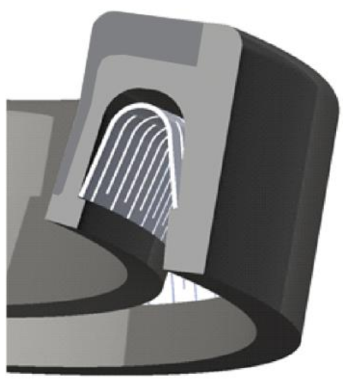
Chapter E6

KLS 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

In oil well drilling, a rotating control device[1] (RCD) is used to maintain the pressure of the drilling fluid column below, or comparable to, the pressure of the reservoir. This helps to reduce pressure-related damage to the formation, which improves production potential. Some of the advantages of underbalanced drilling include the ability to evaluate well effluents while drilling, reduced risk of differential sticking, and the ability to take advantage of less expensive drilling fluids.

Kalsi-brand rotary seals have been used in lubricant overpressure-type RCDs for many years. In such systems, the pressure of the bearing lubricant is controlled to a value that is greater than the pressure of the drilling fluid. Although such equipment can be highly capable when used with Kalsi Seals, the need for active control of the lubricant pressure causes added expense and complexity.

RCDs that that lack a pressure control system cost less to build, but present a very significant challenge to the rotary seals. Originally, there were no suitable Kalsi Seals for such RCDs. This changed with the advent of the KLS® seal, which is shown in Figure 1.

This chapter provides guidance for implementing KLS seals into RCDs that lack a pressure control system. The guidance provided herein is also relevant to other types of high pressure rotary seal assemblies, such as water drilling heads.

Figure 1

The KLS-brand RCD seal

The KLS seal is a spring-loaded, lip-type RCD seal. It has an elastomer core that is reinforced with an extrusion-resistant plastic overlay. The inner surface of the seal incorporates hydrodynamic waves that lubricate the dynamic sealing interface when the mandrel of the RCD rotates.

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1 Also known as a rotating diverter, rotating drilling head, rotating head, rotating blowout preventer, rotary blowout preventer, rotary BOP, rotating BOP, or rotary control device. If required, Kalsi Engineering can provide elastomer batch acceptance information, to help our seal customers meet API Specification 16RCD, "**Specification for Drill Through Equipment—Rotating Control Devices**".

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2. Description of the KLS-brand RCD seal

The KLS is a patented spring-loaded high-performance lip seal with an elastomer core and an extrusion-resistant plastic overlay. Such seals are used to retain differential pressure acting from the spring side of the seal. They were initially developed for lower cost RCDs that do not pressurize the bearing lubricant.

Like other Kalsi Seals, the KLS has hydrodynamic waves that that reduce friction, wear, and seal-generated heat by pumping a lubricant film through the dynamic interface during rotation. The reduced seal temperature promotes extrusion resistance by reducing the temperature-related modulus loss of the seal materials.

Unlike typical Kalsi-brand rotary shaft seals, the hydrodynamic waves are situated near the low-pressure end surface and pump the film of lubricant toward the high-pressure seal end. Differential pressure acting from the spring side of the seal forces the waves into contact with the mandrel of the RCD. The waves initiate the hydrodynamic pumping action if mandrel rotation is present, and are specially designed to resist pressure-induced deformation. The unique wave placement and design means that a KLS can operate with a simple low-pressure lubricant supply, such as the lubricant within the unpressurized bearing chamber of an RCD.

Figure 2

The inner periphery of a KLS-brand RCD seal

This photo shows the inner periphery of a 9.75” (247.65mm) KLS-brand RCD seal. The seal is oriented with the spring-energized lips facing down, as it is oriented in an RCD. The lower end of the dynamic lip is made from an HNBR elastomer, and the remainder of the inner surface and upper end of the seal consists of a high performance, extrusion resistant plastic. The uniquely-shaped hydrodynamic waves near the upper end of the seal engage the mandrel and force a film of lubricant into the dynamic sealing interface when differential pressure and rotation are present.

3. Recommended implementation of KLS-brand RCD seals

KLS-brand RCD seals should be used in pairs below the bearings, with the space between them filled with a lubricant that is pressure-balanced to the pressure of the drilling fluid. This arrangement is illustrated schematically by Figure 3. The lubricant between the seals is referred to as the barrier lubricant, and the lubricant above the inboard seal is referred to as the bearing lubricant. The bearing lubricant is not pressurized (except for any pressure resulting from optional circulation) and serves as the lubricant supply for the inboard KLS seal.

