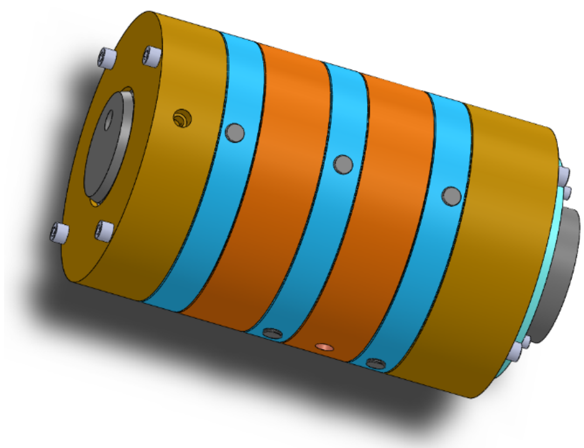
Chapter E2

Using Kalsi Seals in hydraulic swivels



Revision 7 October 16, 2020

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1. Introduction

What is a hydraulic swivel?

Hydraulic swivels communicate hydraulic fluid and pressure between a shaft and a housing that have relative rotation with respect to each another. Side port hydraulic swivels[1] orient the housing ports radially to provide radial communication between the housing and shaft, and often define multiple hydraulic circuits. Coaxial swivels communicate axially between housing and shaft bores and define a single hydraulic circuit.

What are Kalsi Seals®?

Rotary seals are a critical component of hydraulic swivels, because they define the hydraulic circuits. Kalsi-brand hydraulic swivel seals are radially compressed polymeric seals that incorporate hydrodynamic waves on the dynamic sealing lip (Figure 1). During rotation, these waves pump a thin film of hydraulic fluid into the sealing interface between the seal and the shaft. This reduces friction, heat, and wear and allows the seals to operate with higher speeds and pressures than conventional swivel seals.

Figure 1

Kalsi Seals for hydraulic swivels

Kalsi Seals incorporate hydrodynamic waves that pump a film of hydraulic fluid into the dynamic sealing interface during rotation. This interfacial lubrication reduces friction, heat, and wear. Kalsi Seals are designed for one direction of differential pressure, so two seals are used to define each hydraulic circuit.

A pair of Kalsi Seals are typically used to define each hydraulic circuit.

Kalsi-brand swivel seals are designed to withstand high differential pressure in only one axial direction. The dynamic lip is fully supported in that pressure direction, to minimize pressure-related seal distortion and maximize pressure capacity. High pressure acting in the opposite direction distorts the dynamic lip in ways that impact lubrication of the dynamic sealing interface. While this type of seal can handle extremely high differential pressure, a pair of seals are normally required to define each hydraulic circuit. For example, four seals are normally required to define two adjacent hydraulic circuits.

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1 Side port swivels are also known as side entry swivels and rotating manifolds.

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Seal material options and hardware design implications

Kalsi-brand swivel seals are available with all elastomeric construction and with plastic-elastomer composite construction. Seals that incorporate a plastic layer at the dynamic surface have considerably greater pressure capacity than seals constructed entirely of elastomer and are much less likely to experience damaging circumferential slippage within the seal groove. Because of the stiffness of the plastic layer, some sizes[2] of plastic lined seals™ require a removable groove wall to permit assembly into the seal housing, as shown in the schematic of Figure 2. With smaller diameter plastic lined seals, an installation chamfer is typically required at the open end of the groove bore to ease the seal into the groove bore (Figure 2).

Many all-elastomeric Kalsi Seals can be installed into one-piece seal grooves, which means that multiple seal grooves can be incorporated into the same housing. Installability into a one-piece groove depends on diameter, radial cross-sectional depth, and axial cross-sectional width. Smaller diameters and larger axial and radial cross-sections make installation into a one-piece groove more difficult. The difficulty of installation and extraction also increases significantly with the axial distance between the groove and the end of the housing.

For additional information about our high pressure swivel seals, see the "Catalog & Technical Data" section of this handbook, or contact us directly.

