

Chapter C17

KLS high pressure lip seals



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1. What is a KLS lip seal?

KLS[®] spring-loaded lip seals (Figure 1) are polymeric seals for high pressure applications having unidirectional rotation. They have a composite body construction consisting of an elastomer core that is reinforced by an integrally molded extrusion resistant plastic liner. The flexible dynamic lip is loaded against the shaft by a V-spring. KLS lip seals were initially developed for use in lower cost oilfield rotating control devices (RCDs) that do not pressurize the bearing lubricant. We believe they are the best lip seals ever designed for such service.

Like other Kalsi-brand rotary shaft seals, the KLS lip seal incorporates hydrodynamic waves that pump a thin film of lubricant into the dynamic sealing interface during rotation, producing beneficial hydroplaning activity that reduces friction and wear.

Unlike most other Kalsi Seals[®], the hydrodynamic waves are located near the low-pressure end of the seal (Figure 2), and pump lubricant toward the high-pressure end of the seal. This unique configuration means that this high-pressure seal design can be fed by a simple low-pressure lubricant supply, such as the lubricant column that is present in the bearing region of an oilfield RCD. If desired, the low-pressure lubricant can be circulated with a low-pressure pump for seal and bearing cooling purposes.

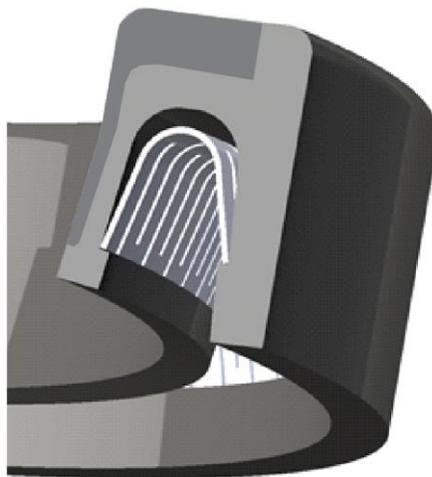


Figure 1
KLS high pressure lip seals

The KLS is a spring-loaded hydrodynamic lip seal for applications with unidirectional rotation and differential pressure acting from the spring side. No lubricant overpressure is required; the seals can be used with a simple gravity fed lubricant reservoir. These high-performance seals were originally designed as oilfield rotating control device seals.

For available seal sizes, visit kalsiseals.com.



Figure 2

The waves of the KLS Seal are located near the low-pressure end

This photograph shows the inside surfaces of a 9.75" (247.5mm) KLS lip seal that is designed for clockwise mandrel rotation. This photo was taken with the spring facing down, showing the seal as it would be oriented in an oilfield RCD. As can be seen here, the free end of the dynamic lip is formed from elastomer, and most of the inner surface of the seal is formed from a high-performance plastic. The upper end of the plastic portion of the seal forms uniquely-shaped hydrodynamic waves that engage the mandrel and force a lubricant film into the sealing interface when differential pressure and rotation are present.

2. High pressure rotary lip seal test results

3.375" (85.73mm) KLS lip seals were tested at 1,000 psi (6.89 MPa) with a surface speed of 543 feet per minute (2.76 m/s), using an ISO 150 viscosity grade lubricant.¹ The speed is equivalent to a 10.375" (263.53 mm) RCD mandrel rotating at 200 rpm. Tests in excess of 200 hours were performed, and the KLS Seals were still in good condition. Test durations were based on those specified in API 16RCD, "**Specification for Rotating Control Devices**". Similar lip seals without the hydrodynamic waves failed in only a few hours at the same surface speed, with only 500 psi (3.45 MPa) differential pressure.

A 10.500" (266.70mm) KLS lip seal was tested at 1,500 psi (10.34 MPa) with a rotary speed of 50 rpm using an ISO 320 viscosity grade lubricant a radial extrusion gap clearance of 0.015" (0.38mm). The seal was in excellent condition at the conclusion of over 200 hours of operation (Figure 3). The hydrodynamic pumping related leak rate was 0.52 ml/hr.

We have also tested 3.375" (85.73mm) KLS lip seals at 1,500 psi (10.34 MPa) with a surface speed of 137 feet per minute (0.7 m/s), using an ISO 460 viscosity grade lubricant maintained at about 150 to 160°F (65.6 to 71.1°C). The rotary speed is equivalent to a 10.375" (263.53 mm) RCD mandrel rotating at 50 rpm. The seals were in good condition at the conclusion of 100 and 200-hour tests. Tests of 3.375" (85.73mm) seals were also performed at pressures that were incrementally increased from 100 psi to 1,000 psi.

