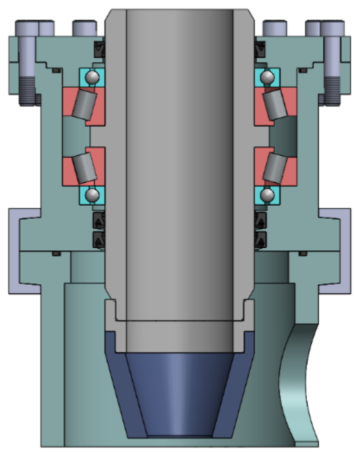
Chapter E7

BDRP seals in RCDs without lubricant overpressure



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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.

1. Introduction

A rotating control device (RCD) establishes a sealed relationship with the rotating drill string of an oil well. This allows underbalanced drilling, where the pressure of the drilling fluid column within the well is kept below or comparable to the reservoir pressure. This pressure management technique improves the production potential of the well by reducing pressure-related formation damage and allows the use of less expensive drilling fluids.

The sealed relationship with the drill string is accomplished with a mandrel mounted stripper element. Friction between the stripper element and the drill string causes the mandrel to rotate with the drill string. Rotary seals establish dynamic sealing between the rotating mandrel and the bearing housing of the RCD.

From a rotary seal standpoint, RCDs can be divided into two main types: those that use lubricant overpressure and those that do not. In lubricant overpressure RCDs, the pressure of the seal lubricant is controlled to be greater than the pressure of the drilling fluid.[1] The lubricant pressure control system adds complexity and expense. RCDs without a lubricant pressure control system are considerably less expensive but create significant challenges to the rotary seals. BDRP seals were developed to meet these challenges.

This chapter includes guidance for incorporating BDRP seals into RCDs and similar high-pressure rotary sealing assemblies that do not pressurize the bearing lubricant.

2. BDRP seal description

BDRP seals (Figure 1) were developed for lower cost RCDs that do not have a lubricant pressure control system. They are patented direct compression rotary seals that are capable of withstanding differential pressure acting in either axial direction. They have an elastomer body and an extrusion-resistant plastic liner. Because of the plastic liner, they require an outboard barrier seal when used to retain abrasive fluids.

As with other Kalsi Seals, BDRP seals have hydrodynamic waves that pump a lubricant film through the dynamic interface during rotation to reduce friction, wear, and seal-generated heat. This promotes extrusion resistance by reducing the temperature-related modulus loss of the plastic liner. BDRP seals have higher pressure and speed capacity, and higher hydrodynamic pumping related lubricant leakage, compared to KLS seals.

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[1] In a lubricant overpressure RCD, the pressure retaining rotary seal can be located above or below the bearings. When the pressure retaining seal is above the bearings, the bearing lubricant is pressurized and serves as the seal lubricant. When the pressure retaining seal is below the bearings, the pressurized seal lubricant is separate from the bearing lubricant.

When used in an RCD, the hydrodynamic waves of a BDRP face the unpressurized bearing lubricant, and pump into the region between the BDRP seal and the outboard barrier seal.

Figure 1

BDRP seals

BDRP seals are patented direct compression hydrodynamic seals that have an elastomer body and a high-performance plastic liner. In an RCD, the waves face the unpressurized bearing lubricant and pump a film of the lubricant into a pressurized region between the BDRP seal and an outboard barrier seal. This hydrodynamic pumping related leakage can be used to flush and lubricate a lip-type barrier seal or can be returned to the bearing chamber with our patented lubricant return valve.

3. Implementation recommendations for BDRP-type RCD seals

Implementation overview

In an RCD without a pressurized lubricant supply, the BDRP seal and an outboard barrier seal are located below the bearings, and the unpressurized bearing lubricant serves as the lubricant supply for the BDRP seal (Figure 2). The region between the BDRP seal and the outboard barrier seal is filled with "barrier lubricant" that is pressure-balanced to the drilling fluid pressure with small pistons. With this arrangement, the barrier seal is exposed to the drilling fluid but protected from high differential pressure, and the BDRP seal is exposed to high differential pressure but protected from the abrasive drilling fluid.

