floating backup ring arrangement.

For available seal sizes, visit [kalsiseals.com](http://kalsiseals.com).

## 2. Available materials

Plastic lined Kalsi Seals are available in four liner materials. For available material combinations, see Table 1.

The -32<sup>1</sup> and -35 liner materials are directed at extremely high pressure sealing applications, and both of them have significantly better extrusion resistance than the -33 liner material, as well as relatively low breakout torque. The -35 material has somewhat greater high pressure capacity than the excellent -32 material, and retains modulus better at elevated temperature, but costs significantly more. The -34 material is a variation of the -32 material, having lower breakout friction, better moldability, and less pressure capacity, compared to the -32 material.

Seals with the -33 liner material have relatively low breakout torque, even when compared to -106 LF dual durometer Kalsi Seals that have a low friction treatment. The extrusion resistance of a seal with a -33 liner is in the same range as a -106 seal.<sup>2</sup>

There are two different elastomer options for the rotary seal body. The 80 Shore A -10 body material reduces the lip loading, compared to the 85 to 90 Shore A -11 body material. In many cases, the higher lip loading can be desirable, to overcome the inherent stiffness of the plastic liner material.

	Liner	Body Material		
Dash No.	Liner Dash No.	Body Dash No.	Compound Name	Durometer, Shore A
-303	-32	-11	HNBR	85 - 90
-307	-33	-10	HNBR	80 ± 5
-308	-33	-11	HNBR	85 - 90
-313	-34	-11	HNBR	85 - 90
-318	-35	-11	HNBR	85 - 90

**Table 1**  
**Material combinations for plastic lined Kalsi Seals**

<sup>1</sup> We use the traditional dash numbering system to identify seal materials within seal part numbers. The part number includes the seal drawing number and the material dash number. At Kalsi Engineering, "-32" is spoken as "dash 32".

<sup>2</sup> Our tests of the -33 liner have been at 160°F (71.1°C) bulk lubricant temperature.

For available seal sizes, visit [kalsiseals.com](http://kalsiseals.com).

### 3. Available dynamic lip widths

Plastic lined Kalsi Seals are available in standard, wide footprint, and extra wide lip widths. The wide footprint lip is about 1.5 times wider than the standard width lip, and the extra wide lip is about 2.4 times wider than the standard width lip.

The -33 material is compatible with all three dynamic lip widths. The -32 liner material is preferred to be used with the extra wide lip width, but is compatible with the wide footprint lip with if the Type A enhanced lubrication wave is used. The -34, and -35 liner materials are only appropriate for use with the extra wide lip width.

### 4. Hardware considerations

#### ***Designing for maximum high pressure extrusion resistance***

Most of the high pressure tests of plastic lined seals have been performed with a floating backup ring or with a floating washpipe. These hardware arrangements, which are described in the “*Engineering*” and “*Application Engineering*” sections of the handbook, allow Kalsi-brand rotary shaft seals to achieve the maximum performance in high differential pressure service.<sup>3</sup> Floating seal carriers, which are described in the “*Engineering*” section of the handbook, are also a good hardware arrangement for high pressure sealing, if the diameter<sup>4</sup> is large enough to permit seal installation into the one-piece groove such carriers have.

#### ***Plastic lined seals typically require removable gland walls***

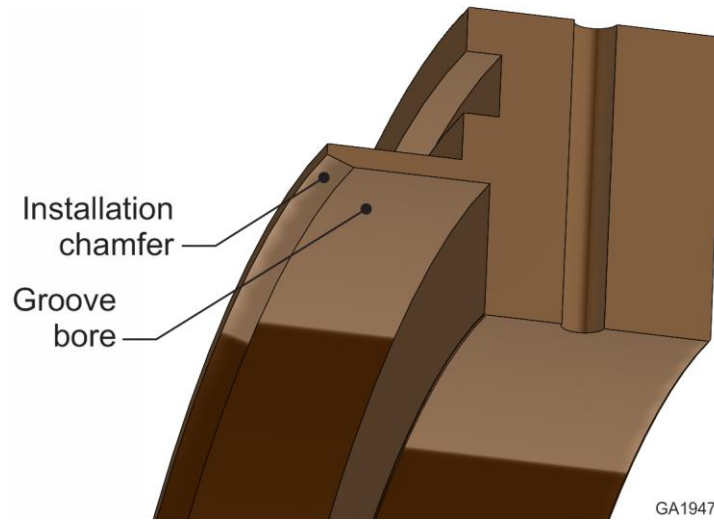
Generally, plastic lined seals should be used with a seal groove having a removable groove wall to ease installation and minimize the risk of seal damage.<sup>5</sup> The cylindrical bore of the seal groove should terminate with a conical installation chamfer, to ease compression of the elastomer as the seal is pressed into the bore (Figure 2). Since floating backup ring arrangements maximize high differential pressure performance, and readily accommodate a removable gland wall, we strongly recommend them for use with plastic lined seals.

