

Chapter C16

Plastic Lined Kalsi Seals



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1. Higher differential pressure, lower breakout torque

Plastic Lined™ Kalsi-brand rotary seals (Figure 1) 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 design is directed at increasing high pressure sealing capacity and reducing breakout torque, compared to an elastomer shaft seal.

We recommend Plastic Lined Kalsi Seals™ for use as pressure-retaining oil seals in extreme pressure applications that employ lubricant pressure. Examples of such equipment are washpipe assemblies, side entry cement swivels, hydraulic swivels, coring 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 surface. The significant level of hydrodynamic efficiency that is required to lubricate a plastic seal in high differential pressure conditions is achieved by our patented 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 significantly 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 groove.



Figure 1

An early screening test of plastic lined oil 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 waves facing downward in this photo. The seal is in excellent condition, as is 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 (See Table 1).

For available seal sizes, visit kalsiseals.com.

2. Available materials

Plastic Lined Kalsi Seals are available in four different high-performance liner materials. For available material combinations, see Table 1.

The -32¹ 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 and is less tolerant of wear. The -34 material is a variation of the -32 material, having lower breakout friction and less pressure capacity, compared to the -32 material. The -32 material is not recommended for temperatures above 225°F (107.2°C) and the -35 material is not recommended for temperatures above 320°F (160°C).

Seals with the -33 liner material have relatively low breakout torque, even when compared to -106 LF Dual Durometer Kalsi Seals™ with a low friction treatment. The extrusion resistance of a seal with a -33 liner is in the same range as a -106 seal.²

There are two different elastomer options for the rotary seal body. The 80 Shore A -10 HNBR seal material reduces the lip loading, compared to the 85 to 92 Shore A -11 HNBR seal material. In many cases, the higher lip loading is 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 - 92
-307	-33	-10	HNBR	80 ± 5
-308	-33	-11	HNBR	85 - 92
-313	-34	-11	HNBR	85 - 92
-318	-35	-11	HNBR	85 - 92

Table 1
Material combinations for Plastic Lined Kalsi Seals

¹ 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".

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

For available seal sizes, visit kalsiseals.com.

Seal manufacturing considerations

Plastic Lined Seals require dedicated tooling and cannot be manufactured in tooling designed for elastomer rotary seals. Molding shrinkage of Plastic Lined Seals varies as a function of size and seal materials.

3. Available dynamic lip widths

Plastic Lined Kalsi Seals are available in extra wide, extra wide plus, and super wide lip widths. The extra wide plus and super wide lip widths provide added durability in extreme high pressure applications. Manufacturing advances have allowed a reduction in overall seal body width and groove width, compared to our earlier Plastic Lined Seals. If you are planning to commission a new size of Plastic Lined Seal, contact our staff engineers for seal body width and recommended groove width.

4. Hardware considerations***Plastic Lined Seals typically require removable gland walls***

Most sizes of Plastic Lined Seals require a seal groove having a removable groove wall to ease installation and minimize the risk of seal damage.³ The cylindrical bore of the seal groove should terminate with a conical installation chamfer, to ease compression of the elastomer body as the seal is pushed into the bore (Figure 2).

Designing for maximum high pressure extrusion resistance

Most of our high-pressure tests of Plastic Lined Seals have been performed with a floating backup ring (Figure 2) or with a floating washpipe. Floating backup rings are described in the “*Engineering*” and “*Application Engineering*” sections of the handbook.⁴ Since floating backup ring arrangements maximize high pressure seal performance, and readily accommodate a removable gland wall, we strongly recommend them for use with Plastic Lined Seals. Floating seal carriers, which are described in the “*Engineering*” section of the handbook, are incompatible with most sizes of Plastic Lined Seals because they do not allow a removable groove wall.

While the highest pressure capacity is achieved by running a Plastic Lined Seal in a floating backup ring these seals have very good pressure capability with non-floating seal carriers. A pair of 4.50” diameter 682-22-318 seals were tested in a non-floating seal

³ One type of damage associated with attempting to install a Plastic Lined Seal into a one-piece groove is wrinkling of the plastic layer. The feasibility of using Plastic Lined Seals with one-piece grooves appears to depend on factors such as diameter, radial cross-section, axial seal body width, axial lip width, and liner material. We were unable to install 10.49” Extra Wide Plastic Lined Seals made with the -318 material combination into a one-piece groove without seal damage.

⁴ Also see the technical paper “*Advancements in Extreme Pressure Rotary Sealing*” (OTC-26899-MS).

carrier with a 0.01” radial extrusion gap. The seals still looked good after running for a combined 22.5 hours at 175 rpm and 7,500 psi, 20 hours at 175 rpm and 6,500 psi, 23 hours at 220 rpm and 4,000 psi, and 17 hours at 220 rpm and 2,000 psi.