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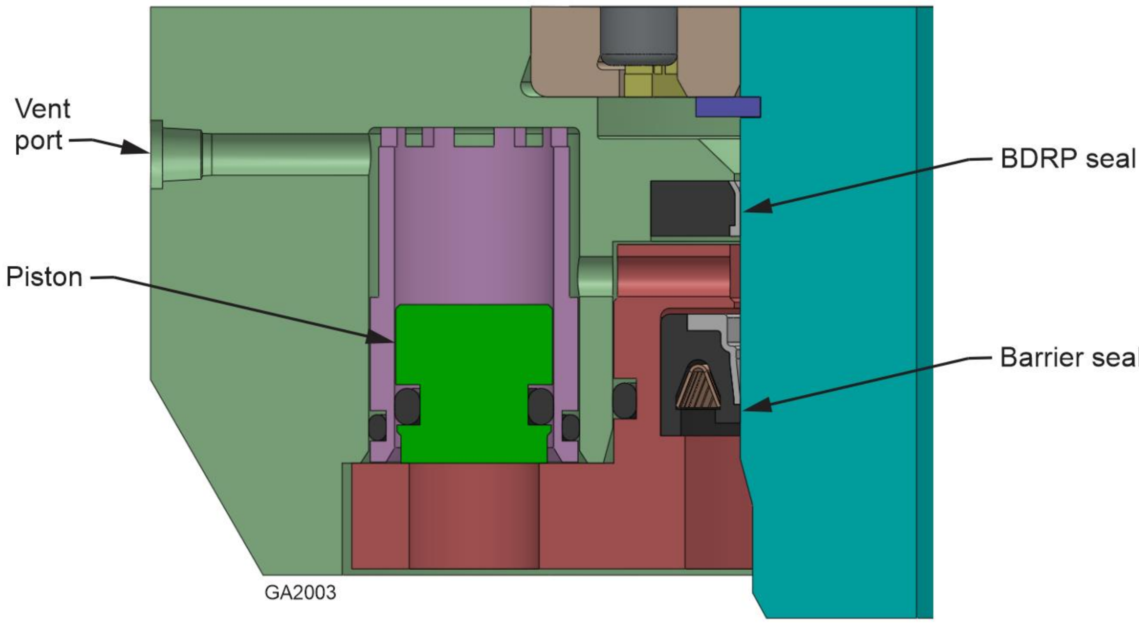

Figure 2

Pairing a BDRP seal with a lip seal in an RCD

This illustrates a BDRP seal paired with an outboard barrier seal in an RCD. The mandrel is positioned and guided for rotation by bearings. The barrier seal housing forms a removable groove wall for the BDRP seal. The barrier lubricant between the rotary seals is balanced to the pressure of the drilling fluid by small pistons. As a result, the BDRP seal is exposed to differential pressure but isolated from the drilling fluid, and the barrier seal is exposed to drilling fluid but isolated from differential pressure. Depending on the implementation, the hydrodynamic pumping related leakage of the BDRP seal either vents past the barrier seal or is returned to the bearing chamber by a lubricant return valve (Figure 3).

Ideally, to better accommodate higher rotary speeds, the unpressurized bearing lubricant is circulated through a reservoir and heat exchanger for cooling purposes. The dissipation of heat generated by the seals and bearings is an important consideration for higher speed operation because temperature increases with speed, and high temperature reduces seal life and pressure capacity. Circulation can be accomplished with an inexpensive low-pressure pump, if the low pressure circuit is protected from inadvertent high pressure by a check valve. During circulation, flow resistance creates moderate pressure in the bearing lubricant. This pressure varies with temperature due to temperature-related lubricant viscosity changes. The rotary seal above the bearings must be able to withstand this circulation-generated pressure.

During mandrel rotation, the BDRP seal hydrodynamically pumps a small amount of lubricant from the bearing chamber into the barrier lubricant. If the bearing lubricant is being circulated through an adequately sized reservoir, the pumping action of the BDRP seal can be used to flush and lubricate a lip type outboard barrier seal. If the bearing lubricant is not being circulated, a non-venting outboard barrier seal can be used and the pumping related leakage of the BDRP seal can be returned to the bearing chamber with our patented[2] lubricant return valve (Figure 3). The lubricant return valve communicates between the barrier lubricant and the bearing chamber and is normally closed. When the hydrodynamic pumping action of the BDRP seal causes the pressure of the barrier lubricant to rise above the pressure of the drilling fluid, the valve opens slightly and allows a small amount of the barrier lubricant to return to the bearing chamber.

