Chapter C18

Overview of high-pressure Kalsi Seals

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Individual chapters of the Kalsi Seals Handbook are periodically updated. To determine if a newer revision of this chapter exists, please visit www.kalsi.com/seal-handbook.htm.

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1. Introduction to the high-pressure Kalsi Seal categories

There are four general categories of Kalsi-brand rotary shaft seals that are used in high differential pressure rotary service. Each category was developed for specific hardware configurations and pressure situations. The first high-pressure seal category is the largest and includes various solid cross-section, direct compression oil seals that are used to retain pressurized lubricant. The next two high pressure seal categories involve lip seals that are used with unpressurized lubricant: our KLS-brand spring-loaded seals and our unique high pressure washpipe packing. The final category is represented by our BDRP seals™, which are designed for lubricant pressure acting in either axial direction. Each of these high-pressure seal categories are summarized below.

2. Category 1: Seals for high pressure oil retention

Category 1 Kalsi Seals (Figure 1) are direct compression-type seals that are used for retaining pressurized lubricant. They have specially designed hydrodynamic waves that are oriented toward the pressurized lubricant. During shaft rotation, these waves pump a film of lubricant into the dynamic sealing interface between the seal and the shaft, reducing friction, wear, and seal generated heat. This reduces temperature-related loss of material properties, which helps to preserve high pressure extrusion resistance. Because of this rotation driven hydrodynamic pumping action, a slight amount of pumping related lubricant leakage occurs during periods of shaft rotation. Optional wave forms are available that provide different degrees of lubrication and associated hydrodynamic pumping related leakage. For examples of available seal designs, see our Wide Footprint, Enhanced Lubrication, Hybrid, and Plastic Lined rotary shaft seal product lines.

Figure 1

Category 1 high pressure rotary shaft seals

Category 1 Kalsi Seals are direct compression high pressure oil seals that are used to retain a pressurized lubricant. Such seals have hydrodynamic waves that are exposed to the high pressure lubricant. When the shaft rotates, these waves pump a thin film of lubricant into the dynamic interface between the seal and the shaft, which reduces friction, wear, and seal-generated heat. This example of a Category 1 seal incorporates an extrusion-resistant plastic liner that increases pressure capacity and reduces startup friction.

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When retaining a pressurized process fluid that is not a lubricant, a pair of oppositely facing Category 1 seals is used, and a seal lubricant is provided between them, as shown schematically in Figure 2. The seal lubricant pressure is maintained at a value that is equal to or moderately greater than the process fluid pressure. One of the rotary shaft seals partitions the process fluid from the lubricant, and the other retains the pressurized seal lubricant. The lubricant pressure is provided by a lubricant supply that also accommodates the hydrodynamic pumping related leakage of the rotary shaft seals.

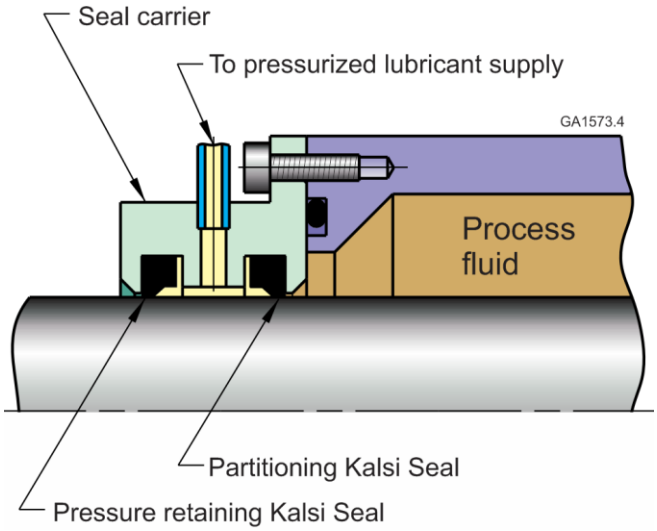

Figure 2

How Category 1 seals are used to retain a high-pressure process fluid

Since Category 1 Kalsi Seals are high-pressure oil seals, a pair of them are required to retain a high-pressure process fluid. The seal lubricant between the Kalsi Seals is pressurized to a value that is equal to or greater than the pressure of the process fluid. The right-hand seal partitions the process fluid from the seal lubricant, and the left-hand seal retains the high-pressure seal lubricant.

How the extrusion gap influences high pressure sealing

The purpose of any high-pressure rotary shaft seal is to prevent gross loss of a pressurized fluid through the unavoidable radial clearance that exists between a rotating shaft and the housing that surrounds it. In the seal industry, this clearance is known as the "extrusion gap" because the high differential pressure tends to extrude seal material into the gap, causing "extrusion damage" to the rotary shaft seal. The smaller the extrusion gap, and the less the extrusion gap changes due to shaft runout, lateral shaft deflection, and pressure breathing of the housing, the better a rotary shaft seal can resist high differential pressure — provided that heavily loaded contact doesn't occur between the

shaft and housing. Such contact can generate enough heat to significantly reduce the extrusion resistance of the rotary shaft seal and can damage the shaft and housing in ways that can quickly destroy the seal.