Preferably, the mandrel and the seal housing are located radially with respect to one another by a radial bearing that is mounted in a bore of the seal housing. This configuration allows the best possible guidance between the seal housing and the mandrel. This allows the extrusion gap clearance above the seals to be relatively small, which is desirable from a seal high pressure extrusion resistance standpoint. In some cases, the thrust bearings of an RCD also provide a degree of radial control, such as when angular contact bearings are employed as thrust bearings. To minimize the risk of over-constraint in such an arrangement, the seal housing can be bolted to the main bearing housing after being located radially with respect to the mandrel by the radial bearing. Failure to provide adequate radial guidance between the seal housing and the mandrel can result in seal-damaging metal-to-metal contact between the seal housing and mandrel. Such contact can also inflict significant damage to the seal housing and the mandrel.

In Figure 3, a small local piston is used to balance the pressure of the barrier lubricant to the pressure of the drilling fluid. The inboard KLS is exposed to the pressure difference between the barrier lubricant and the bearing lubricant and is protected from the abrasive drilling fluid. The outboard KLS is exposed to the drilling fluid and protected from high differential pressure. This arrangement puts both seals in the best situation to perform their respective functions. More than one piston can be used if needed.

When designing the RCD, provide for a reliable method of filling the barrier lubricant that doesn't trap air in the barrier lubricant region. If excess air is present, the system will not function as intended because the piston will bottom out in the empty position without balancing the pressure of the barrier lubricant to the pressure of the drilling fluid. The volume of air in the system (including air entrained in the barrier lubricant) must not exceed the displacement volume (bore area times stroke length) of the piston(s)

