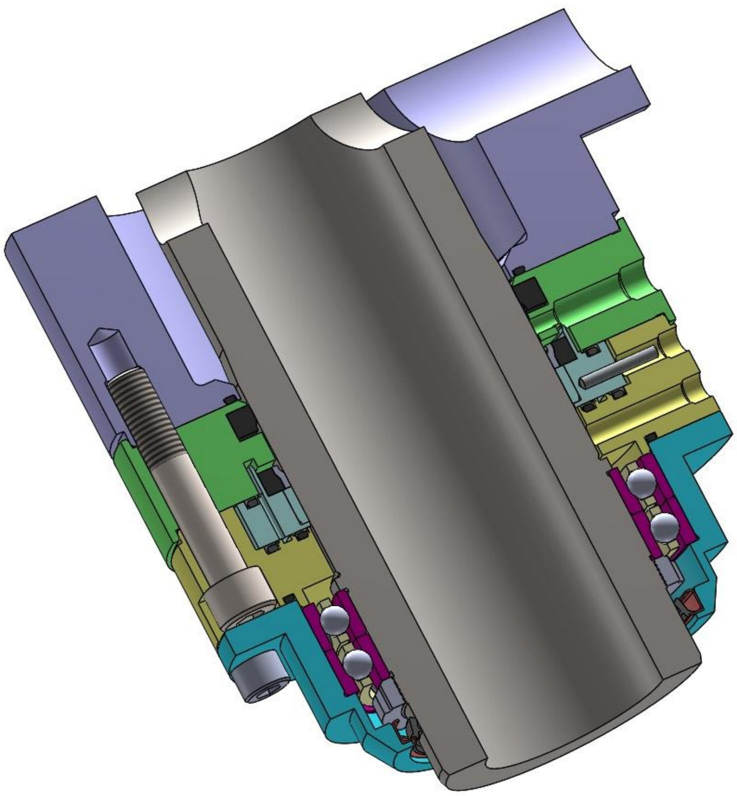
Chapter E5

Using Kalsi Seals in extreme pressure side port swivels



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1. Introduction

This chapter describes using Kalsi-brand rotary shaft seals and floating metal backup rings to achieve extreme pressure operation in high pressure side port swivels.[1] In a 4.500" size, this seal and backup ring combination has achieved 10,000 psi operation at 120 to 175 rpm for hundreds of hours. In a similar arrangement, 2.750" seals achieved 7,500 psi operation at 350 rpm for 1,000 hours. See Chapter D17 for high pressure seal testing results. Contact our staff for sales and technical support and backup ring licensing information.

2. Overview of the high pressure side port swivel

Figure 1 is a section view of a high pressure side port swivel. Only half of the swivel is shown, to allow the image to be larger.

The housing assembly consists of housing components that are retained by axially oriented bolts. The components include a radially ported central housing, partitioning seal and bulkhead housings bolted to the central housing, and bearing housings bolted to the bulkhead housings. The bolts retaining the partitioning seal housings and bulkhead housings engage tapped holes in the radially ported central housing. The same bolts can be used to retain the bearing housings, or (as shown) separate bolts can engage tapped holes in the bulkhead housings. Floating metal backup rings within the bulkhead housings guide and locate the pressure retaining rotary shaft seals.

The housing assembly and the rotatable mandrel are located axially and radially with respect to one another by bearings. Lip-type rotary shaft seals located outboard of the bearings retain the bearing lubricant.