Because the shaft-to-housing extrusion gap is so crucial to high pressure rotary shaft seal performance, floating seal housing arrangements (Handbook Chapter D17) have been developed that allow very small extrusion gaps to be employed without risk of heavily loaded metal-to-metal contact between the shaft and the housing. For example, see Figure 3.

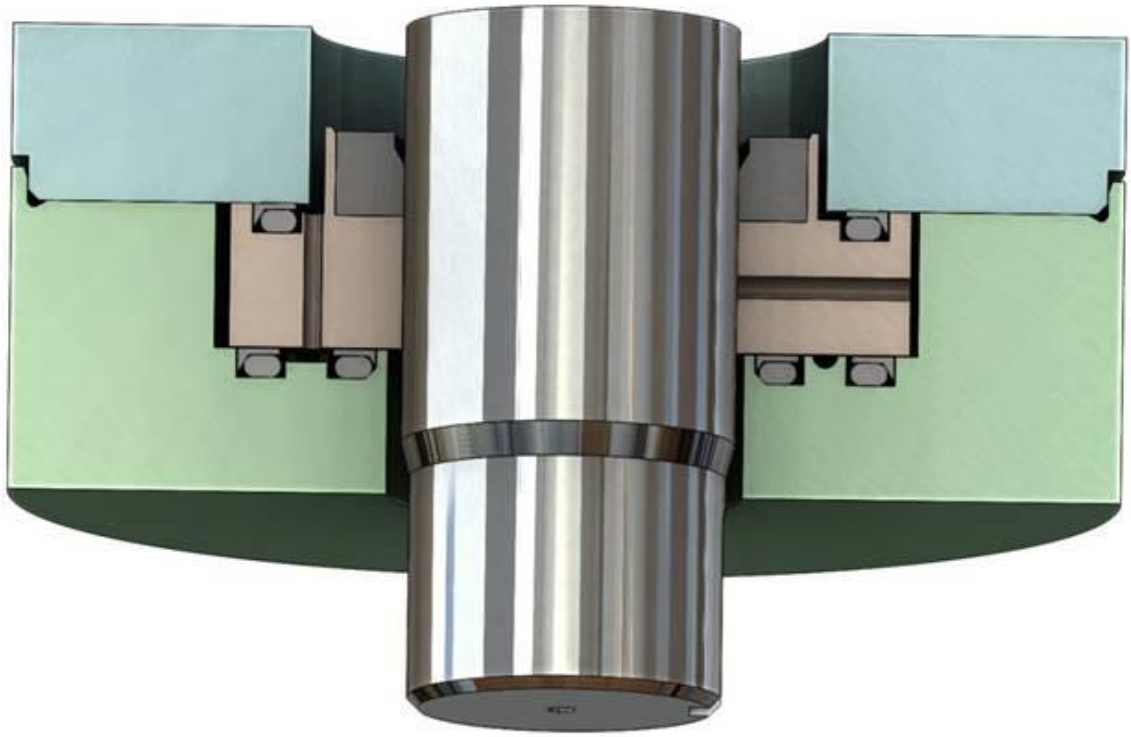

Figure 3

Floating seal housing arrangements for maximum high-pressure seal capacity

To achieve maximum high-pressure capacity, Category 1 rotary shaft seals are used with our patented floating seal housing arrangements. These highly refined seal housings are radially pressure balanced to minimize pressure-related extrusion gap distortion. They are also hydraulically force balanced in the axial direction, which allows them to move laterally to accommodate shaft runout and misalignment. This feature allows the seal housing to define the smallest possible extrusion gap while eliminating the risk of destructive heavily loaded metal-to-metal contact at the extrusion gap.

Factors that affect the pressure capacity of a Category 1 rotary shaft seal

The pressure capacity of a Category 1 rotary shaft seal depends on several factors, including the size of the shaft-to-housing extrusion gap, the materials used to construct the seal, the aggressiveness of the hydrodynamic waves, the rotary speed of the shaft, the ambient temperature, heat transfer efficiency, and the required life of the seal. For example, at 7,500 to 7,800 psi (51.71 to 53.78 MPa) lubricant pressure and a surface speed of 252 feet per minute (1.28 m/s), a pair of 2.75″ (69.85mm) plastic lined Kalsi Seals were still in good condition after 1,000 hours of operation. The seals had the benefit of a seal carrier arrangement that minimized the extrusion gap, and a small amount of fluid circulation inside the hollow rotating shaft that maintained the pressurized seal lubricant approximately at 130°F (54.44°C).

Category 1 high pressure rotary shaft seals are available in a variety of materials and seal designs. Seals that have an extrusion-resistant plastic liner have the most pressure capacity, followed by "dual durometer" seals that have a liner made from a higher modulus elastomer. For seal material options, visit our materials web page. For additional information, call us at 281-240-6500.

3. Category 2: KLS-brand high pressure lip seals

KLS-brand rotary shaft seals (Handbook Chapter C17) are high-pressure V-spring energized lip seals for unidirectional rotation. This highly capable seal design was originally developed as an RCD seal for low cost oilfield rotary control devices with unpressurized bearing lubricant. We are not aware of any seal that is better for such RCD service. Handbook Chapter E6 describes how to implement KLS seals for RCD service.

