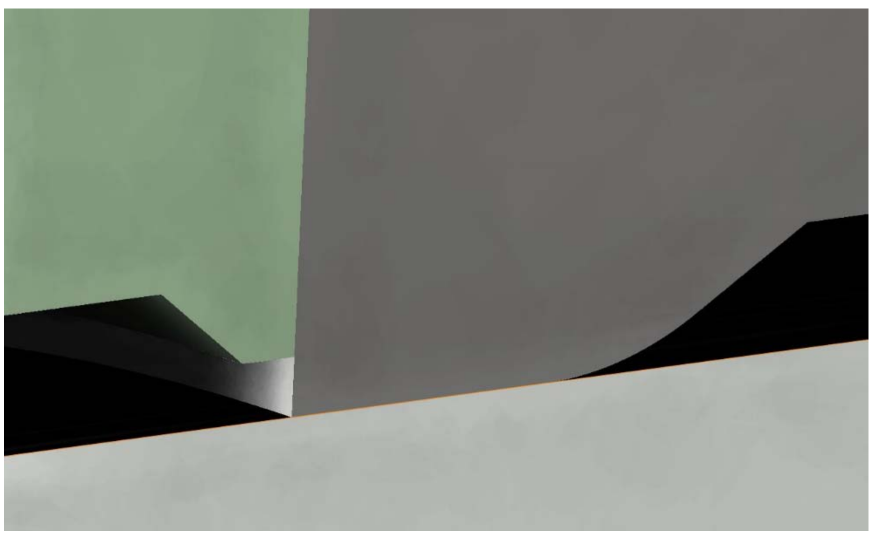
Chapter D7

Extrusion gap considerations



Revision 5 June 30, 2020

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/.

1. Introduction and scope

Scope

This chapter is applicable to Kalsi-brand rotary seals designed for lubricant overpressure applications where the pressure of the seal lubricant is greater than the pressure of the environment. It is also applicable to ACS Seals™, which are designed for applications where the pressure of the seal lubricant is roughly the same as the pressure of the environment. For seals designed for lubricant under-pressure conditions, such as KLS and BDRP Seals™, refer to seal-specific chapters, or contact our engineering staff.

Introduction

The clearance between the shaft and the seal housing at the low pressure groove wall is referred to as the "extrusion gap", as shown in Figure 1. Service conditions, such as the magnitude of differential pressure and the presence or absence of abrasives, are important considerations when determining the extrusion gap clearance and width, as described in this chapter.

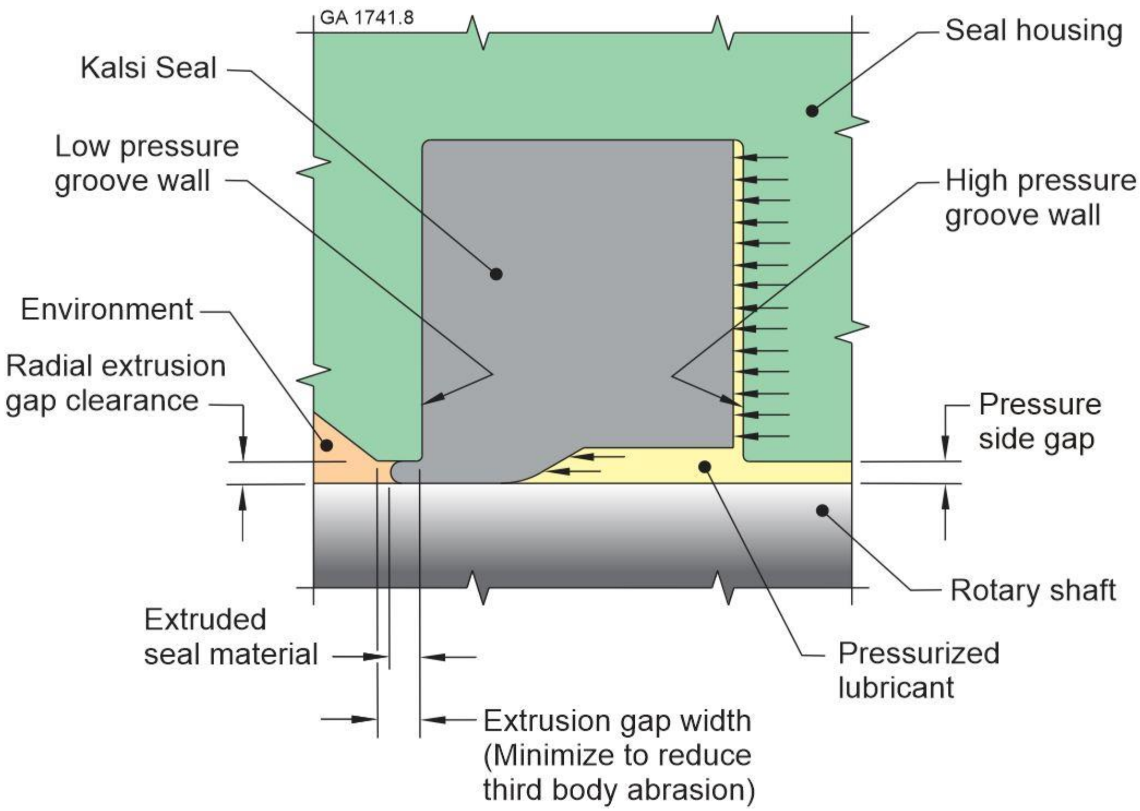


Figure 1

Extrusion gap nomenclature

The extrusion gap is the clearance between the seal housing and the shaft at the low pressure groove wall that the seal must bridge. Information on sizing the pressure side gap at the high pressure groove wall is provided in Chapter D5.