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<sup>3</sup> Also see the technical paper “*Advancements in Extreme Pressure Rotary Sealing*” (OTC-26899-MS).

<sup>4</sup> We were able to install 10.375" seals made with both the -303 and the -318 material combinations into a one-piece groove (i.e., no removable groove wall) without damaging the seals.

<sup>5</sup> One type of damage associated with installing a plastic lined seal into a one-piece groove is wrinkling of the plastic layer. Although not a recommended practice, in some cases, it may be possible to minimize wrinkling of -32 and -34 liners after installation by applying heat with a heat gun, followed immediately by installation onto a shaft while still warm. When we tried this with seals having a slightly wrinkled -32 liner, we extracted the shaft after a few hours and the wrinkles were gone. Two days later when we reexamined the seals, the dynamic surface was still smooth.



**Figure 2**

**Use a seal groove with a removable groove wall**

This groove bore of this Type 2 floating backup ring terminates at a seal installation chamfer. The installation chamfer eases insertion of a plastic lined seal into the groove bore by gradually compressing the elastomeric portion of the seal. In our experience, the installation chamfer is merely a convenience for 10.50" diameter seals made with the -318 material combination, but absolutely mandatory for 4.50" seals made with the -318 material combination. A separate component, not shown here, forms the left-hand groove wall.

## 5. Seal manufacturing implications

Seals using the -32, 34, and -35 liner materials require dedicated tooling, and cannot be manufactured in tooling designed for elastomer rotary seals. Seals using the -33 liner can be made in tooling designed for elastomer seals, but will be larger in diameter, compared to elastomer seals made in the same tool.<sup>6</sup>

Molding shrinkage of plastic lined Kalsi Seals varies as a function of seal materials, and seal diameter. Certain sizes of seals that we lack experience with may require the manufacture of mockup sealing rings to determine appropriate mold shrinkage design factors. This increases lead time; plan accordingly.

<sup>6</sup> For example, in manufacturing trials with tooling made for 9.765" seals with -106 dual durometer elastomeric construction, seals made with -307 plastic lined construction were about 0.080" oversize in diameter. We tested 2.800" seals with -307 plastic lined construction on a 2.750" shaft, and did not experience any issues with this level of circumferential compression.

## 6. Testing for washpipe and cement swivel operating conditions

We performed dozens of rotary seal tests with 2.75” and 4.50” ID plastic lined seals at pressures and speeds directed at simulating the operating conditions of oilfield coaxial mud swivels and side entry cement swivels. This section has summaries of key tests and hydrodynamic pumping related seal leakage data at these conditions.

### **Swivel seal testing with 2.75” seals**

A pair of rotary seals were tested for 1,000 hours on a floating washpipe with 7,500 to 7,800 psi (51.71 to 53.78 MPa) lubricant pressure and a surface speed of 252 ft/minute (1.28 m/s). This surface speed is equal to 200 rpm on a 4.875” (123.83mm) OD washpipe. The rotary seal test fixture is shown in Figure 3.

The seals were in excellent condition at the conclusion of the 1,000 hour test (Figure 4), and could have kept running for much longer. A conventional washpipe packing only lasts a few hours under such extreme conditions, and an entire set may only last a day or two.

In our 1,000 hour test, the seal lubricant was an ISO 150 viscosity grade (VG) synthetic hydrocarbon lubricant, and was maintained at a temperature of 130°F (54.44°C) to simulate the drilling fluid temperature.

Based on this long duration, extreme pressure test, and other tests, we consider extra wide -303 plastic lined Kalsi Seals an excellent choice for the pressure retaining seals of extreme pressure washpipe assemblies and cement swivels. In either application, we recommend that the partitioning seal be an elastomeric Kalsi Seal, and recommend that the pressure retaining plastic lined seals be supported by floating backup rings. For information on the design of floating backup rings, see the “*Engineering*” section of the handbook, and contact our engineering staff.