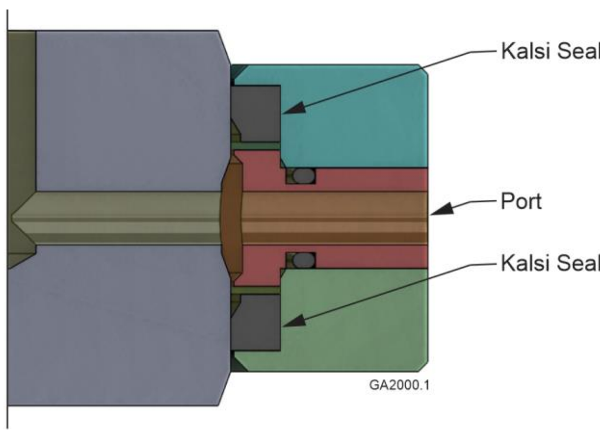

Figure 2

Removable gland walls are required for Kalsi Seals with plastic liners

Some sizes of Kalsi-brand swivel seals that incorporate plastic liners require a removable groove wall to permit the seal to be installed in the housing groove without damage. For smaller diameter seals with plastic liners, the end of the groove bore requires an installation chamfer to ease the seal into the housing groove. This schematic representation of a single port hydraulic swivel shows one way to incorporate removable gland walls. The bearings that are required to locate the components relative to each other are not shown in this schematic.

[2] We were able to Install 9.75" and larger plastic lined seals with -303 construction into one-piece grooves.

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2. Bearing guidance

Hydraulic swivels are used in various ways. Selecting and implementing an appropriate bearing arrangement to accommodate the various design forces is the Design Engineer's responsibility. Some of these potential forces relate to:

- Weight of the swivel components that are supported by the bearings[3]
- Weight of associated fluid filled hoses, pipe, tubing, and fittings
- Reaction of bearing and seal torque to prevent rotation of the housing or shaft
- Hydraulic pressure imbalance
- Stiffness of high pressure hoses
- Hydraulic pressure within hoses
- Mechanical misalignment of mating machine components
- Weight of mating equipment borne by the swivel bearings
- The method of causing swivel rotation
- Differential thermal expansion between the shaft and the housing.
- Forcing misaligned metal tubing into alignment with ports

Bearing mounting practices

Bearing manufacturers provide literature that details bearing mounting practices. One critical swivel design mistake is wide separation between opposed thrust-capable bearings. The seal generated heat goes into the shaft, causing the shaft to thermally expand more than the housing. If a wide separation exists between the thrust bearings, and there is little to no bearing end play, then the axial differential thermal expansion can impose enormous axial forces that quickly ruin the bearings. In the swivel concept shown in Figure 3, the thrust-capable angular contact bearings at the lower end of the housing are close together, making them insensitive to longitudinal differential thermal expansion between the shaft and housing. The radial bearing at the upper end of the shaft has a slip fit with the bore of the housing in accordance with normal bearing mounting practices, allowing the outer race to slide axially to accommodate shaft thermal expansion. This feature makes the bearings immune to longitudinal differential thermal expansion between the shaft and housing.

3 Typically, the manifold housing will be mounted to a structure and support the shaft through the bearings, or the shaft will be mounted to a structure and support the manifold housing through the bearings.