The spring end of the KLS seal is formed from elastomer and faces the pressurized fluid that is being retained. The opposite end of the seal, which is reinforced with a high-performance plastic, incorporates hydrodynamic waves (Figure 4) that are exposed to a lubricant, such as the unpressurized bearing lubricant of a machine assembly. Differential pressure acting across the seal forces the hydrodynamic waves into contact with the shaft. When the shaft rotates, the waves pump a thin film of lubricant into the dynamic sealing interface between the seal and the shaft, reducing friction and wear.

When practicable, we recommend using a pair of KLS seals, with the pressure of the lubricant between the seals balanced to the pressure of the fluid being sealed. With this implementation, the inboard KLS seal contains the differential pressure and its lubricant pumping action lubricates and flushes the outboard seal.

Figure 4
Category 2: KLS-brand rotary shaft seals

Category 2 Kalsi Seals are spring-loaded high-pressure lip seals that incorporate hydrodynamic waves which face an unpressurized lubricant, such as the bearing lubricant of an oilfield RCD. Differential pressure causes these waves to engage the shaft. During rotation, they pump a thin film of the lubricant into the dynamic interface between the seal and the shaft. This film of lubricant reduces friction, wear, and seal-generated heat, which facilitates successful high-pressure operation.

4. Category 3: High pressure washpipe packing

Kalsi-brand high pressure washpipe packing (Handbook Chapter C15) was developed for 5,000 psi operation in the washpipe assemblies used on oilfield top drives and power swivels. It is interchangeable with conventional washpipe packing and uses the same fabric reinforced elastomer construction. As with conventional packing, Kalsi packing is clamped between and supported by a stack of form-fitting metal spacer rings. Unlike conventional packing, unidirectional hydrodynamic waves (Figure 5) are incorporated along the low-pressure edge of the dynamic sealing lip. The conventional re-greasing operation provides these waves with lubricant. During rotation, these unique waves facilitate lubrication of the most heavily stressed portion of the packing ring, which reduces friction, wear, and packing temperature. In order to promote maximum packing performance, we provide hardware-related engineering guidance to organizations that purchase our packing. The unique wave form is also adaptable to other types of fabric-reinforced packing rings; call for information.

Figure 5
Category 3: High pressure washpipe packing

Category 3 Kalsi Seals are high pressure washpipe packing rings with fabric-reinforced construction. They feature hydrodynamic waves that sweep grease into the most highly stressed portion of the dynamic sealing interface during rotation. As a result of this interfacial lubrication, Kalsi packing runs noticeably cooler than conventional washpipe packing, with less wear in higher pressure, higher speed operation.

5. Category 4: BDRP-type rotary shaft seals

BDRP-type rotary shaft seals (Handbook Chapter C7) are direct compression-type seals with an elastomer body and a dynamic sealing lip that incorporates an integral extrusion resistant plastic liner. The liner features aggressive hydrodynamic waves which cause the liner to hydroplane on a thin lubricant film. Unlike KLS seals, these waves engage the shaft regardless of whether differential pressure is present and provide hydrodynamic interfacial lubrication in either direction of rotation. Unlike other categories of Kalsi-brand rotary shaft seals, BDRP seals are designed for differential pressure acting in either axial direction, which allows any two adjacent BDRP seals to define a hydraulic swivel pressure circuit, regardless of which axial direction the waves are facing. In one direction of differential pressure, a BRDP seal has the same extreme pressure capacity as a plastic lined Kalsi Seal. In the opposite direction, the pressure capacity is roughly the same as a KLS-brand rotary shaft seal. Since the plastic liner is integrally molded to the elastomer body, BDRP seals do not experience the damaging elastomer-to-plastic slippage that occurs with conventional cap seal-type hydraulic seals.

The ability to contain a pressurized fluid when used with an unpressurized seal lubricant makes this unique seal design a candidate for service as RCD seals in RCDs that have unpressurized bearing lubricant. Although BDRP seals have relatively high

hydrodynamic pumping related lubricant leakage with typical higher viscosity RCD bearing lubricants in low differential pressure operating conditions, the leakage can be captured and returned to the bearing chamber with the valve and dual seal arrangement described in U. S. Patent Application Publication No. US 2019/0112890. In such an arrangement the net leakage from the bearing chamber could be essentially zero, depending on the hydrodynamic pumping characteristics of the outboard rotary shaft seal.

Figure 6

Category 4: BDRP-type rotary shaft seals

Category 4 Kalsi Seals are plastic lined rotary shaft seals that are designed to produce effective levels of hydrodynamic interfacial lubrication in either direction of pressure or rotation. BDRP seals were originally designed for service as hydraulic swivel seals in multi-channel swivels, and as RCD seals in RCDs with pressurized or unpressurized bearing lubricant. When used to retain pressurized fluids that contain abrasives, the BDRP should be protected by an outboard rotary shaft seal, and the region between the seals should be pressure balanced to the pressurized fluid. For an example of such a dual seal arrangement, see U. S. Patent Application Publication No. US 2019/0112890.