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2. High-pressure seal extrusion damage explained

When the rotary seal is exposed to lubricant pressure that is greater than the environment pressure, the resulting differential pressure forces the seal against the low pressure groove wall (Figure 1). Since the seal has generally the same flat shape as the low pressure groove wall, the wall provides support against the pressure differential at all points except the extrusion gap. When the differential pressure is high, a small portion of the seal may bulge (extrude) into the extrusion gap. Various phenomena, such as shaft deflection, shaft runout, and pulsating pressure can flex and overstress the extruded material, causing pieces to break away from the seal. For an example of high-pressure extrusion damage, see Figure 2. Shaft eccentricity increases extrusion damage because the extrusion gap clearance is larger on one side.

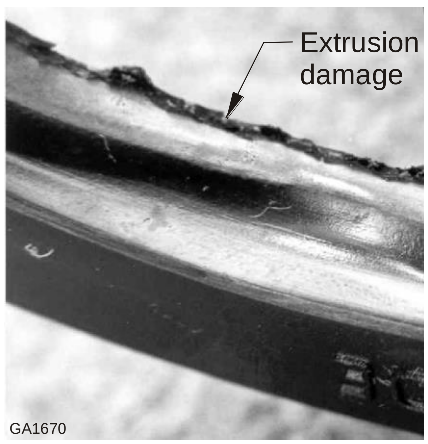

Figure 2
Example of high-pressure extrusion damage

This photo shows a Kalsi Seal™ with material loss from nibbling type high-pressure extrusion damage. Extrusion damage is caused by cyclic stressing of the seal material that protrudes into the extrusion gap. The stress causes the protruding material to fatigue and break away from the seal.

In some cases, the extrusion damage stabilizes, while in other cases, it may continue until breaching the dynamic sealing lip. In extreme cases of extrusion related material loss, the hydraulic force of the lubricant pressure may hold the seal in fluid sealing engagement, even though the seal is no longer in radial compression as a result of material loss. In such cases, the extrusion damage can cause a local portion of the seal to roll within the groove, as more and more material is consumed by the extrusion mechanism.

A relatively small extrusion gap is necessary for proper seal support in high differential pressure conditions, so the rotary shaft seal can bridge the gap without suffering excessive extrusion damage. Wider dynamic sealing lips, and higher modulus materials, provide better resistance to extrusion damage and can tolerate larger extrusion gaps — provided the lip is adequately lubricated. Increased interfacial lubrication also increases seal extrusion resistance by allowing the seal to run cooler, with less temperature related modulus loss.

Some factors that affect seal extrusion damage are:

- Magnitude of the differential pressure.
- Radial extrusion gap clearance, and any increase to that clearance that results from abrasive wear or eccentricity due to shaft deflection or misalignment.
- Defects at the extrusion gap corner, such as nicks, burrs, or poor surface finish, that can cut or abnormally constrain the seal.
- Repetitive extrusion gap dimensional fluctuations related to factors such as shaft dynamic runout, shaft vibration, and pressure breathing (pressure related dimensional changes) of the seal carrier and/or the shaft.
- Strength of the seal material at the extrusion gap.
- Axial width of the dynamic sealing lip.
- Temperature related softening of the seal and reduction of tensile strength[1], including overheating of the seal that can occur because of inadequate heat transfer, inadvertent heavily loaded shaft contact at the extrusion gap, etc.
- Circumferential seal slippage, particularly when extrusion gap corner damage is present.
- Lubricant pressure fluctuations or pulsations that produce cyclic stress-induced extrusion damage by causing repetitive fluctuations in the magnitude of extrusion. For example, sudden stoppage of hydraulically actuated equipment can produce pressure spikes well above nominal system pressure.[2]
- Adequacy of interfacial lubrication, minimizing seal-generated heat.
- Profile of the extrusion gap “corner” at the low pressure groove wall.

Generally, for rotary seals exposed to high differential pressure, the smaller the extrusion gap the better — provided that heavily loaded contact between the seal housing and the shaft cannot occur.

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1 For examples of tensile strength variation with temperature, see Robert Flitney's 2007 "**Seals and Sealing Handbook**" (Elsevier B.V.).

2 Mechanical brakes may be useful to decelerate hydraulically actuated equipment slowly to minimize pressure spikes. Pressure relief valves may also be useful.

3. Heavily loaded metal-to-metal contact causes seal damage

Inadvertent heavily loaded metal-to-metal contact at the extrusion gap can cause significant damage to the seal, the seal carrier, and the shaft. When such contact occurs, the seal carrier receives loads intended for the radial bearings, and rapid frictional heat buildup occurs near the rotary seal. This heat reduces the mechanical properties of the seal material, adversely affecting extrusion resistance, compression set resistance, etc. In some cases, the rotary seal may exhibit evidence of local heat damage, as shown in Figure 3. In other cases, the shaft and the seal carrier may be damaged in ways that cut, abrade, and destroy the rotary seal (Figure 4). Metal-to-metal contact is often due to a combination of factors such as load-induced shaft deflection, shaft articulation within bearing mounting and internal clearances, and tolerance accumulation.

An additional contributing cause of metal-to-metal contact at the extrusion gap is connection-related misalignment between machine housings. The use of good square mating shoulders, and the use of close-fitting pilot diameters may help to avoid such misalignment problems. Ideally, the seal groove is located in the same housing as at least one of the radial shaft bearings.