¹ In our experience, KLS lip seals perform better with oil-type lubricants than with grease. Our grease testing was limited to Valvoline-brand multi-service grease.

The high-pressure performance of the KLS Seal is remarkable for a spring-loaded lip seal. This dramatically enhanced performance is the result of the hydrodynamic interfacial lubrication that is provided by the patented wave geometry. As rotation occurs, this geometry wedges a film of lubricant between the shaft and the plastic dynamic surfaces that reduces friction, wear, and associated seal-generated heat. The reduced operating temperature reduces temperature-related modulus loss, which enhances the extrusion resistance of the seal.



Figure 3

A 10.500” KLS lip seal after 200 hours of 1,500 psi operation at 50 rpm

The objective of the 1,500-psi test was to establish whether a 10.500” KLS lip seal could reach the 200-hour testing goal established by API 16RCD, “**Specification for Rotating Control Devices**” when operating at 50 rpm with an ISO 320 viscosity grade lubricant and a radial extrusion gap clearance of 0.015”. We stopped the test at 214.3 hours to examine the condition of the used seal. The condition was excellent, as shown in this photo.

3. Hardware design guide for KLS lip seals

Design for pressure retaining service with non-abrasive fluids

When KLS lip seals are used to retain a pressurized non-abrasive fluid, only one seal is required, and the seal lubricant can be supplied from a simple unpressurized gravity fed lubricator.² For example, if the seal is located below the bearings, the seal can simply utilize the bearing lubricant to lubricate the dynamic sealing interface. The need for the pressure of the seal lubricant to be greater than or equal to the pressure of the environment (i.e., lubricant overpressure) is eliminated.

Design for pressure retaining service with abrasive fluids

Our testing of KLS and similar rotary lip seal designs indicates that the ability to exclude an abrasive drilling fluid is good in zero differential pressure conditions, and inconsistent when the pressure of the abrasive fluid is greater than the pressure of the seal lubricant.

² If a gravity fed lubricator is remotely mounted, any connecting piping must be free of restrictions that can prevent gravity-induced flow of the viscous lubricant. In our seal test lab, we encountered a problem when a small but open valve added enough restriction to a small diameter lubricant supply line that gravity-induced lubricant flow was interrupted.

When KLS lip seals are used in abrasive service, they should be used in pairs, with the region between them filled with lubricant. When practicable, this barrier lubricant should be pressure-balanced to the pressure of the abrasive fluid. In this arrangement, the outboard seal excludes the abrasive fluid and is exposed to substantially zero differential pressure, and the inboard seal retains the pressure of the barrier lubricant and is isolated from abrasives. The pressure-balancing can be accomplished with small pistons.

Figure 4 is a schematic illustration of a pair of KLS lip seals mounted for abrasive service. The shaft and seal housing are located radially with respect to one another by bearings mounted in a bore of the seal housing, and the KLS Seals are performing a bearing seal function in addition to a pressure seal function. The barrier lubricant between the KLS Seals is balanced to the process fluid by a piston, which exposes the inboard seal to the pressure difference between the process fluid and the unpressurized bearing lubricant. Because the inboard seal is protected from the abrasive process fluid, it only has to serve as a high-pressure oil seal. The hydrodynamic pumping action of the inboard seal causes the piston to eventually bottom out on the captured transverse pin. Once the piston bottoms out, the hydrodynamic pumping action increases the pressure of the barrier lubricant to the degree necessary to allow the pumped lubricant to vent past the outboard seal. If either seal fails, the surviving seal takes over both the pressure retention and abrasive exclusion functions. The outboard seal should also be a KLS lip seal, so that it can operate hydrodynamically if it is exposed to high differential pressure due to failure of the inboard seal.

In Figure 4, the outermost gland wall is reduced in radial depth. This prevents the dynamic lip of the outboard KLS Seal from sealing off against the outboard wall and preventing the necessary venting action. It also eases installation of the outboard seal, reducing the risk of installation damage. Assembly testing has shown that the one-piece housing design shown in Figure 4 permits installation of 9.75” and larger KLS lip seals. Due to stiffness of the seal material, seals smaller than 9.75” may require that the gland walls between the inboard and outboard seals be removable to permit installation of the inboard seal. In some cases, removable gland walls may be desirable even though the inboard seal may be installable without one. Contact Kalsi Engineering for additional information.