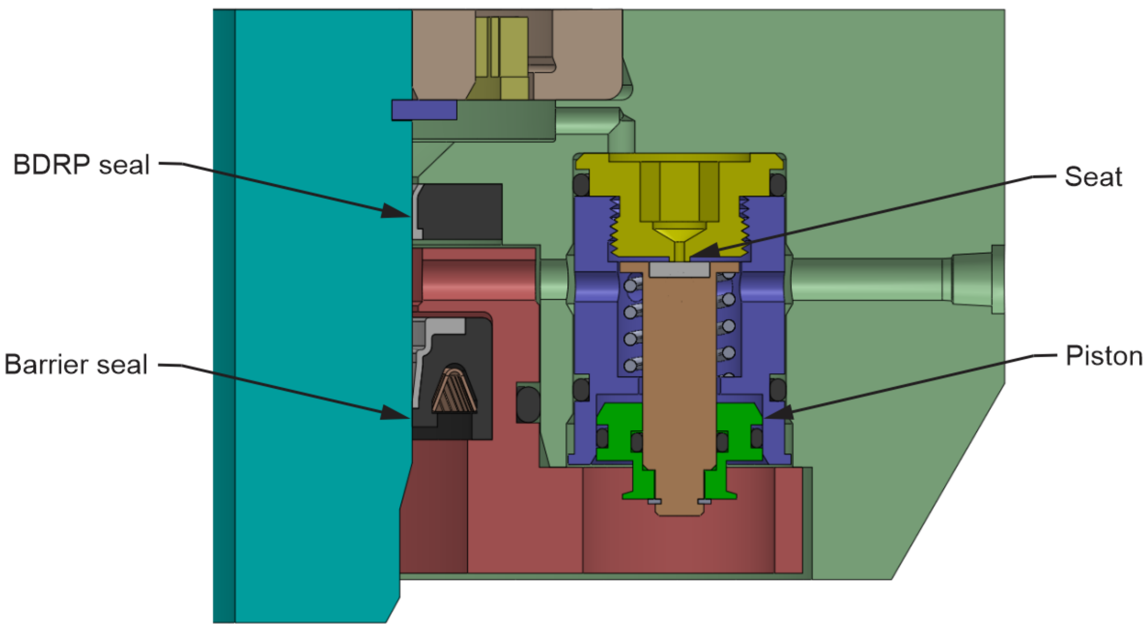

Figure 3

Lubricant return valve

A spring holds the valve closed when the pressure of the barrier lubricant is substantially equal to the pressure of the drilling fluid. When the pressure of the barrier lubricant exceeds the pressure of the drilling fluid, the valve opens slightly, relieving the pressure difference by allowing a small amount of barrier lubricant to return to the bearing chamber.

Seal housing design for the BDRP seal

One RCD design goal is to provide a small seal housing-to-mandrel clearance immediately above the BDRP seal, while avoiding housing-to-mandrel contact. The small clearance is beneficial because it reduces pressure-related seal extrusion damage. Inadvertent housing-to-mandrel contact must be avoided, because it can damage the housing and mandrel and create conditions that destroy the seal.

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[2] U.S. Patent 10,435,981, Seal arrangement for rotating equipment.

The most accurate way to locate the housing and mandrel laterally with respect to one another is to mount the lower radial bearing directly in the housing that has the groove for the BDRP seal, as shown in Figure 2. This is true whether the seal groove is in the bearing housing of the RCD or in a separate seal housing that is bolted to the bearing housing.

When the lower radial bearing is mounted in a separate seal housing, there is a risk of misalignment related bearing over-constraint if the thrust bearings provide radial guidance. This risk can be minimized by bolting the seal housing to the bearing housing after the mandrel and thrust bearings are installed in the bearing housing.