### **Swivel seal testing with 4.50” seals**

The 4.50” rotary seal test fixture incorporates our easy to assemble stacked housing design. We have tested -32 and -35 plastic lined seals to collect seal leakage under different pressure, lubricant, and lubricant temperature combinations. A summary of the bounding leak rates at 252 ft/minute (1.28 m/s) from tests with ISO 46 and 68 VG lubricants and 682-3-303 and 682-3-318 seals at different pressures is shown in Table 2.

For additional information on washpipe and swivel design with Kalsi Seals, see the “*Application Engineering*” section of the handbook, and contact us.

Pressure, psi	Leak Rate, ml/hour per seal	Bulk Lubricant Temperature, °F
200	55.97	91
600	54.75	94
2000	12.23	99
4000	2.21	121
6000	1.03	137
6500	0.52	135
7500	0.64	145

**Table 2**

**Bounding leak rate for 4.50" Plastic Lined Seals**

The highest leak rate at a given pressure from eight tests using 682-3-303 and 682-3-318 rotary seals is given. Some tests were run with an ISO 46 VG lubricant and some with an ISO 68 VG lubricant. Tests with the ISO 68 VG lubricant did not always have the highest leak rate at a given pressure.



**Figure 3**

**7,500 psi rotary seal test fixture**

The 1,000 hour, 7,500 to 7,800 psi test of plastic lined Kalsi Seals was performed in this washpipe-based test fixture. The washpipe was guided by radially pressure balanced backup rings. The rotary seals were in excellent condition at the conclusion of the test.

For available seal sizes, visit [kalsiseals.com](http://kalsiseals.com).



**Figure 4**

**The plastic lined seals were in excellent condition after 1,000 hours at 7,500 psi**

These photos were taken at the conclusion of a 1,000 hour, 7,500 to 7,800 psi test of plastic lined Kalsi Seals under simulated oilfield washpipe operating conditions (1,890,000 PV). The speed was equivalent to a 4.875" washpipe rotating at 200 rpm. The washpipe was guided by radially pressure balanced backup rings. The rotary seals were in excellent condition at the conclusion of the test, as can be seen in these photos. The upper rotary seal is shown in the upper photo, and the lower rotary seal is shown in the lower photo. Both seals are shown with the exclusion edge up.



## 7. Testing for the sealing conditions of RCDs

We performed initial testing of plastic lined seals at RCD conditions with 2.75” seals installed in floating backup rings. We now test RCD seals in our 10.49” diameter RCD seal test fixture. We can test with RCD seals installed in conventional seal carriers or floating backup rings.

Based on our testing, these high performance seals are the most pressure capable polymeric RCD seals. The tests summarized below all exceed the 100 hour minimum duration required by API 16RCD. All but one of the tests met or exceeded the 200 hour maximum test duration stated by API 16RCD.

### ***RCD seal condition testing with 2.75” seals***

200 and 300 hour tests of type A, extra wide, plastic lined seals, installed in floating backup rings simulating the extrusion gap clearance that is obtainable in RCDs, are summarized. The test fixture is shown in Figure 5.

The rotary seals were tested with 3,000 psi (20.68 MPa) lubricant pressure and 0.010” (0.25mm) dynamic runout, FIM. The rotary speed was 750 rpm on a 2.75” (69.85mm) shaft, which is equivalent to a surface speed of 200 rpm on a 10.375” (263.53mm) shaft. (A 2.75” shaft at 750 rpm subjects the seals to 3.75 times more runout cycles, compared to a 10.375” shaft at 200 rpm.) The seal lubricant was an ISO 150 VG synthetic hydrocarbon lubricant maintained at 200°F (93.33°C).

The seals in both tests survived, and clearly benefited from the advantages provided by the floating backup ring cartridges, although some of the seals were in worse condition than others. Based on surviving these severe test conditions, we recommend these seal and hardware technologies for pressurized lubricant-type RCD designs requiring 1,000 psi or greater dynamic sealing capacity across the bearing seals. The low breakout friction characteristics of plastic lined Kalsi Seals also make them attractive as RCD seals.

### ***RCD seal condition testing with 10.49” -318 material seals***

Our newest test fixture is sized for testing 10.49” rotary seals used to retain high pressure in rotary control devices (RCD’s). The fixture tests two rotary seals at a time. The lubricant pressure is supplied between the pair of seals, simulating the high pressure rotary seal location of an RCD.