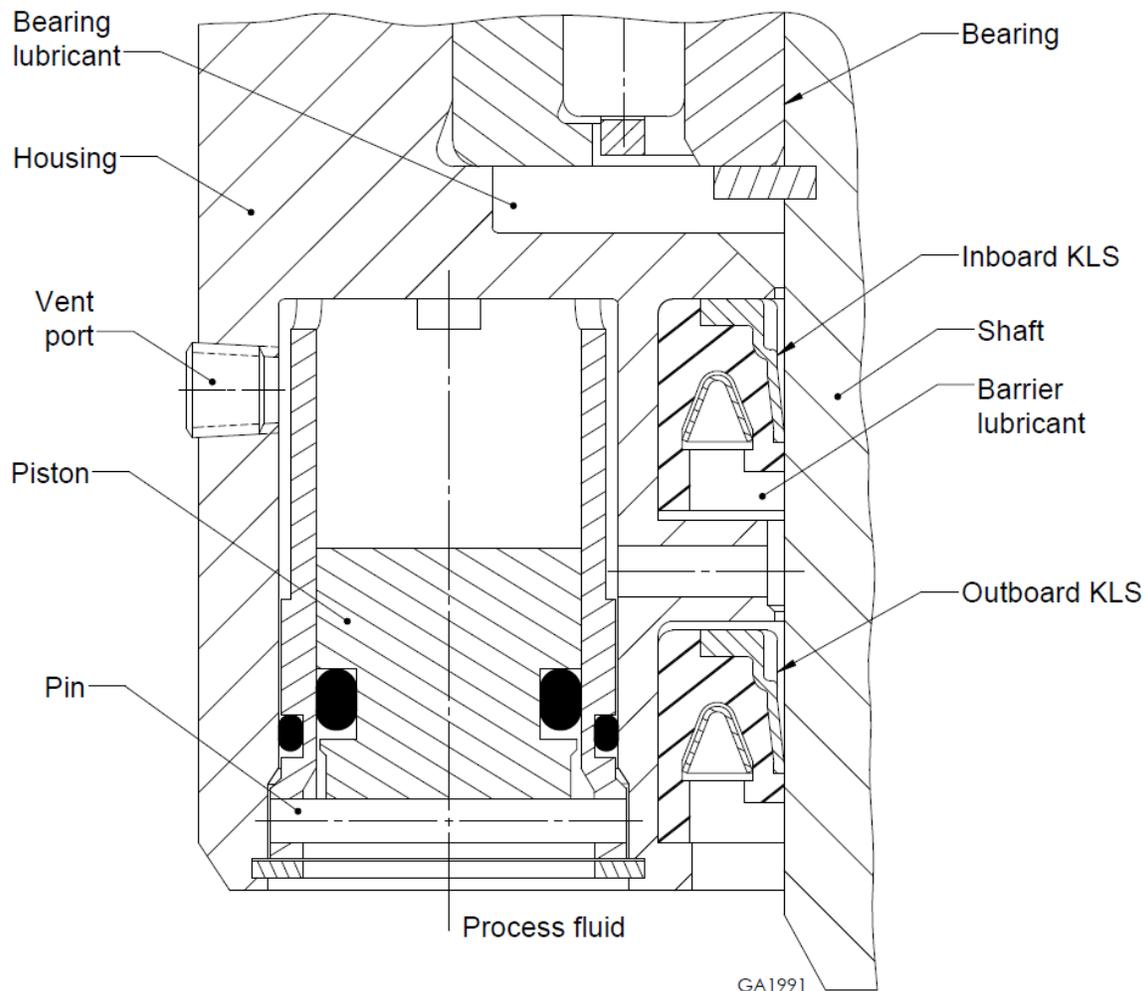


Figure 4

A hardware design for using KLS lip seals in abrasive service

In this arrangement, the pressure of the barrier lubricant is substantially balanced to the pressure of the high-pressure process fluid, so the inboard seal is exposed to high differential pressure in a clean environment, and so the outboard seal is exposed to very little differential pressure. This is the preferred way to use KLS lip seals in abrasive service. The gland wall of the outboard seal has only enough radial depth to hold the seal in place axially. This partial gland wall ensures that the hydrodynamic pumping related leakage of the inboard KLS Seal can vent past the outboard KLS Seal. It also helps to prevent damage to the outboard KLS Seal during installation. When small diameter KLS Seals are used, the gland walls between the KLS Seals may need to be removable to prevent damage to the inboard KLS Seal during installation.