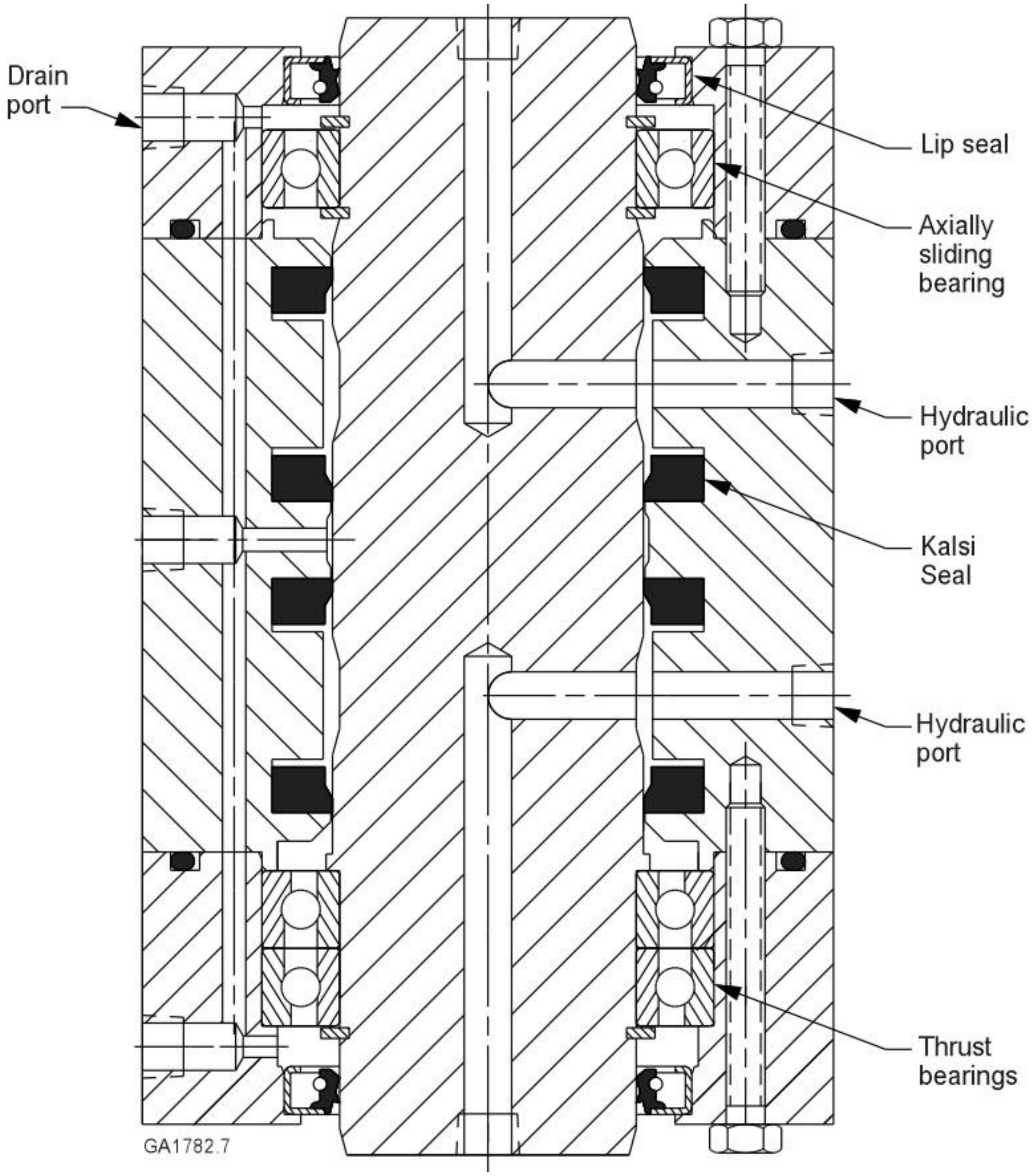

Figure 3

Bearing concept for a multi-port hydraulic swivel with a rotating shaft

In this multi-port hydraulic rotary swivel concept, the thrust-capable lower bearings are close together so axial differential thermal expansion between the shaft and the housing cannot bind the bearings. Because the shaft rotates relative to the load, the bearings are a press fit to the shaft and a slip fit with the housing. The radial holes in the shaft are recessed to prevent seal damage during assembly of the swivel. The drain prevents pressure buildup between pairs of rotary seals.

In bearings that have inner and outer races, it is common practice to mount one race with an interference fit, and the other with a clearance fit. Which race is press fitted depends on which race has relative rotation with respect to the bearing-supported load. Failure to have an interference fit on the race that needs it typically causes slippage of the race and wear of the mating component. Follow the bearing manufacturer's mounting guidelines.