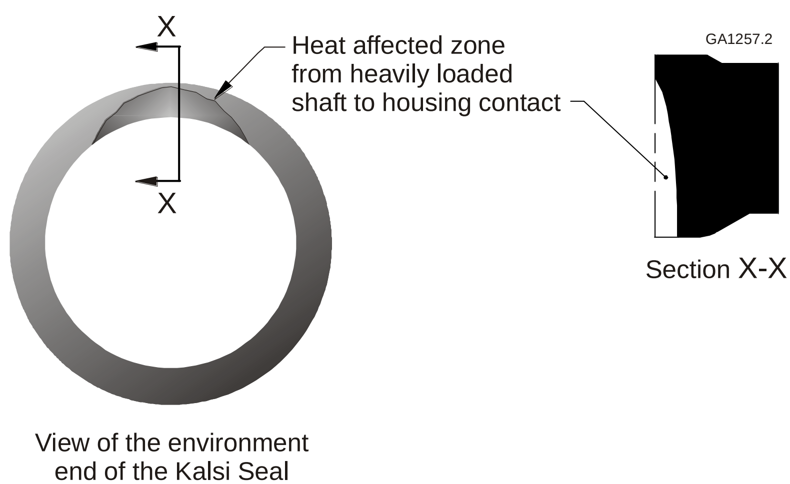

Figure 3

Seal heat damage from shaft-to-seal housing rubbing

If metal-to-metal contact occurs at the extrusion gap between the shaft and the seal housing, then the resulting frictional heat may damage the rotary seal. In high differential pressure applications, the seal may suffer extra extrusion damage on the non-contacting side, where the maximum extrusion gap clearance occurs.

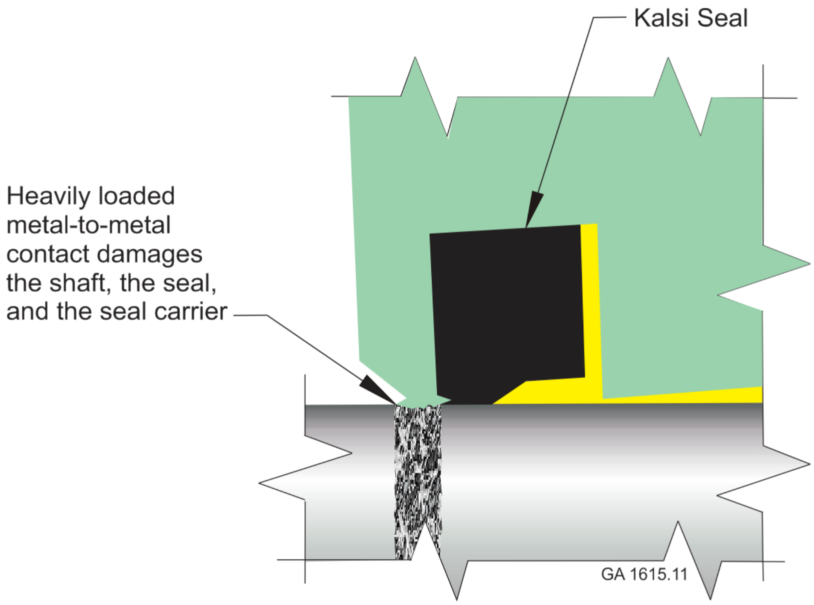

Figure 4

Avoid heavily loaded metal-to-metal contact at the extrusion gap

Heavily loaded metal-to-metal contact at the extrusion gap can damage the shaft and the seal carrier in ways that destroy the rotary seal. For high-pressure sealing applications, the designer's challenge is to determine the smallest extrusion gap clearance that presents no danger of heavily-loaded metal-to-metal contact.

Avoiding metal-to-metal contact at the extrusion gap

Inadvertent metal-to-metal contact at high-pressure extrusion gaps can sometimes be avoided by careful selection of fits and tolerances, in conjunction with placing the rotary seal close to a radial bearing that is mounted directly in the seal carrier. In applications with heavy overhanging side loads, such as downhole mud motors, extra measures may be necessary to limit shaft deflection at the extrusion gap. One way is to situate the rotary seal between two radial bearings. For example, an outboard journal bearing can be mounted in an axially movable barrier compensation piston that allows the primary equipment bearings to receive most of the load, but limits peak shaft deflection, as shown in Figure 5.

Seal design has a significant impact on extrusion gap clearance requirements. In general, rotary seals with wider dynamic lips have greater extrusion resistance, as do seals that place a higher modulus material at the extrusion gap, and seals that provide generous lubrication and cooler operation. When relatively large extrusion gaps are required to avoid metal-to-metal contact, it may be necessary to use seals with larger radial cross-sections and more compression to accommodate lateral shaft motion.

When space is available, laterally translating sealing assemblies can be employed to avoid heavily loaded metal-to-metal contact at the extrusion gap while minimizing extrusion gap clearance; see Chapters D16 and D17. In such assemblies, the component that defines the extrusion gap is hydraulically force balanced in the axial direction. This allows the component to move laterally in unison with shaft motion, avoiding heavily loaded contact with the shaft.