1 Side port swivels are also referred to as side entry swivels, side inlet swivels, or side feed swivels.

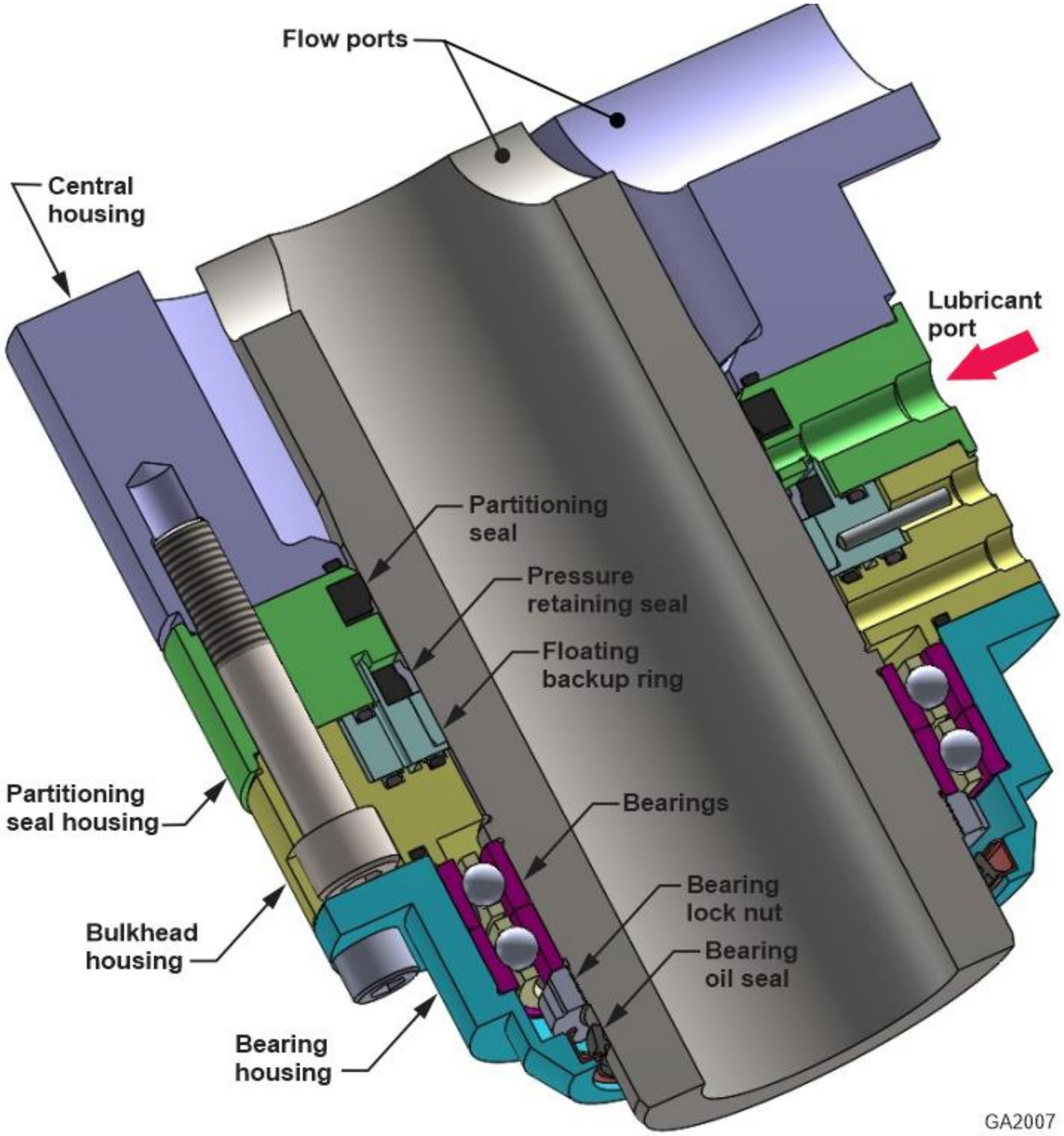

Figure 1

High pressure side port swivel

This shows half of a high pressure side port swivel. The partitioning seal separates the flowing fluid within the swivel from the pressurized seal lubricant, and the pressure retaining seal retains the pressurized lubricant. The housings are piloted to one another and retained by bolts. If desired, the partitioning seal housings can be integral with the central housing.

3. How the high pressure side port swivel operates

The general purpose and arrangement of a high pressure side port swivel

A side port swivel conducts a flowing high pressure fluid through the radial flow ports of the housing and mandrel, and through the bore of the mandrel. One common use of a high pressure side port swivel is for the cementing operation of an oil well.

In a high pressure cement swivel, the mandrel is supported and rotated by the rig, and the housing and associated cement supply line are supported by the bearings. In other high pressure swivel applications, the housing is supported by the structure of other associated machinery, and the rotating mandrel is supported by the swivel bearings.

Floating backup rings allow the minimum possible extrusion gap clearance

One key to the extreme pressure capacity of the side port swivel in Figure 1 is the use of our patented floating backup rings. They provide the smallest practicable extrusion gap clearance, which allows the pressure retaining seals to operate at their highest pressure potential. These backup rings, which are axially force balanced and radially pressure balanced, are guided radially by a journal bearing-type fit with the mandrel. The axial force balance allows the backup rings to move laterally with mandrel runout and misalignment, while avoiding heavily loaded metal-to-metal contact at the extrusion gap, and the seal-damaging heat that such contact produces. The radial pressure balance minimizes pressure-related distortion of the backup rings, and the extrusion gap clearances they define. Floating backup rings are described in more detail in chapter D17. Our experienced engineering staff is available to support the implementation of floating backup rings in your high pressure swivel design.

Kalsi brand rotary shaft seals

Another key to the extreme pressure capacity of the side port swivel in Figure 1 is the use of our patented super wide plastic lined rotary shaft seals as the pressure retaining seals. Because of their unique design and construction (Figure 2), these seals have the highest pressure capacity of any polymeric rotary shaft seal. Hydrodynamic waves cause the extrusion resistant plastic liner to hydroplane on a film of oil when the mandrel rotates. This reduces friction, wear, and seal generated heat, allowing the seal to operate in high differential pressure conditions for long periods of time.

In Figure 1, the partitioning seal is a Super Wide Kalsi Seal with all-elastomer construction. The interfacial lubrication provided by the patented hydrodynamic waves allows the dynamic sealing lip to be very wide, providing extra sacrificial material to accommodate third body wear.