Barrier lubricant fill methodology to eliminate air

When designing the seal housing, the method of filling the barrier lubricant must be taken into consideration. The fill method should provide a reliable method for allowing air to escape as the barrier lubricant is introduced. The piston cannot balance the pressure of the barrier lubricant to the pressure of the process fluid if the air volume in the barrier

lubricant region exceeds the displacement volume (bore area times stroke length) of the piston. One workable solution is to start with the piston fully stroked to the empty position, with the axis of the shaft horizontal, the fill port facing down, and the piston and associated vent port facing up. As the oil enters from the underside, the air escapes out the vent port. Plug the vent port after lubricant rises to the vent port, then pump the piston to the full position. The pressure of the barrier lubricant will rise when the piston reaches the full position, serving as a signal that filling is complete.

4. Understanding sealing directionality

KLS lip seals retain differential pressure acting from the spring side of the seal. Differential pressure acting in this direction forces the waves into contact with the shaft, which initiates the hydrodynamic pumping action if relative rotation is present.

In the opposite pressure direction, sufficient differential pressure will overcome the spring force that holds the dynamic lip against the shaft and cause the seal to vent. In a bench test with a submerged 3.375" diameter KLS Seal using pressurized air, we saw bubbles begin to vent past the dynamic lip at about 50 psi. The differential pressure required to initiate venting can vary depending on factors such as lubricant viscosity, seal diameter, cross-sectional size, seal temperature, seal damage, and gland dimensions.

If a pump is used to fill the barrier lubricant in the Figure 4 arrangement, the pressure can inadvertently be pumped up to a relatively high pressure, because one can pump lubricant in much faster than it can vent out past the dynamic lip of the outboard seal. This pressure will bleed down to the venting pressure over time.

5. Abrasive testing with little or no differential pressure

The recommendation to use KLS lip seals in pairs when sealing abrasive fluids is based on testing with water-based drilling fluid that is produced to our specifications. The testing was performed with 3.375" (85.73 mm) seals at 615 rpm. This produced a surface speed of 543 feet per minute (2.76 m/s), which corresponds to a 10.375" mandrel turning at 200 rpm. In the first three tests described below, the bulk lubricant temperature was controlled to approximately 162°F (72.2°C). In all four tests, the seal lubricant was an ISO 150 viscosity grade lubricant.

Two tests with zero pressure differential were performed with PN 668-4 KLS Seals. One test had 0.010" (0.25 mm) intentional runout, and the other had very little runout. These tests were shut down at 265 hours, to permit seal inspection. The test seals were in very good condition.

For available seal sizes, visit kalsiseals.com.

Two additional tests were performed with PTFE lip seals that have the same basic geometry as KLS lip seals, but do not have the hydrodynamic waves that allow the KLS Seals to operate as high-pressure shaft seals. The first of these tests, which had 0.010” runout and zero pressure differential, was shut down at 145 hours to inspect the seals, which were in good condition.

The second of these tests, which had no intentional runout, 5 psi pressure differential, and a bulk lubricant temperature of 197°F (91.66°C), was shut down at 201 hours to inspect the seals, which were in good condition.

6. Lip seal handling tips

Individuals who handle KLS lip seals should be trained not to manually squeeze the lips. With any kind of rotary lip seal that has a V-spring, there is a risk of yielding the spring if the lips are manually squeezed. A locally yielded spring can have a significant negative influence on seal performance.

When installing KLS Seals, take care not to overstress and kink the plastic liner.

7. Breakout torque of KLS lip seals

Although specific breakout torque data is currently unavailable for KLS lip seals, the breakout torque will be similar to other plastic-lined rotary lip seal designs in zero differential pressure conditions. The breakout torque will be far less than that of an all-elastomer Kalsi Seal™ because of the low friction characteristics of the dynamic lip material, and because of the reduced lip load associated with spring loading. This reduced breakout torque may be beneficial in oilfield RCD sealing applications.

8. Available sizes of KLS-brand rotary lip seals

A table of available KLS sizes and gland dimensions is available on the [shaft seal catalog](#) portion of our website. Additional sizes can be provided, subject to a one-time tooling charge to help to defray associated engineering, machining, and set-up expenses.

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