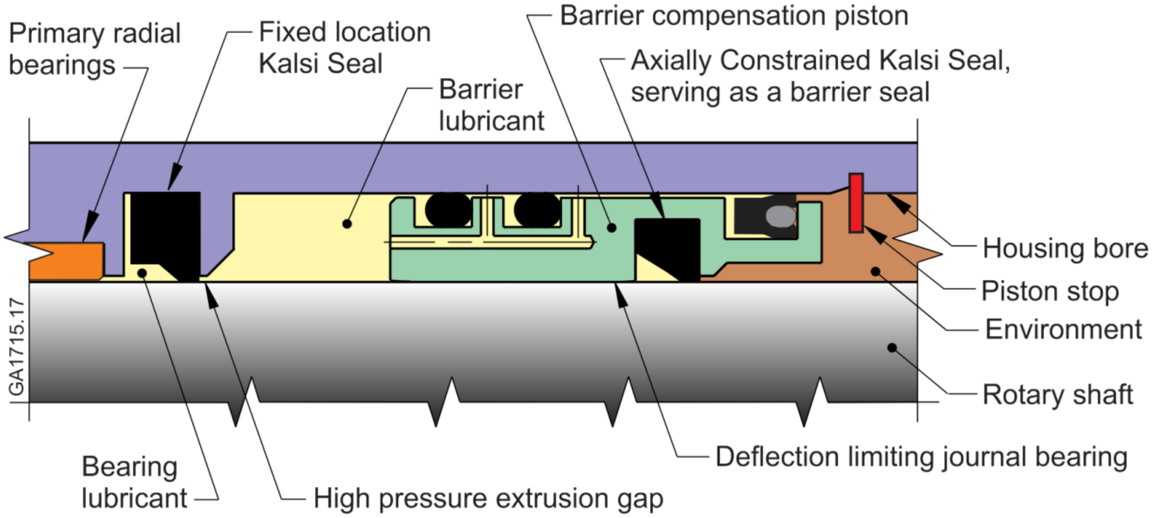

Figure 5

Limiting elastic shaft deflection with a barrier compensation piston

In this oilfield mud motor seal arrangement, the primary radial bearings mount directly in the high-pressure seal housing for maximum concentricity with the bore that defines the high-pressure extrusion gap. The journal bearing in the barrier compensation piston limits elastic shaft deflection, so that metal-to-metal contact does not occur at the high-pressure extrusion gap. The primary radial bearings react most of the side load, and the barrier compensation piston only receives the portion of the load not absorbed by the elastic deflection of the shaft. In this schematic the two O-rings are used for anti-rotation. Depending on bearing load additional anti-rotation measures may be needed to prevent the barrier compensation piston from turning with the rotating shaft.

4. Misc. factors that affect extrusion gap clearance

Seal housing pressure breathing

In large diameter or thin wall components, the size of the extrusion gap may change significantly in response to pressure induced deformation. This phenomenon is called “pressure breathing” and can cause the extrusion gap to increase or decrease, depending on the pressure location.

If the extrusion gap increases significantly in response to pressure, the rotary seal may experience additional extrusion damage. If the extrusion gap decreases substantially in response to pressure, metal-to-metal contact between the shaft and seal carrier may occur and cause seal and shaft damage (Figures 3 and 4). If system pressure fluctuates, the resulting fluctuations in extrusion gap clearance may cause seal extrusion damage due to the repeated working of any seal material protruding into the extrusion gap.

One way to reduce pressure breathing is by increasing radial wall thickness. Another way is to balance the interior and exterior pressures, as shown in Figure 6.

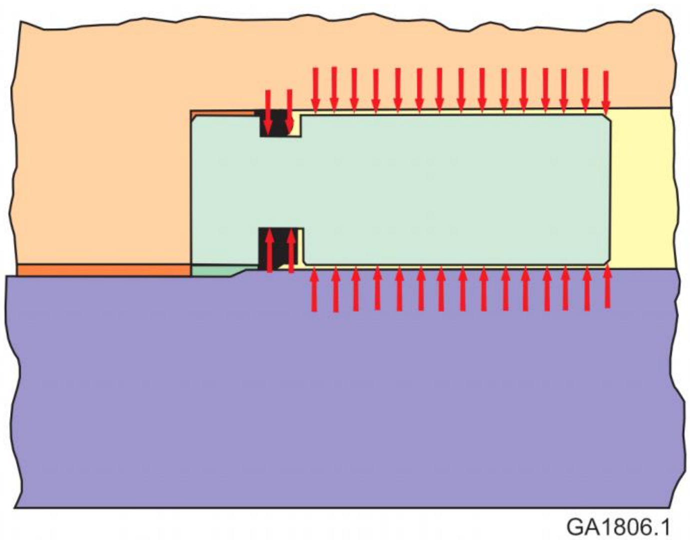

Figure 6
Radial pressure balance

Placement of the static and rotary seals causes this seal carrier to be radially pressure balanced, which reduces pressure breathing. This arrangement is not radially force balanced, because the pressure acts on more surface area on the outside of the seal carrier.

Finite element analysis should be employed to evaluate pressure breathing of high pressure equipment — particularly when larger diameters are involved. In some cases, it may be necessary to match the pressure breathing of a seal carrier to the simultaneous pressure breathing of the mating shaft.

Threaded connection influence on extrusion gap clearance

The location of highly torqued threaded connections can influence bearing and extrusion gap clearance. In Figure 7, component deformation resulting from tightening the tapered thread connection with a breakout machine will reduce both the journal bearing clearance and the extrusion gap clearance.

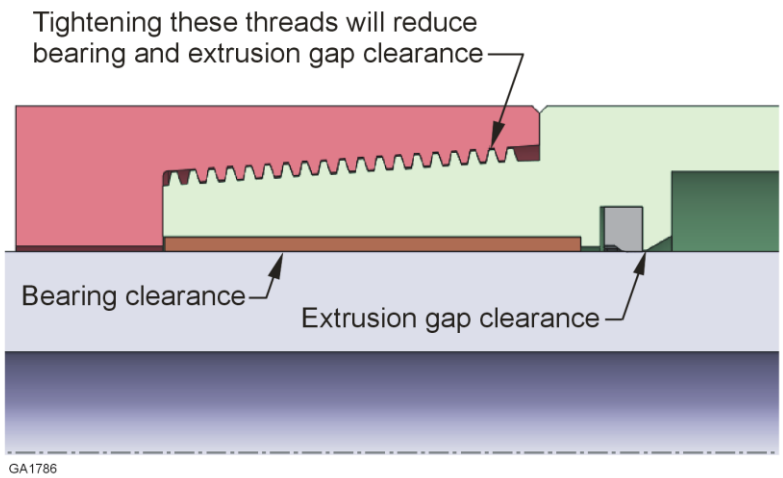

Figure 7

Threaded connection location influences extrusion gap clearance

Oilfield mud motor threaded connections are tightened to very high torque values to prevent thread loosening in the high vibration downhole drilling environment. When the threads shown here are tightened, the resulting hoop stress may cause enough deformation to bind the journal bearing against the shaft, and to significantly reduce the extrusion gap clearance.

5. Pressure testing with various seal types and extrusion gaps

Standard Kalsi Seals™

Several decades ago, when Standard Kalsi Seals were the only rotary shaft seal design we offered, testing at higher pressures (such as 1,000 psi) was conducted with 0.010” (0.25mm) radial extrusion gap clearance. Such testing was typically performed at 162° (72.2°C) with minimal runout. Standard Kalsi Seals have been displaced by seals with wider lips and now are largely relegated to low pressure seal applications where extrusion resistance is not a factor.