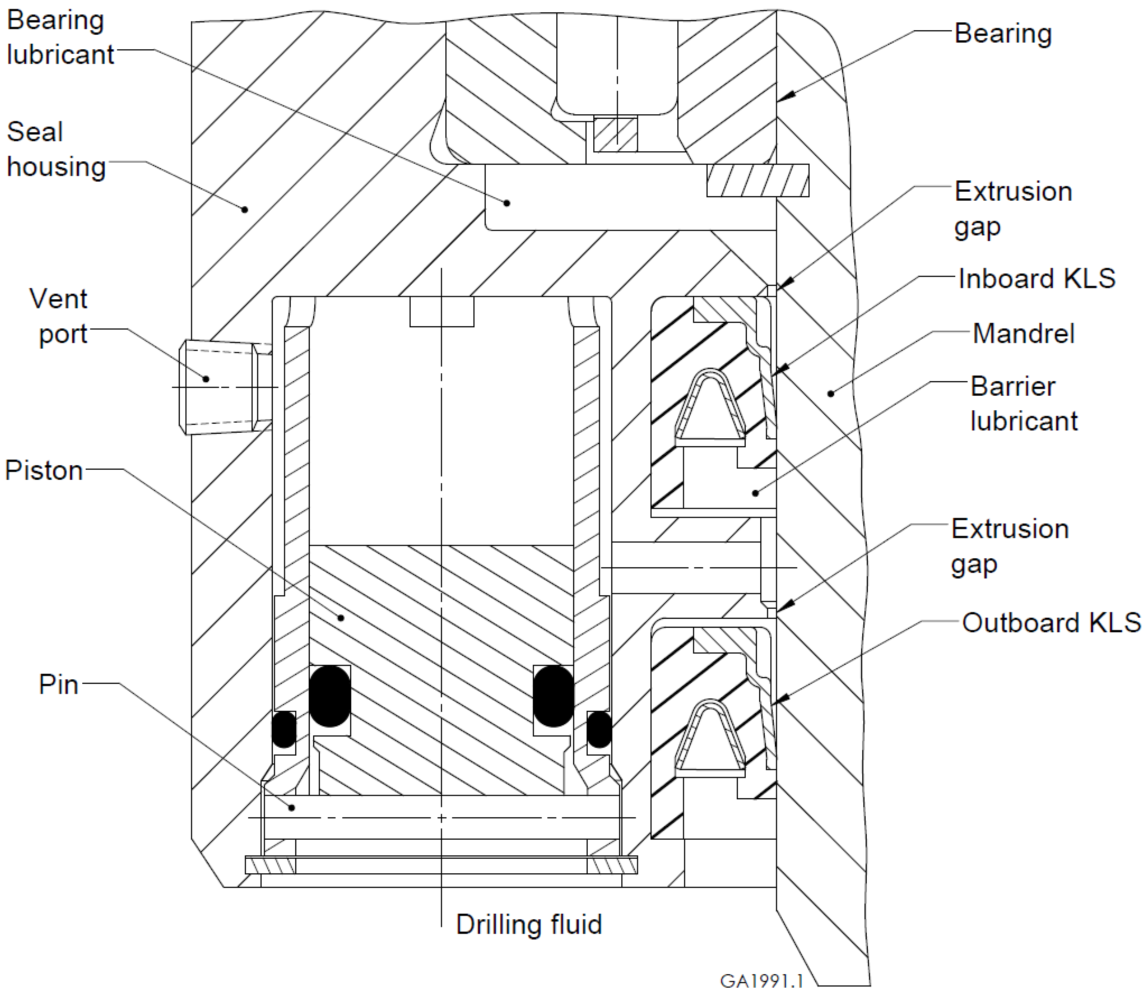

Figure 3

Using KLS seals in an RCD

This is a schematic illustration of the recommended way to employ KLS seals in an RCD. The seal housing and mandrel are located radially with respect to each other by a radial bearing. A piston balances the pressure of the barrier lubricant to the potentially high pressure of the drilling fluid. The inboard KLS seal is exposed to the potentially high differential pressure in a clean lubricated environment, and the outboard KLS seal is exposed to the abrasive drilling fluid and protected from the potentially high differential pressure. The partial gland wall of the outboard KLS ensures that the hydrodynamic pumping of the inboard KLS can vent past the outboard KLS, and also helps to prevent seal installation damage.

One way to purge air from the barrier lubricant region is to orient the RCD horizontally during the filling operation, with the piston bottomed out in the empty position. Introduce the barrier lubricant from the lower side, while allowing air to escape from a vent port located on the upper side. With this method, the air is displaced by the rising level of the barrier lubricant. A vent port is illustrated schematically in Figure 3. In an actual RCD, a cross-drilled hole may be required to position the vent port at a suitable axial location. After lubricant rises to and starts leaking out from the vent port, plug the port, and then pump the piston to the full position. When the piston reaches the full position, the pressure of the barrier lubricant will rise because the barrier lubricant fill pump introduces lubricant at a much faster rate than the outboard KLS can vent. This pressure increase serves as a signal that the fill is complete. Over time, the pressure of the barrier lubricant will bleed down to the venting pressure of the outboard KLS.

During operation, the pressure of the drilling fluid causes the piston to move to an intermediate position due to compression of the small amount of air that is inadvertently entrained in the barrier lubricant. The hydrodynamic pumping action of the inboard KLS produces enough pressure to cause the piston to move, and eventually causes the piston to bottom out in the full position. After this happens, the hydrodynamic pumping action increases the pressure of the barrier lubricant to the level necessary to vent barrier lubricant past the outboard KLS. This venting action helps to lubricate and flush the outboard KLS.

In Figure 3, the piston stop is defined by a transverse pin. Whatever the configuration, the piston stop must be designed to be strong enough to withstand the axial hydraulic force produced by the venting pressure of the outboard KLS seal. The venting pressure can vary depending on factors such as seal temperature, diameter, and cross-sectional size, lubricant viscosity, gland dimensions, and seal damage (such as a damaged spring[2] or sealing surface).

In Figure 3, the outer gland wall of the outboard KLS is reduced in radial depth. This wall configuration prevents the dynamic lip of the outboard KLS from sealing off against the wall, which would prevent the necessary venting action. The reduced radial gland depth of the outer gland wall also eases installation of the outboard KLS, which reduces the risk of seal installation damage.

If the inboard seal fails before the outboard seal, the piston moves to the empty position, and the outboard seal assumes both the abrasive exclusion and the pressure retention functions. Because of this potential failure mode, the outboard seal should be a KLS rather than a non-hydrodynamic lip seal, so that it can operate hydrodynamically as a pressure retaining seal when exposed to significant differential pressure. If the outboard seal fails first, the inboard seal assumes the abrasive exclusion and pressure retention functions.

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[2] Employees should be trained that the lips of KLS-brand RCD seals should not be manually squeezed. As with any type of seal that utilizes a V-spring, such squeezing can yield the spring, and dramatically alter the dynamic performance and pressure venting characteristics of the seal.