Other attributes of Figure 3

Figure 3 also shows a cross-drilled drain arrangement, in which a single drain accommodates the hydrodynamic pumping related leakage from all the Kalsi Seals, and then returns it to the hydraulic fluid reservoir. The drain port is located at the top of the swivel so that the upper bearing and bearing seal are exposed to and lubricated by the column of hydraulic fluid that is retained within the swivel by gravity. Select bearing seals with enough pressure capacity to handle the pressure head of the hydraulic fluid.

3. Housing-to-shaft clearance

The radial extrusion gap clearance between the swivel housing and shaft at the rotary seal has a significant influence on high pressure seal performance. For maximum performance, use the smallest extrusion gap that can be obtained without risk of heavily loaded housing-to-shaft contact. If heavily loaded housing to shaft contact occurs, then the resulting friction can severely damage the seals, shaft and housing. For extreme pressures, consider using the hydraulic rotary swivel design described in Section 4.

Proper design of the extrusion gap clearance requires a review of tolerances, bearing fit, bearing internal clearance, pressure-induced shaft and housing deformation, and the potential for differential thermal expansion between the shaft and housing.

4. A modular hydraulic swivel design for extreme pressure sealing

When hydraulic rotary swivels that provide the longest service life at the highest service pressures are required, Kalsi Engineering recommends the modular swivel design shown by Figures 4 and 5. Although only one hydraulic circuit is shown, the basic design can be expanded to include more.

One key to the pressure capacity of this type of swivel is the hydrodynamically lubricated Kalsi-brand swivel seals. Another key is our patented floating metal backup rings, which align on the shaft while providing the minimum practicable extrusion gap clearance, as described in more detail below.

The modular high pressure swivel consists of a stack of relatively simple housings that are bolted together. The floating metal backup rings are located by bulkhead housings. The shaft is guided by rolling element bearings that are mounted in bearing housings bolted to the outboard ends of the bulkhead housings.[4] The radial bearing slides in its mating housing bore to accommodate shaft thermal expansion.[5] The housings are located radially by pilots that are impossible to bind due to their short length. Pins ensure correct angular alignment between housings. The bearing lubricant is retained by seals mounted in the bearing housings. A drain port returns the hydrodynamic pumping related leakage of the Kalsi Seals to the hydraulic fluid reservoir, preventing pressure buildup in the bearing lubricant.

The modular swivel design is robust, economical to manufacture, and easy to assemble and disassemble. Unlike typical high pressure hydraulic swivel designs, there is no long housing, with precision diameters along the entire length and difficult-to-access seal grooves. There are also no difficult-to-assemble radial static seals.

Floating backup rings provide the minimum possible extrusion gap clearance

The floating backup rings are radially pressure balanced, axially force balanced, and guided radially by a journal bearing-type fit with the shaft. Anti-rotation pins prevent the backup rings from rotating with the shaft. This mechanical arrangement provides the best high pressure sealing performance of any we have tried.

The radial pressure balance minimizes pressure-related dimensional changes at the extrusion gap clearance between the backup rings and the shaft. This allows the minimum

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4 One advantage of having the bearing housings separate from the pressure housing assembly is that the bearing housings do not expand as a result of hydraulic pressure, preserving the fit between the bearing housings and the bearings. This helps to minimize shaft runout.

5 In the illustrated assembly, the bearings are a press fit with the shaft and a slip fit with the bearing housings. The actual location of the press fit depends on whether the load rotates relative to the housing assembly, or relative to the shaft. Follow the bearing manufacturer’s recommended fitting practices and design the assembly accordingly.

possible clearance to be maintained, thereby achieving maximum seal extrusion resistance. The radial pressure balance is accomplished by radial passages through the backup rings.

The axial force balance allows the backup rings to move laterally to accommodate shaft runout and misalignment while avoiding heavily loaded metal-to-metal contact at the extrusion gap, and the seal-damaging heat such contact would produce. The axial force balance is created by equally sized sealed areas on both ends of each backup ring. Axial holes through the backup rings communicate hydraulic pressure between the sealed areas.