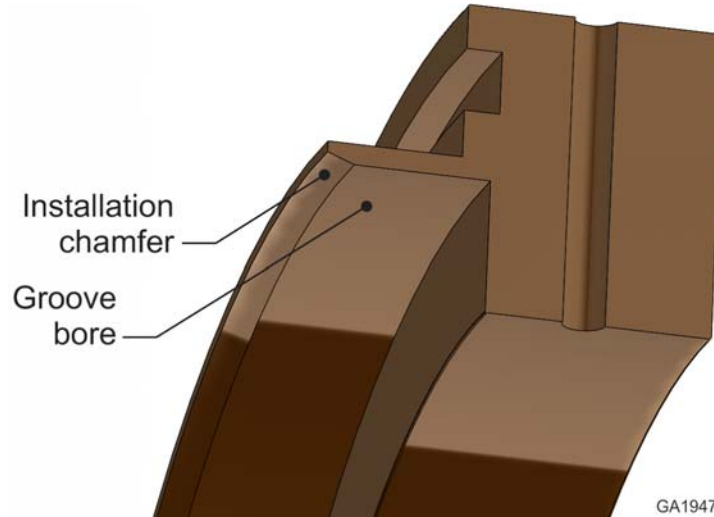


Figure 2

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. 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 at 7,500 psi with 2.75” extra wide seals

A pair of 2.75” extra wide rotary seals made with the -303 material combination 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 to be a good choice for the pressure retaining seals of extreme pressure washpipe assemblies and cement swivels. In either application, we recommend that the pressure retaining Plastic Lined Seal be supported by a floating backup ring. For information on the design of floating backup rings, see the “*Engineering*” section of the handbook, and contact our engineering staff.



Figure 3

7,500 psi rotary seal test fixture

The 1,000 hour, 7,500 to 7,800 psi test of Plastic Lined Extra Wide 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.



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 -303 Extra Wide Plastic Lined 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 floating 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 facing upward.

3,900 psi testing with an ISO 32 viscosity grade lubricant

A pair of 2.75" PN 682-5-303 Extra Wide Plastic Lined Seals were tested in floating backup rings at 325 rpm and 3,900 psi for 100 hours using an ISO 32 viscosity grade lubricant. The seals were in excellent condition at the conclusion of the test.

9,800 psi testing with 4.50" Extra Wide Plus Plastic Lined Swivel Seals

A pair of 4.50" PN 749-1-303 Extra Wide Plus Plastic Lined Seals were tested in floating backup rings at 120 RPM and 9,800 psi for 125 hours using an ISO 68 viscosity grade lubricant maintained at 120°F. The seals were in very good condition at the conclusion of the test as seen in Figure 5.



Figure 5

Extra Wide Plus rotary seals from the 9,800 psi test

The upper and lower high-pressure rotary seals are in very good condition after 125 hours of operation at 9,800 psi and 120 rpm on a 4.50" shaft.

9,500 to 9,800 psi testing with 4.50" Super Wide Plastic Lined Swivel Seals

A pair of 4.50" PN 750-1-318 Super Wide Plastic Lined Swivel Seals were tested in floating backup rings at 120 rpm and 9,500 to 9,800 psi for 320 hours using an ISO 68 viscosity grade lubricant maintained at 100 to 120°F. The test was ended at 320 hours because the 300-hour operating goal had been exceeded.

The 4.50" high pressure seal test fixture is shown in Figure 6. The dynamic runout was 0.0060" at one seal location and 0.0045" at the other. One seal was in excellent condition at the conclusion of the test (Figure 7), and the other had wear. The worn seal remained functional despite the wear due to the extra margin provided by the extra width of the super wide dynamic lip.