A pair of 10.5” (266.7mm) PN 381-35-11 Standard Kalsi Seals were tested at 300 psi (2.07 MPa) for 32 hours and 500 psi (3.44 MPa) for 83 hours with 0.003” to 0.007” (0.076 to 0.178mm) runout using 0.020” (0.51mm) radial extrusion gap clearance. The rotary speed was 100 rpm (274.88 ft/minute) and the bulk temperature of the 320 ISO viscosity grade lubricant between the rotary seals was maintained at ~148°F (64.44°C). This was a leak rate test for RCD seal applications, rather than a duration test.

We tested Standard Kalsi Seals in -11 HNBR material with a 0.020” (0.51mm) radial extrusion gap at 162°F (72.2°C) with 70 psi (482.6 kPa) lubricant pressure and a spring force that was calculated to be equivalent to 29 psi (199.95 kPa). The testing was performed with drilling fluid and minimal runout. The seals were not challenged.

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We tested Standard Kalsi Seals in -30 FKM material with a 0.020” (0.51mm) radial extrusion gap. The bulk lubricant temperature was maintained at 300°F (148.9°C). The seals were tested with 15 psi (103.4 kPa) lubricant pressure and a spring force that was calculated to be equivalent to about 45 psi (310.26 kPa) at 400°F (204.4°C). These tests indicate that the -30 FKM seal material is compatible with the usual range of axial spring loading at the temperatures that HNBR seal material is normally used.

We tested Standard Kalsi Seals in -8 FEPM material with 0.020” (0.51mm) radial extrusion gap clearance at temperatures up to 375°F (190.6°C). The tests were conducted with 38 psi (262 kPa) lubricant pressure and a spring force that was calculated to be equivalent to about 45 psi (310.26 kPa) at 400°F (204.4°C). The used seals had noticeable protrusion into the extrusion gap clearance but were otherwise in good condition.

Axially Constrained Kalsi Seals™

The Axially Constrained Seal™ design was developed for substantially pressure-balanced operating conditions, and for such service we typically recommend a radial extrusion gap clearance of 0.020”.

Wide Footprint Kalsi Seals™

The Wide Footprint Seal™ design was developed using comparative 480 rpm (345.6 ft/minute) testing of competing 2.75” (69.85mm) designs using the -11 HNBR seal material, a 0.010” (0.254mm) radial extrusion gap clearance, and minimal runout. Many of the tests consisted of about 24 hours at each of the following pressures: 15, 500, 1,000, and 1,500 psi (0.10, 3.45, 6.89, 10.34 MPa). This comparative testing was typically performed with an ISO 320 viscosity grade lubricant maintained at a bulk lubricant temperature of 200°F (93.3°C).

Testing indicates that Wide Footprint Seals™ are unsuitable for 1,500 psi (10.34 MPa) operation with a 0.020” (0.51mm) radial extrusion gap clearance.

We tested 2.75” (69.85mm) PN 507-5-11 Wide Footprint Seals with a 0.020” (0.51mm) radial extrusion gap clearance at 200°F (93.3°C) bulk lubricant temperature and 500 psi (3.44 MPa) lubricant pressure with an air environment. The hydrodynamic pumping related leakage was clean, suggesting reasonable lubrication. We went on to test these seals at higher lubricant overpressure that produced dark hydrodynamic pumping related leakage and seal damage. Unfortunately, we did not observe seal condition before the pressure was increased.

Extra Wide Kalsi Seals™

A pair of 2.750” (69.85mm) PN 655-4-114 Extra-Wide Type A Enhanced Lubrication Kalsi Seals™ were tested at 5,000 psi (34.47 MPa) for 950 hours with 0.010” (0.25mm) dynamic runout using a 0.002” nominal radial extrusion gap clearance that was established by a floating metal backup ring. The test was performed at 252 ft/minute (1.28 m/s) with a bulk lubricant temperature that was maintained at 120 to 130°F (48.9 to 54.4°C).

Extra Wide Type C Hybrid Seals were developed to better withstand larger extrusion gaps in mud motor pressure retaining service. A pair of 2.750” (69.85mm) seals constructed of -11 material were tested at 1,000 psi (6.89 MPa) for 24 hours and 1,500 psi (10.34 MPa) for 24 hours with a 0.020” (0.51mm) radial extrusion gap clearance. Testing was performed with 0.010” (0.254mm) dynamic runout at 480 RPM (345.6 ft/minute) with an ISO 320 viscosity grade lubricant that was maintained at 302°F (150°C). Although the Extra Wide Seals™ sustained considerable damage, they fared much better than -11 Wide Footprint Seals, which failed in about an hour due to gross extrusion damage.

Super Wide Kalsi Seals™

2.75” (69.85mm) PN 739-1-11 Type F Super Wide Kalsi Seals™ were tested at 1,500 psi (10.34 MPa) for 95 hours with a 0.020” (0.51mm) radial extrusion gap clearance and sustained very little damage. The rotary speed was 200 rpm (144 ft/minute) and the bulk temperature of the ISO 68 viscosity grade lubricant was maintained at about 162°F (72.2°C).

2.75” (69.85mm) PN 739-1-11 Type F Super Wide Kalsi Seals were tested at 15 to 200 psi (103.4 to 1378.9 kPa) for 305 hours with a 0.020” (0.51mm) radial extrusion gap clearance and sustained virtually no damage. The rotary speed was 200 rpm (144 ft/minute) and the bulk temperature of the ISO 68 viscosity grade lubricant was maintained at about 162°F (72.2°C).