Licensing information

Kalsi Engineering prefers to license the patented features of the modular hydraulic swivel design with a simple unilateral license that grants permission to a specific manufacturer to manufacture, use, and sell the design, provided that it is used with rotary seals that are purchased from Kalsi Engineering. When this type of license arrangement is used, the licensing fee can be included in the price of the seals, or as a per-seal or per-swivel licensing line item. It can also be handled by a part number representing a combination that includes the seal and the hardware technology license.

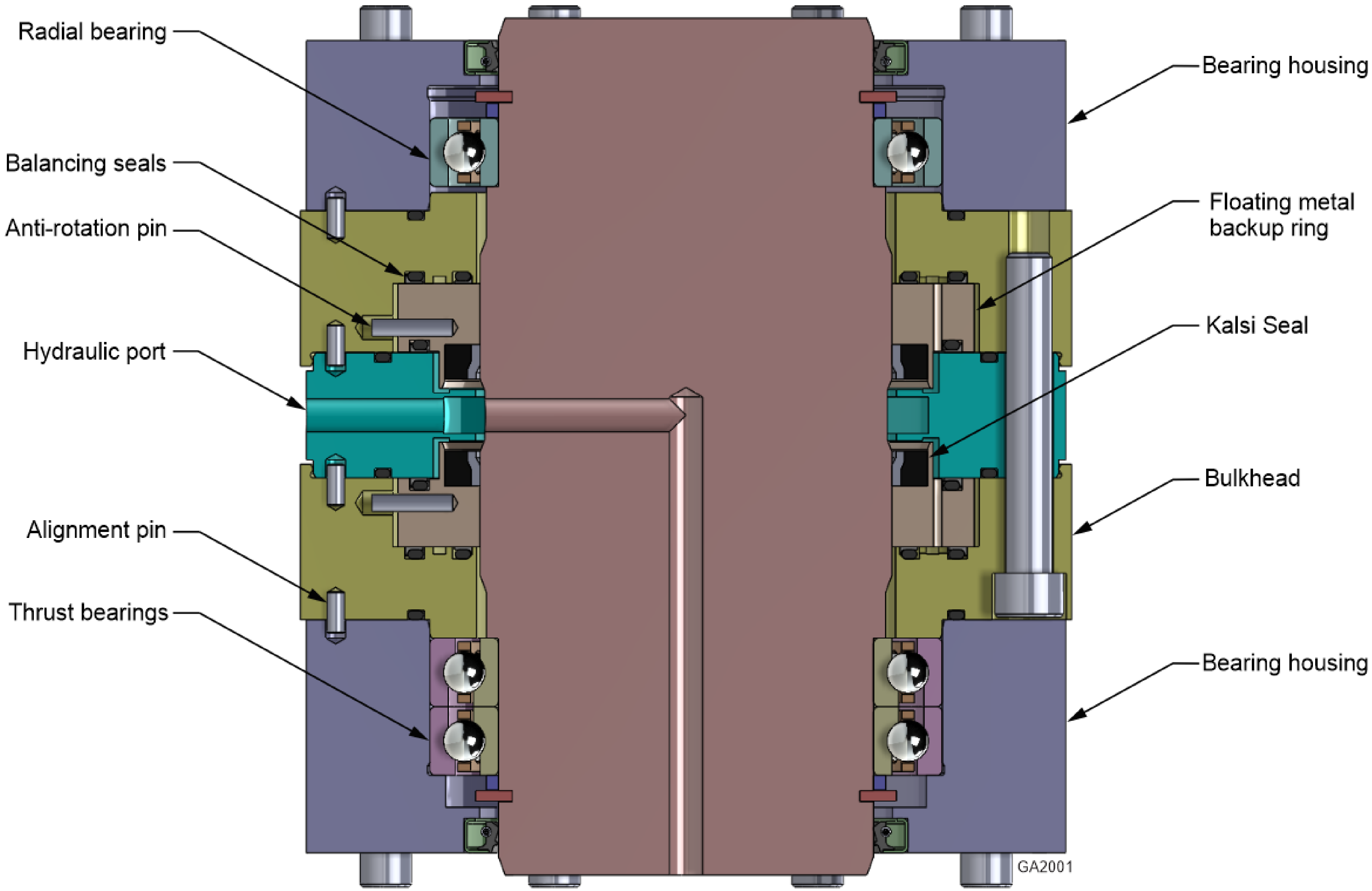

Figure 4

Cross-section through the hydraulic port of a modular high pressure hydraulic swivel