In Figure 3, the seal housing is illustrated as a one-piece component. Our testing indicates that KLS seals at least as small as 9.75” can be installed without the use of a removable gland wall. We found that a removable gland wall was needed to permit damage-free installation of 3.375” KLS seals. Removable gland walls may be desirable in some circumstances, even though they are not required for installation. Contact Kalsi Engineering for additional information.

Optional cooling for circulation purposes

Seal-generated heat is a function of running torque and speed. Dissipation of seal and bearing generated heat is a matter of significant concern in high speed operation because high temperatures negatively impact seal pressure capacity and life. Because the pressure of the bearing lubricant is low when KLS seals are used, it can easily be circulated by an inexpensive low-pressure pump for cooling purposes. Such cooling facilitates operation at higher rotary speeds. A check valve should be used to protect the low-pressure circuit from high drilling fluid pressure, in the event of total rotary seal failure. If the bearing lubricant is circulated, the seal above the bearings must have sufficient pressure capacity to withstand the circulation-related bearing lubricant pressure. The circulation-related pressure will vary with temperature due to temperature-related viscosity changes, and flow rate.

4. Kalsi Engineering testing of KLS seals

Introduction

Our testing of KLS and similar non-hydrodynamic seals for RCD operating conditions was performed with 3.375” (85.73mm) seals. A fixture for rotary testing of 10.50” KLS seals is being developed at the time of this writing.

Testing indicates that the ability to exclude drilling fluid is good in zero differential pressure conditions, and inconsistent when the pressure of the drilling fluid is significantly greater than the pressure of the seal lubricant. This testing provided the basis for our published RCD seal implementation recommendations, where the inboard seal receives the differential pressure and is protected from the drilling fluid.

High pressure seal testing

We tested KLS-brand rotary seals at 1,000 psi (6.89 MPa) with a surface speed of 543 feet per minute (2.76 m/s) with an ISO 150 viscosity grade seal lubricant. The surface speed is equivalent to a 10.375” (263.53 mm) mandrel rotating at 200 rpm. The seals were still in good condition after 1,000 psi tests that exceeded 200 hours. Seals that had the same geometry but lacked the the unique hydrodynamic waves failed in a few hours when exposed to only 500 psi (3.45 MPa) differential pressure.

We also tested 3.375" KLS seals at 1,500 psi (10.34 MPa) and a speed of 137 feet per minute (0.7 m/s) with an ISO 460 viscosity grade lubricant. The surface speed of these tests was equivalent to a 10.375" (263.53 mm) mandrel rotating at 50 rpm. At the conclusion of 100 and 200-hour tests, the seals were still in good condition.

Low pressure testing with drilling fluid

Our recommendation to employ KLS seals in pairs in RCDs is based on rotary testing of 3.375" (85.73 mm) seals with water-based drilling fluid and an ISO 150 viscosity grade seal lubricant. The tests were performed at 615 rpm, which equates to a surface speed of 543 feet per minute (2.76 m/s). This corresponds to a 10.375" mandrel rotating at 200 rpm.

Two tests with zero pressure differential were performed with PN 668-4 KLS seals and a bulk lubricant temperature that was controlled to approximately 162°F (72.2°C). One test had 0.010" (0.25 mm) intentional runout, and the other had very little runout. These tests were arbitrarily shut down at 265 hours to inspect the seals, which were in very good condition. In these 615 rpm tests of 3.375" seals, the seals are exposed to more runout cycles, compared to a 10.375" seal running at the same surface speed.

We also performed two tests of seals that have the same basic geometry as KLS seals, but lack the hydrodynamic waves that are necessary for high pressure operation. The first test had 0.010" runout and zero pressure differential. The seal was still in good condition when the test was terminated at 145 hours to inspect the seals. The second test had a bulk lubricant temperature of 197°F (91.66°C), 5 psi pressure differential, and no intentional runout. The seals were still in good condition when the test was terminated at 201 hours for seal inspection.

5. Available sizes of KLS seals

Currently available sizes of KLS seals are listed on the shaft seal catalog portion of our website, along with basic groove dimensions. Additional sizes of KLS seals can be provided. Small quantity orders of new seal sizes are subject to a one-time tooling charge to help to defray associated engineering, machining, and set-up expenses.