Extra Wide Plastic Lined Kalsi Seals™

2.75” (69.85mm) Extra Wide Plastic Lined Kalsi Seals using the -303 material combination have been tested at 7,500 to 7,800 psi (51.71 to 53.78 MPa) for 1,000 hours. The test, which was directed at applications such as power swivels, used radial extrusion gap clearance of about 0.0015” that was established by a radially pressure balanced metal backup ring and a floating washpipe. The testing was performed at 240 feet/minute. The bulk lubricant temperature was maintained at ~130°F (54.4°C).

Extra Wide Plastic Lined Kalsi Seals using the -303 material combination were tested at 4,800 to 5,000 psi (33.09 to 34.47 MPa) for 50 hours using a nominal radial extrusion gap clearance of 0.010” (0.254mm). The testing was performed at 80 ft/minute (0.41 m/s) with a bulk lubricant temperature that was maintained at ~110°F (43.3°).

Extra Wide Plastic Lined Kalsi Seals using the -318 material combination were tested at 9,800 psi (67.57 MPa) with a radial extrusion gap clearance of 0.0025” that was established by a floating backup ring. The test was conducted at 28 ft/minute and the bulk lubricant temperature never exceeded 96°F (35.6°C). The test duration was limited to 6.5 hours to meet an application-specific duration goal.

10.50” (266.7mm) PN 682-20-318 Extra Wide Plastic Lined Seals™ were tested at 2,300 psi (15.86 MPa) and 100 rpm for 187 hours using a 0.020” (0.51mm) nominal radial extrusion gap clearance. Coolant was circulated near one of the rotary seals at about 2 gpm (7.57 liters/min).

A pair of 10.50” (266.7mm) PN 682-21-303 Extra Wide type A Plastic Lined Seals were tested for 100 rotating hours at 2,300 psi (15.85 MPa) using a nominal radial extrusion gap clearance of 0.015”. The 45 rpm (123.6 ft/minute) test was directed at hydraulic seal applications and included 353 rotational start/stop cycles under full pressure. the bulk temperature of the ISO 68 viscosity grade lubricant ranged from 100 to 120°F (37.77 to 48.89°C). The seals were in excellent condition at the conclusion of the test.

Super Wide Plastic Lined Kalsi Seals™

Super Wide Plastic Lined Kalsi Seals with the -318 material combination have demonstrated the highest pressure capacity of all Kalsi-brand rotary shaft seals. We have tested 4.500” (114.3mm) seals at 9,500 to 10,000 psi (65.5 to 68.95 MPa) for 320 and 368 hours using a nominal radial extrusion gap clearance of about 0.0025” established by a floating backup ring. Testing was performed at 141 to 206 ft/min (0.72 to 1.05 m/s) with a bulk lubricant temperature ranging from 103 to 120°F (39.44 to 46.11°C).

Filled Kalsi Seals™

Filled Kalsi Seals are used as air-side seals in Kalsi-manufactured cement pump seal cartridges. The radial extrusion gap clearance is 0.020” (0.51mm) and the lubricant pressure is about 30 psi (203.84 kPa).

6. Environmental abrasion considerations with extrusion gaps

Introduction

Lubricant overpressure-type Kalsi Seals® are sometimes used in applications that partition a lubricant from an abrasive environment, such as drilling fluid. This subjects the rotary seal to third body abrasion — i.e., abrasion due to the abrasive content of the environment. Implementation factors that influence the rate of third body abrasion include measures to prevent skew-induced wear, the rate and magnitude of shaft runout, friction between the seal and the low pressure wall that influences seal response to runout, and the axial width and radial clearance of the extrusion gap. This section covers extrusion gap-related factors that influence third body abrasion.

The influence of extrusion gap clearance on third body wear

Our testing (described below) of lubricant overpressure-type seals in relatively low differential pressure conditions indicates that the third body abrasion of the seal and the shaft increases with a small extrusion gap clearance (Figure 8). Based on this testing we recommend avoiding a tight extrusion gap clearance with seals exposed to an abrasive environment that operate with consistently low lubricant overpressure. With changing pressure, the extrusion gap size should be governed by the highest differential pressure.

Abrasive wear can increase the size of the seal housing bore that defines the extrusion gap. The bore should be inspected on a regular basis and may need periodic repair (by plating or hard coating) or replacement to restore the diameter.

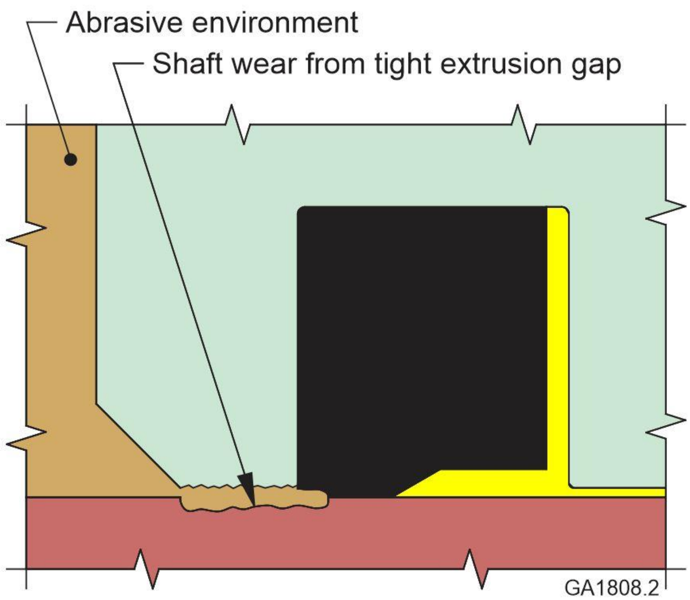

Figure 8

Tight extrusion gaps accelerate seal, shaft, and seal housing wear

Third body wear of the shaft, seal housing, and seal due to lateral and rotary shaft motion is accelerated by a small extrusion gap clearance. The shaft wear can undermine and wear the rotary seal, especially if any relative axial shaft motion is present.