Regardless of whether the seal groove is in the bearing housing or a separate seal housing, assembly typically involves mounting the bearings on the mandrel, and then inserting the mandrel into the bearing housing. If a separate seal housing is used, it is then slipped over the lower radial bearing and bolted to the bearing housing.

BDRP seals are relatively stiff due to the plastic liner. In our experience, a removable groove wall is required to install a BDRP seal into a seal groove without damage. Either the bearing-side groove wall or the barrier fluid side groove wall can be made removable, and either location involves design tradeoffs. A removable bearing side groove wall impacts concentricity between the extrusion gap bore and the mandrel and requires extra length for adequate strength. A removable barrier fluid side groove wall requires a separate seal housing for the barrier seal, as shown in Figure 2.

Seal selection and housing design for the outboard barrier seal

Select an outboard barrier seal that is capable of excluding abrasives. For BDRP-based RCDs that incorporate a lubricant return valve, the pressure capacity of the barrier seal must be compatible with the barrier lubricant pressure required to actuate the lubricant return valve. If the barrier seal is a lip seal, it should not vent at a pressure lower than the pressure required to actuate the lubricant return valve.

For BDRP-based RCDs that do not incorporate a lubricant return valve, the outboard barrier seal should be a lip seal that is capable of venting barrier lubricant pressure. We recommend the KLS lip seal, because of its ability to withstand reasonably high pressure if the inboard BDRP seal fails. In the absence of a lubricant return valve, if the barrier seal is incapable of venting pressure, the pumping action of the BDRP seal will cause excessive barrier lubricant pressure.

Follow the seal manufacturer's guidelines when designing the groove for the outboard barrier seal. Design for achieving maximum concentricity between the seal groove bore, the extrusion gap bore, and the bore that locates the lower radial bearing.

To ensure the ability of a KLS seal to vent barrier lubricant pressure, the radial depth of the outboard groove wall should be just deep enough to hold the outer lip of the seal in place, as shown in Figure 2. This groove wall configuration prevents the inner lip of the KLS seal from sealing off against the wall – which would prevent the lip from venting barrier lubricant pressure. This wall configuration also reduces the risk of installation-related seal damage.

Filling the barrier lubricant

Provide a dependable way to fill the barrier lubricant that does not trap air between the rotary seals. The volume of any trapped air must not exceed the displacement volume (bore area times piston stroke) of the pressure balancing pistons. The compression of excess trapped air will cause the pressure balancing pistons to bottom out in the empty position without balancing the barrier lubricant pressure to the drilling fluid pressure.

One way to minimize air entrapment in the barrier lubricant region during filling is to position the RCD horizontally, with the piston(s) stroked to the empty position. Pump the barrier lubricant into the RCD from the lower side. This arrangement allows air to escape through a venting port that is located on the upper side of the RCD as the rising level of the barrier lubricant displaces the air. (Alternately, a vacuum can be drawn by attaching a vacuum pump to the vent port.) The vent port in Figure 2 is schematically illustrated. In a real RCD, a cross-drilled hole may be necessary to allow the vent port to be located at a suitable axial position. Plug the vent port when lubricant begins to leak out, and then pump the piston(s) to the full position. The pressure of the barrier lubricant will increase when the piston(s) stroke to the full position. This increase in pressure is a signal that the lubricant fill is complete. Over time, the pressure of the barrier lubricant will bleed down to the venting pressure of the outboard lip type barrier seal or the lubricant return valve.

Operation

During initial operation of the RCD, the drilling fluid pressure causes the pressure balancing pistons to stroke to an intermediate position due to factors such as air entrained in the barrier lubricant. The hydrodynamic pumping action of the BDRP seal strokes the pistons to the full position. Once this occurs, the pumping action of the BDRP seal raises the pressure of the barrier lubricant.

In RCDs with a lip type outboard barrier seal and no lubricant return valve, the increasing pressure of the barrier lubricant causes the lip seal to vent, allowing the leakage of the

BDRP seal to flush and lubricate the lip seal and escape into the drilling fluid. In RCDs with a lubricant return valve, the increasing pressure of the barrier lubricant actuates the valve and returns the leakage of the BDRP seal to the bearing chamber.