We built this fixture to test with a mandrel that approximates the thermal mass of an actual RCD mandrel. This allows us to perform more realistic comparisons of the speed and pressure capabilities of various rotary seal designs. The test fixture is shown in Figure 6. Two key tests are summarized.

For available seal sizes, visit [kalsiseals.com](http://kalsiseals.com).

A pair of 682-20-318 RCD seals (Type A wave type) were installed in non-floating seal carriers that define a 0.02” radial extrusion gap with the mandrel. The seals ran at 102 RPM for three hours with the lubricant pressure at 1,000 psi, two hours with the lubricant pressure at 1,500 psi, and 182.5 hours with the lubricant pressure at 2,200 psi. The ISO 220 VG seal lubricant bulk temperature was 132 to 159°F. The runout was 0.07” T.I.R. at the upper seal location and 0.003” T.I.R. at the lower seal location. The leak rate data is shown in Table 3.

Both RCD seals were in good condition after 187 hours of continuous operation at these pressures.

Pressure, psi	Leak Rate, ml/hour per seal	Bulk Lubricant Temperature, °F
1,000	22.5	132
1,500	11.5	156
2,200	4	159

**Table 3**

**Leak rate for 10.49” RCD Seals made from -318 material**

A pair of 682-20-318 RCD seals were tested in non-floating seal carrier with a 0.02” radial extrusion gap at 102 RPM with an ISO 220 VG lubricant at various pressures and temperatures.

***RCD seal condition testing with 10.49” -303 material seals***

A pair of 682-21-303 RCD seals (Type A wave type) were installed in non-floating seal carriers that define a 0.01” radial extrusion gap with the mandrel. The test ran for a total of 266 hours at four load steps.

- 16 hours with 300 psi lubricant pressure and 170 RPM shaft speed,
- 20 hours with 1,000 psi lubricant pressure and 102 RPM shaft speed,
- 29.4 hours with 1,500 psi lubricant pressure and 102 RPM shaft speed, and
- 200.4 hours with 2,300 psi lubricant pressure and 102 RPM shaft speed.

The ISO 220 VG seal lubricant bulk temperature was 199°F to 288°F. The seals had some damage on the dynamic lip but were still functional at the end of the test.

Pressure, psi	Leak Rate, ml/hour per seal	Bulk Lubricant Temperature, °F
300	0.47	227
1,000	0.44	208
1,500	0.41	220
2,300	0.28	227

**Table 4**

**Leak rate for 10.49” RCD Seals made from -303 material**

A pair of 682-21-303 RCD seals were tested in non-floating seal carrier with a 0.01” radial extrusion gap at 102 RPM with an ISO 220 VG lubricant at various pressures and temperatures.

For recommendations on using Kalsi Seals in RCDs, see the “*Application Engineering*” section of the handbook, and contact us.



**Figure 5**

**3,000 psi test of plastic lined seals in simulated RCD operating conditions**

This photo was taken 280 hours into a 300-hour test of a plastic lined Kalsi Seal under simulated RCD seal operating conditions. The speed was equivalent to a 10.375” shaft at 200 rpm. The dynamic runout was 0.010” FIM. The bulk lubricant temperature was maintained at 200°. The floating backup ring provided a diametric extrusion gap clearance of 0.008”. This clearance is easily achievable with a 10.375” RCD shaft when a floating backup ring is used, but is not achievable with a fixed seal groove arrangement.

For available seal sizes, visit [kalsiseals.com](http://kalsiseals.com).



**Figure 6**

**10.49" RCD seal test fixture**

This fixture tests two rotary seals at a time. This rotary seals fixture allows us to collect useful data such as leak rate and pressure capacity for RCD seals.

**8. Slow speed testing at high differential pressure**

***Slow speed testing at ~10,000 psi with floating backup rings***

We tested a pair of 4.50" (114.30 mm) PN 682-7-318 seals (Type F wave type) at 24 rpm with 9,800 psi (67.57 MPa) lubricant pressure for 6.5 hours, to simulate the operating conditions of a high pressure cementing swivel seal. The fixture tests two rotary seals at a time, exposing each to the full test pressure. The seals, which were tested with our patented floating backup rings, were still in excellent condition at the conclusion of the test (Figure 7). The lubricant was an ISO 68 viscosity grade synthetic hydrocarbon lubricant. Thanks to the interfacial lubrication provided by the unique seal design, the bulk lubricant temperature never exceeded 96°F (35.6°C).