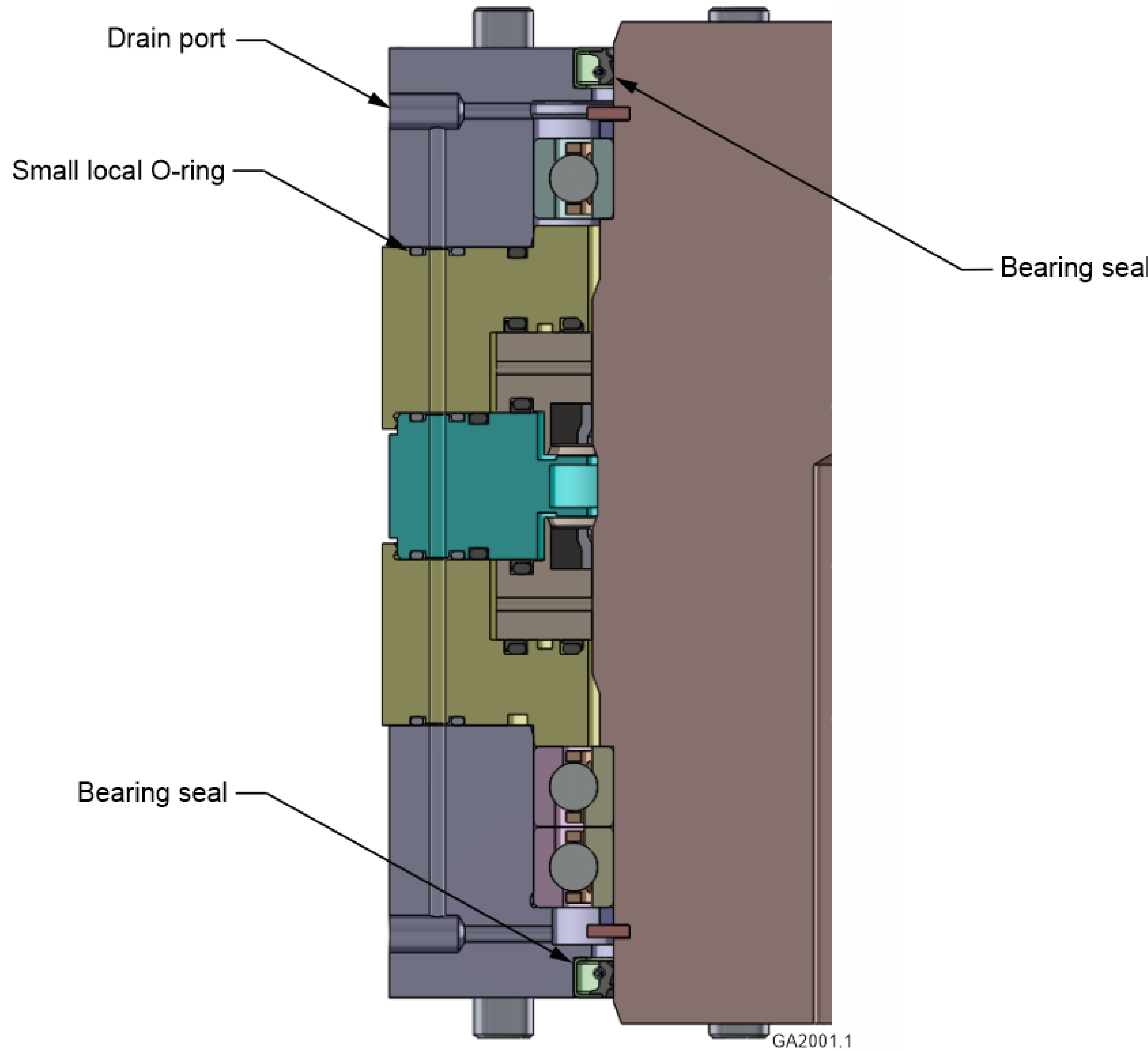

Figure 5

Cross-section through the drain porting of a modular high pressure hydraulic swivel

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5. Cooling hydraulic swivel seals

Depending on rotary speed and duration, shaft diameter, differential pressure, seal type, and quantity of hydraulic circuits in a hydraulic swivel design, coolant circulation may be necessary for optimal rotary seal life. Cooling the swivel prevents seal overheating, providing a temperature condition that is desirable from both a seal lubrication standpoint and a seal high-pressure extrusion resistance standpoint. The need for cooling increases as the speed and duration of rotation increases.

Figure 6 is a schematic representation of a hydraulic rotary swivel that shows a convenient way to use circulating hydraulic fluid as the coolant. Low-pressure hydraulic fluid flows in at the coolant inlet, and reaches the shaft bore via cross-drilled holes. A sleeve guides the flow along the length of the shaft. Seal-generated heat transfers from the shaft to the flowing fluid. Cross-drilled holes guide the flow to a coolant drain that returns the hydraulic fluid to the reservoir.