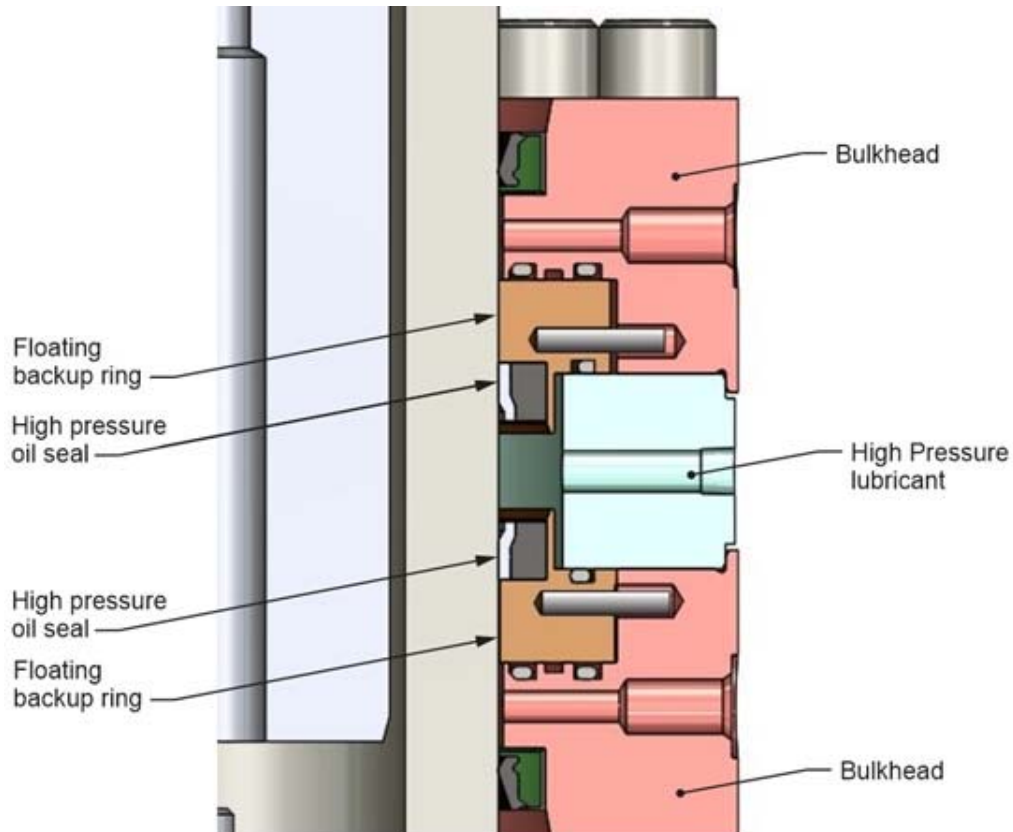


Figure 6

The 4.5" high pressure swivel seal test fixture

This 4.500" test fixture, which incorporates our easy to assemble stacked housing design, was used for the 9,500 to 9,800 psi test. The Plastic Lined Swivel Seals were mounted in our patented laterally floating metal backup rings, which allow a small extrusion gap to be employed for optimum seal performance. We ended the test after 320 hours because the test exceeded the 300 hour operating goal.



Figure 7

The upper swivel seal from the 9,500 to 9,800 psi test

This is the upper high-pressure swivel seal from the 320-hour, 9,500 to 9,800 psi test. It was still in excellent condition. In this fixture, the lower seal usually suffers more damage than the upper seal. The extra width provided by the super wide lip allowed the lower seal to continue to function reliably even though damaged.

For available seal sizes, visit kalsiseals.com.

10,000 psi testing of 4.50" Super Wide Plastic Lined Seals™ in a washpipe assembly

A 4.50" PN 750-1-318 Super Wide Plastic Lined Seal™ was tested at 10,000 psi in a washpipe assembly (Figure 8) for 368 hours using an ISO 68 viscosity grade lubricant. The test included 165 hours at 120 rpm, 165 hours at 150 rpm, and 38 hours at 175 rpm. A non-pressurized fluid was circulated through tubing inside the stagnant pressurized region at about 8 gallons per minute. This approach provides much less cooling than what occurs in field use. The fluid temperature near the high-pressure seal was approximately 103°F at 120 rpm, 110°F at 150 rpm, and 115°F at 175 rpm. The Super Wide Seal™ was still in good condition at the conclusion of the test (Figure 9).



Figure 8

Testing a high pressure washpipe assembly at 10,000 psi



Figure 9

Seal from 10,000 psi washpipe test

This 4.50" Super Wide Plastic Lined Seal is still in excellent condition after 368-hours of operation at 10,000 psi and 120 to 175 rpm in a high pressure washpipe assembly.

For available seal sizes, visit kalsiseals.com.

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 Extra Wide Seals (Type F wave) 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 10). 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.



Figure 10

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.

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 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.

Leak rate testing with 4.50” Plastic Lined Swivel Seals

We have tested -303 and -318 Type A Extra Wide 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 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

This table lists the highest leak rate at a given pressure from eight tests using 682-3-303 and 682-3-318 Type A Extra Wide rotary seals. 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.

For available seal sizes, visit kalsiseals.com.

6. Testing for the sealing conditions of RCDs

We performed initial testing of Plastic Lined Seals at RCD operating 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, we have determined that 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 11.