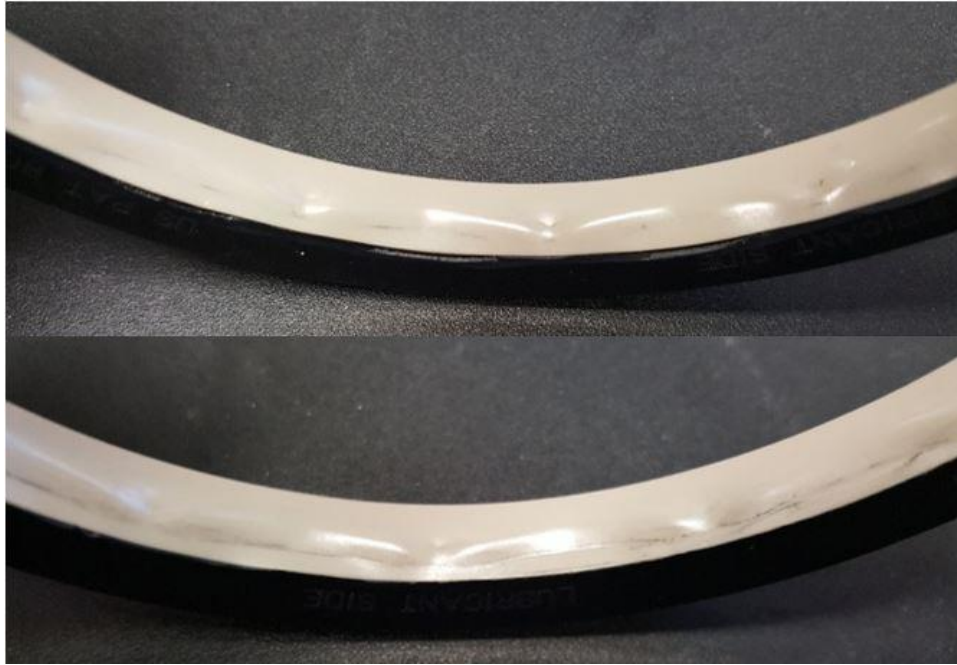
Based on the excellent condition of the seals at the conclusion of the test, it seems obvious that they could have continued to operate for a much longer period of time.

***Slow speed testing at ~5,000 psi without floating backup rings***

We also tested type A, plastic lined seals with -303 construction with an ISO 150 viscosity grade lubricant at 4,800 to 5,000 psi (33.09 to 34.47 MPa) *without* floating

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backup rings. The test duration was 50 hours, the surface speed was 80 ft/minute (0.41 m/s), and the nominal diametric extrusion gap was 0.020" (0.51 mm). The seals were in excellent condition at the conclusion of the test.



**Figure 7**

**9,800 psi test of plastic lined swivel seals in high pressure swivel operating conditions**

This photo shows a pair of used 4.50" (114.30 mm) plastic lined Kalsi Seals that were exposed to 9,800 psi lubricant pressure and a rotational speed of 24 rpm for 6.5 hours. With the support provided by our patented floating backup ring, the hydrodynamically lubricated plastic seal material easily met the pressure and duration requirements of the targeted application while exposed to a rotary speed of 28 ft/minute.

**9. Comparative seal breakout torque**

The breakout torque characteristics of Kalsi Seals, including plastic lined seals, are reported in Chapter C12.

**10. Plastic lined seals are not recommended for abrasive service**

Plastic lined seals are not recommended for service that includes exposure to abrasives. For example, they should not be used to partition a bearing lubricant from an abrasive environment such as oilfield drilling fluid.

For available seal sizes, visit [kalsiseals.com](http://kalsiseals.com).

## 11. Hydrodynamic pumping related leakage trends

The hydrodynamic pumping related leak rates of plastic lined Kalsi Seals are relatively high in lower differential pressure, cooler temperature conditions, and drop off significantly as temperature and differential pressure increase. Contact us for up-to-date testing results.

## 12. Static testing for cold weather conditions

### *Testing of -318 seals*

After a pair of installed 4.500” PN 681-3-318 plastic lined seals were conditioned at -19°F (-28.3°C) for four days, the sealed region was pressurized with shop air and isolated with a valve. The pressure of the sealed region remained constant over the duration that was monitored, demonstrating that a static seal was maintained at the test temperature. After the test, the seals were examined, and no evidence of liner damage was observed.

Dynamic testing in cold weather startup conditions has not been performed.