Figure 6 assumes a rotating shaft and a non-rotating housing. In a hydraulic swivel with a non-rotating shaft and a rotating housing, the inlet and outlet for the circulating coolant can plumb directly into the shaft. The rotary seals that define the coolant circuit must have enough pressure capacity to withstand the coolant circulation pressure. Although Figure 6 shows the coolant sleeve being used with a hydraulic swivel, coolant sleeves can apply in other types of swivels, such as side port process fluid swivels.

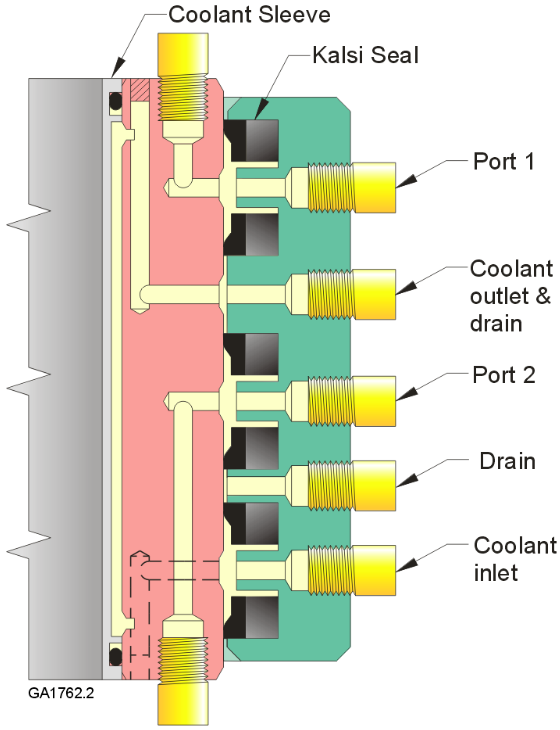

Figure 6

Schematic illustrating a hydraulic swivel with circulating under-sleeve coolant

Coolant circulation allows higher speed operation and promotes better seal lubrication and extrusion resistance. This schematic representation of a hydraulic rotary swivel shows the use of a sleeve to form an internal cooling jacket that accommodates coolant circulation. The required bearings are not shown. This schematic assumes a rotating shaft and a non-rotating housing. In swivels that have a non-rotating shaft and a rotating housing, the coolant inlet and outlet would connect to the shaft, and no rotary seals are needed to define the coolant circuit.