The influence of extrusion gap width on third body seal wear

Our testing of lubricant overpressure-type seals also indicates that the third body abrasion of the seal increases with increasing extrusion gap width. Based on this testing, we recommend that the axial width of the extrusion gap be kept as short as practicable, especially when the extrusion gap clearance is small (Figure 9). For example, with 15 psi (103 kPa) lubricant overpressure and a 0.010” (0.25 mm) radial extrusion gap clearance we observed less wear with a 0.020” (0.51) long extrusion gap, compared to a 0.040” (1.02 mm) long extrusion gap, but would still recommend the use of an outboard barrier seal in either case. There are practical limits to how short an extrusion gap can be machined, and each equipment manufacturer will have to determine the width they are comfortable machining. To avoid tolerance stackup, dimension the axial width of the bore that defines extrusion gap, rather than dimensioning the size of the chamfer (Figure 10).

The accelerated third body induced abrasion of rotary seals with a small extrusion gap is believed to be a hydraulic effect induced by shaft runout. Runout has the effect of rapidly changing the local radial dimension of the extrusion gap. This change displaces some of the abrasive-laden fluid toward the seal. Some of the pressure created when the fluid is displaced must be reacted by the seal. An analogy would be clapping your hands together when they are submerged under water. You can feel water jetting from between your hands, just as the fluid in a small extrusion gap does in response to lateral shaft motion. If you stop the clap while the hands are still one inch apart, not nearly as much water is displaced, and that is analogous to the benefit provided by a radially large extrusion gap. If you only clap two fingers together, not nearly as much water is displaced, and that is analogous to the benefit provided by an axially short extrusion gap width.

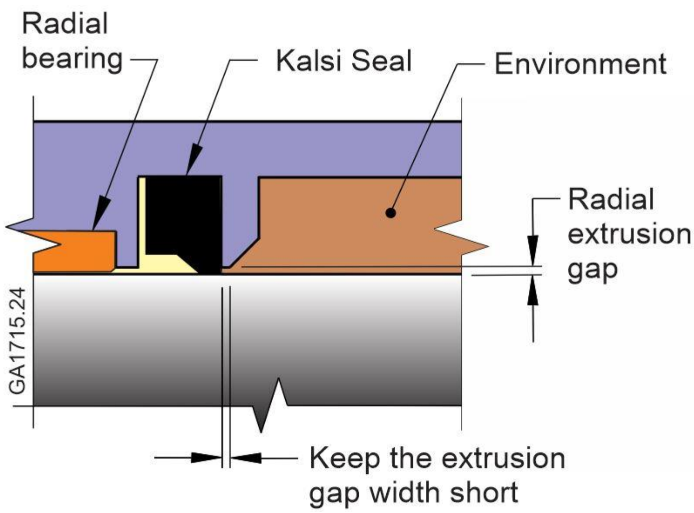

Figure 9

Short extrusion gap width reduces hydraulic effects that cause seal wear

Laboratory tests of standard width -11 HNBR Kalsi Seals were performed with drilling fluid, a 0.01” (0.25 mm) radial extrusion gap clearance, and lubricant over-pressures of 15, 100, and 300 psi. At 15 psi, abrasive wear of the seal was less when the axial width of the extrusion gap was minimized. The level of over-pressure also influenced abrasive wear. Seals with 100 and 300 psi over-pressure experienced less abrasive wear, compared to seals with 15 psi over-pressure.

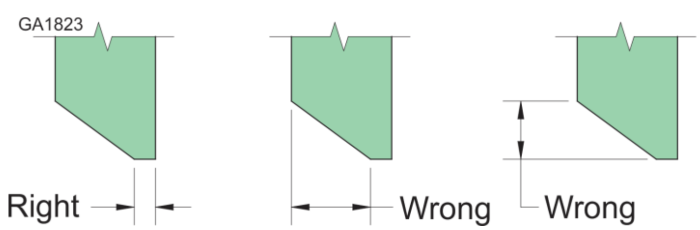

Figure 10

Dimension the width of the extrusion gap, rather than the chamfer size.

Because of the role the width of the extrusion gap plays in the third body abrasion of lubricant overpressure-type seals, dimension the width of the extrusion gap, rather than the chamfer size. This dimensioning practice prevents tolerance stackup from affecting the width of the extrusion gap.

The influence of runout on third body seal wear

The life and reliability of lubricant overpressure type rotary seals increases as shaft runout decreases. This is true both in terms of resistance to pressure-related extrusion damage and resistance to third body wear.

In our 480 rpm seal tests with lubricant overpressure type seals, far less third body abrasion occurred with 0.001” to 0.002” (0.025 to 0.051mm) runout, compared to 0.010” (0.254mm) runout. This phenomenon, which we believe is related to friction between the seal and the low pressure groove wall[3], is an incentive to implement rotary seals in a way that minimizes the runout experienced by the seal. For example, a seal carrier that follows shaft runout isolates the seal from the runout.

The testing basis for recommending a narrow extrusion gap width

We tested 2.75” (69.85mm) single durometer -11 HNBR Kalsi-brand rotary seals against abrasive oilfield drilling fluid at 480 rpm with minimal shaft runout.

One set of tests was conducted using seal carriers with 0.010” (0.25 mm) radial extrusion gap clearance. With 15 psi (103 kPa) lubricant over-pressure and a large extrusion gap width, the seal experienced rapid abrasive wear. With the same 15 psi (103 kPa) lubricant over-pressure, but a 0.020” (0.51 mm) extrusion gap width, the abrasive wear of the seal was significantly reduced, and was an improvement over a 0.040” (1.02 mm) extrusion gap width. With 100 psi (0.69 MPa) lubricant over-pressure and a 0.040” (1.02 mm) extrusion gap width, abrasive wear of the seal was negligible. With 300 psi (2.07 MPa) lubricant over-pressure, abrasive wear of the seal was negligible, even with a large extrusion gap width.