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 rings, 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 high pressure RCD designs that incorporate the high pressure rotary seal below the bearings.⁵ The low breakout friction characteristics of Plastic Lined Kalsi Seals also make them attractive as RCD seals, because the stripper rubber sealing element is less likely to slip.

⁵ Elastomeric type Kalsi-brand RCD seals are recommended for pressurized lubricant-type high pressure RCD designs that place the pressure retaining seal above the bearings, because the seal above the bearings is exposed to the abrasive content of drilling fluid.

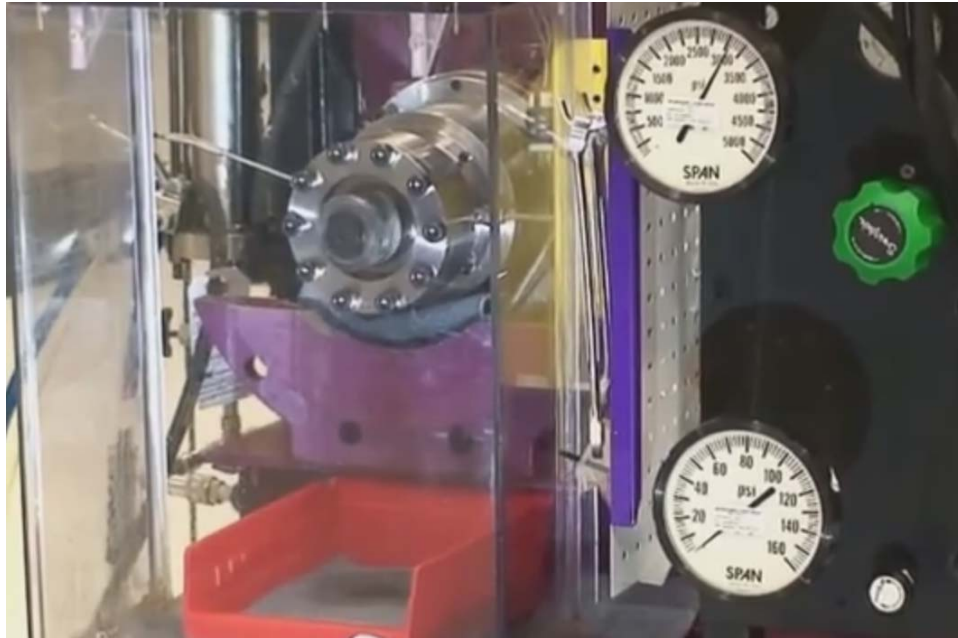


Figure 11

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.

Our full scale RCD seal test fixture

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 12. Several key tests are summarized below.



Figure 12

10.49" RCD seal test fixture

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

RCD seal testing with 10.49" -318 material seals and a 0.020" radial extrusion gap

A pair of 682-20-318 RCD seals (Type A wave) 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 0.007" 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 testing at 2,300 psi with 10.49” -303 material seals

A pair of 682-21-303 RCD seals (Type A wave) 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 carriers with a 0.010” radial extrusion gap at 102 RPM with an ISO 220 VG lubricant at various pressures and temperatures.

For available seal sizes, visit kalsiseals.com.

Hydraulic swivel testing

A pair of 10.49” PN 682-21-303 Extra Wide type seals were also tested for 100 rotating hours at 2,300 psi (15.85 MPa) and 45 rpm (123.6 sfpm) using a nominal radial extrusion gap clearance of 0.015” and an ISO 68 viscosity grade lubricant. The test included 353 rotational start/stop cycles with the full differential pressure. Despite operating with such a large extrusion gap clearance, the seals were still in excellent condition at the conclusion of the test (Figure 13). The hydrodynamic pumping related leak rate for the pair of seals was 0.42 ml/hour. During the test, antifreeze was circulated through a cooling chamber above the pair of seals at approximately 0.9 gpm. The coolant entry temperature was about 76°F and the exit temperature was about 82 to 85°F. A chamber below the seals contained stagnant (i.e. non-circulating) lubricant. The bulk lubricant temperature between the seals ranged from 100 to 120°F.

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



Figure 13

10.49” RCD seals tested with 2,300 psi and a 0.015 radial extrusion gap

These 10.49” Extra Wide Seals were tested at 2,300 psi and 45 rpm with a 0.015” radial extrusion gap. Because the upper seal was exposed to a circulating coolant, it has less wear than the lower seal. Despite the large extrusion gap, both seals are in excellent condition after 100 hours of operation.

7. Comparative seal breakout torque

The breakout torque characteristics of Kalsi Seals, including Plastic Lined Seals, are reported in Chapter C12.

For available seal sizes, visit kalsiseals.com.