Regardless of whether a lubricant return valve is incorporated, the pressure retention and abrasive exclusion functions are assumed by the BDRP seal if the barrier seal fails first and are assumed by the barrier seal if the BDRP seal fails first.

4. Full scale testing of BDRP seals

Introduction

BDRP seals have the same lip width and hydrodynamic inlet geometry as extra wide Type F Plastic Lined Kalsi Seals, and have the same extreme pressure capacity when the differential pressure acts from the wave side of the seal.

Testing of 10.49" (266.45mm) diameter PN 717-1-318 seals has been performed to evaluate pressure capacity when the differential pressure acts from the side opposite the waves, as would be the case in an RCD without lubricant overpressure. These tests are summarized below and described in more detail in the blog portion of our website.

1,000 psi testing of a 10.490" BDRP seal at 170 rpm

A PN 717-1-318 BDRP seal was tested at 170 rpm (467 sfpm) and 1,000 psi (6.89 MPa with an ISO 220 viscosity grade seal lubricant. The pressurized fluid was an ISO 32 viscosity grade lubricant. The seal was mounted in a non-floating seal carrier that defined a 0.020" (0.51mm) radial extrusion gap clearance with the rotating mandrel. The mandrel had 0.007" (0.18mm) of dynamic runout at the seal location. A short portion of the mandrel was exposed to coolant circulation at about 2 gpm to simulate the cooling the mandrel of an RCD receives from the short length that is exposed to drilling fluid. The typical coolant temperature was about 111 to 119°F (43.9 to 48.3°C). The lubricant temperature below the test seal ranged from about 152 to 170°F (66.7 to 76.7°C) due to the proximity of another rotary seal that was also exposed to the test pressure. The lubricant temperature above the test seal ranged from about 136 to 150°F (57.8 to 65.6°C).

When we stopped the 1,000-psi test at 179 hours to accommodate our test schedule, the BDRP seal was still in excellent condition (Figure 4).

Figure 4

A 10.490" BDRP seal after a 179-hour, 1,000 psi test at 170 rpm

The 10.49" BDRP seal was still in excellent condition and performing well at 1,000 psi and 170 rpm when the test was stopped at 179 hours to free up the test fixture for a different test.

1,500 psi testing of 10.490" BDRP seals at 50 to 100 rpm

Extended duration tests of PN 717-1-318 seals were conducted at 75 and 100 rpm (206 and 275 sfpm) with 1,500 psi (10.34 MPa) acting from the side opposite the waves. The waves of the seals were exposed to an ISO 320 viscosity grade seal lubricant that was maintained at about 10 psi (68.95 kPa) to ensure the flow of the seal lubricant through restrictive lubricant supply tubing. As with the 1,000-psi testing, a short portion of the mandrel was exposed to coolant circulating at about 2 gpm. The seals were tested in a non-floating seal carrier that provided a nominal radial extrusion gap clearance of 0.010" (0.25mm) relative to the mandrel.

The first 75 rpm test was stopped for seal inspection at 251 hours, and the second was stopped at 200 hours. The 100 rpm test was stopped at approximately 210 hours for seal inspection. The used BDRP seals from the 75 and 100 rpm tests were still functional and in good condition at the conclusion of the tests (Figures 5 and 6).

During these tests, the hydrodynamic waves of the seals pumped a film of lubricant from the low pressure side of the seal to the high pressure side. In the 100 rpm test, this produced a leak rate of about 18 ml/hr. In an RCD, this leakage can be returned to the bearing chamber with our patented lubricant return valve, or (if the bearing lubricant is being circulated through a generously sized reservoir for cooling purposes) can be used to flush and lubricate a lip-type outboard barrier seal.

Figure 5
10.490" BDRP seals after 1,500 psi tests at 75 rpm

Figure 6
10.490" BDRP seal after a 1,500 psi test at 100 rpm

5. Available sizes of BDRP-type RCD seals

A list of available sizes of BDRP seals and basic groove dimensions is provided in the shaft seal catalog section of our website. Additional BDRP sizes can be provided. Small quantity orders of new sizes require a one-time tooling charge to cover associated engineering, set-up, and mold manufacturing expenses.

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