The seal that had 300 psi (2.07 MPa) lubricant over-pressure excluded abrasives well, despite the 0.010” (0.25 mm) radial extrusion gap clearance and a wide extrusion gap width, because the differential pressure causes the exclusion edge of the seal to bite down harder, and exclude abrasives better. Likewise, a seal that had 100 psi lubricant over-pressure, a 0.010” radial extrusion gap clearance, and a 0.040” extrusion gap width excluded abrasives better than a seal exposed to 15 psi differential pressure and the same extrusion gap dimensions. Even if your differential pressure is in the 100 to 300 psi range (or greater), a small extrusion gap width is recommended, because your application may have more runout than our test fixture, and therefore may experience a more pronounced hydraulic effect.

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3 In tests with 0.010" (0.254mm runout at 480 rpm with a drilling fluid environment, elastomeric lubricant underpressure type Kalsi Seals exhibited significantly less third body wear than lubricant overpressure seals. We believe this is due to the absence of wall friction at the environment end of the seal.

We also tested seals of the same type against drilling fluid using 15 psi (103 kPa) lubricant over-pressure and a 0.020” (0.51 mm) radial extrusion gap clearance. The abrasive wear of the seals was negligible. We did not test for sensitivity to extrusion gap width with the 0.020” radial extrusion gap clearance. Consider using an extrusion gap width of about 0.040” (1.02mm) when a 0.020” (0.51 mm) radial extrusion gap clearance is used.

The potential advantages of lip type outboard barrier seals

Although we do not manufacture lip type barrier seals for use outboard of Kalsi Seals, we believe they have utility if implemented in a way that prevents pressure locking. Chapter D10 provides suggestions for implementing barrier seals. One perceived advantage that lip seals have in barrier seal applications is a lack of friction between the sealing lip and the environment-side wall. In a well-designed barrier seal, this should allow the lip to respond quickly to lateral shaft motion (e.g., runout and vibration).

Low pressure seals located near a shoulder

When a Kalsi-brand rotary seal faces a shoulder in an abrasive environment, seal wear can be reduced by incorporating a narrow step in the extrusion gap (Figure 11). The narrow step helps to prevent the shoulder from packing abrasives against the seal due to any unavoidable end play.

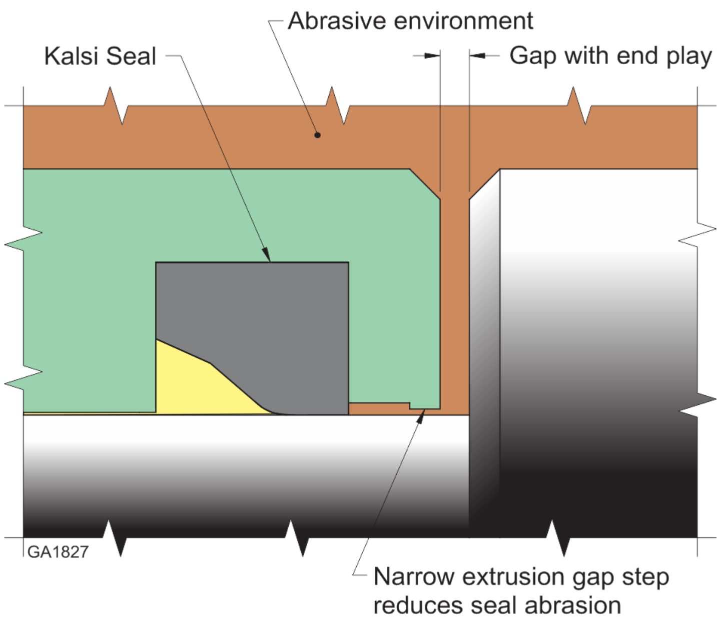

Figure 11

A stepped extrusion gap minimizes end play related seal wear

End play between the seal and the shoulder tends to pack abrasives against the seal, causing wear in equipment such as roller reamers. The stepped extrusion gap helps to reduce packing related wear.

Minimizing wear of the air-side seal in surface equipment

In outdoor surface equipment, various contaminants can enter the air-side extrusion gap. Examples of such contaminants are dust, grimy road splash, and drippings from other equipment. In vertical shaft applications, use of a rotating debris shield (shown in Figure 12) can minimize such contamination. Arrangements are possible that provide a level of protection even in certain horizontal shaft applications; see our U.S. Patent 7,798,496.

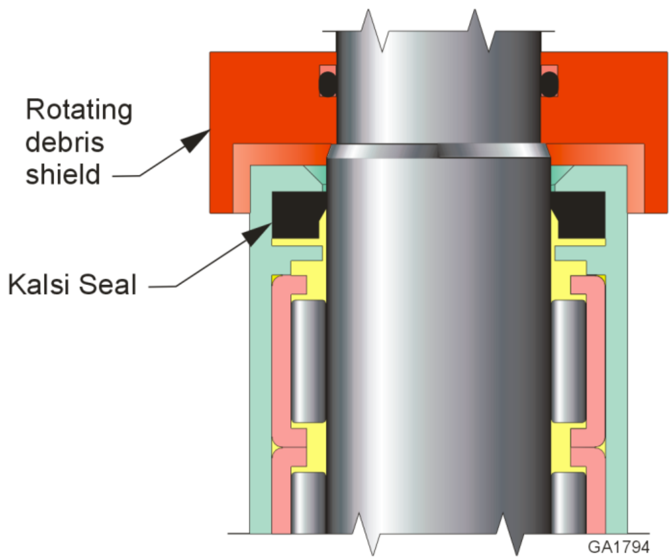

Figure 12

Rotating debris shield

In vertical shaft surface equipment, a rotating debris shield can be used to shield the air-side extrusion gap from contamination. This helps to preserve the life of the air-side seal. Configurations are possible that provide some protection in horizontal shaft applications; see the cement pump seal cartridge in U.S. patent 7,798,496. (Ensure a complete lubricant fill in vertical shaft equipment, so the upper seal is submerged in lubricant, rather than exposed to an air pocket.)