Seal lubricant pressurization

In the high pressure swivel of Figure 1, the seal lubricant is pressurized to a value that is slightly greater than the pressure of the fluid being conducted through the swivel. In extreme pressure swivels, this is best accomplished with a pressure amplification-type lubricant reservoir, as described in chapter D11. If space permits, the reservoir can be mounted to the central housing at a radial port (not shown) located 180° from the radial flow port. Alternate methods of supplying pressurized seal lubricant are described in chapter D11.

Figure 2
Super Wide Plastic Lined Kalsi Seals

Kalsi-brand super wide rotary shaft seals feature a plastic liner and our enhanced lubrication waves. The plastic liner resists high pressure extrusion damage much better than elastomeric seal materials. During rotation of the swivel mandrel, the hydrodynamic waves pump a film of lubricant between the seal and the mandrel, causing the seal to hydroplane on the film. This reduces friction and associated seal-generated heat and reduces wear.

4. Mandrel design considerations for high pressure swivels

Mandrel diameters

The first step in mandrel design is selection of the bore diameter that is required to accommodate the desired volumetric flow rate of the conducted fluid. In cases where the conducted fluid is abrasive, the prudent designer will also consider the flow speed, and its effect on mandrel erosion. Erosion can be managed with a protective hard coating, and by utilizing a less erosive flow speed.

The second step in mandrel design is selecting the seal and bearing diameters. For optimum results, the wall thickness of the mandrel should be designed to minimize pressure-induced deflection at the seals and bearings, and to handle the mechanical loads the mandrel will experience. A complete understanding of the dimensional effect pressure has on mandrel diameter is necessary to design the backup rings. The designer also confirms that stress levels are at acceptable values for normal operating pressure and for proof testing. This evaluation is best accomplished with finite element analysis. The analysis must include the pressures acting along both the interior and the exterior of the mandrel.

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Seal running surface and installation path

The mandrel surfaces contacted by the rotary seals and the backup rings are protected by a ground and polished tungsten carbide surface, per the normal practices described in chapter D2. The installation path for the Kalsi Seals includes installation chamfers and a recess at the radial mandrel ports to avoid cutting the seals during installation, as described in chapter D3. These mandrel features are preferably protected from corrosion to avoid corrosion related seal damage, as described in chapter D3.

Thrust shoulder and bearing nut

The mandrel provides an integral thrust shoulder for the thrust bearing set, as shown, that is designed to convey thrust between the mandrel and the bearings. The thickness of the shoulder is designed to handle anticipated thrust at acceptable stress levels. The shoulder diameter is per the bearing manufacturer's recommendations, and ideally will be at a diameter that allows the bearings to be removed by using a disassembly sleeve that bears against the inner race of the bearing.

The bearing nut and threads are designed to handle the anticipated thrust at acceptable stress levels. The bearing nut is designed to include a locking method (not shown), to prevent loosening in service. In the case of relatively small diameter swivels, it may be possible to use a standard AFBMA nut and the associated AFBMA deforming tang-type lock washer. In other cases, it will be necessary to custom design the bearing nut and locking arrangement.

Avoid thermal binding of the bearings

Figure 1 only shows the end of the high pressure swivel that incorporates the thrust bearings. At the opposite end of the swivel, the bearing(s) must be free to slide axially, per normal bearing fitting practices. This is necessary to accommodate axial differential thermal expansion between the mandrel and the housing assembly. Do not incorporate bearing thrust shoulders at the opposite end of the swivel!

5. Central housing design considerations

The central housing is sized to accommodate the required radial port size, internal clearance over the mandrel ports, and bolt engagement length at acceptable stress levels for mechanical, operating pressure, and proof pressure loads.

6. Partitioning seal housing

The illustrated housing for the partitioning seal is separate from the central housing to facilitate installation and removal of the partitioning seal. As a design refinement, the partitioning seal can be mounted in a floating seal carrier that follows the runout of the mandrel; see chapter D17. A floating seal carrier minimizes the runout experienced by the partitioning seal, and also minimizes runout-related changes to the extrusion gap clearance at the partitioning seal.

The groove for the partitioning seal is designed in accordance with chapter D5. The bore that defines the housing to mandrel extrusion gap clearance is designed in accordance with the guidelines provided in chapter D7.

7. Backup ring and bulkhead design

Additional information on backup rings is provided in chapter D17, and our engineering staff is available to provide design guidance and assistance.

The most critical dimensions are the sealing diameter of the mandrel and the inner diameter (ID) of the backup ring. The ID of the backup ring is designed to fit the mandrel as tightly as possible while still assuring freedom of relative rotation between the mandrel and the backup ring. Design of this fit requires the designer to consider tolerances, differential thermal expansion, and pressure induced deformation.

The axial fit between the backup ring and the bulkhead is also important because it controls the extrusion gap clearance of the face type seals that provide axial force balance. The length of the backup ring and the depth of the mating bulkhead recess are selected to ensure that the backup ring is just a few thousandths of an inch shorter than the recess depth. The force balancing face seal incorporate 712-series plastic backup rings (Figure 3) to prevent extrusion damage and reduce sliding friction. This ensures that the force balancing seals do not become a weak point of the high pressure swivel.

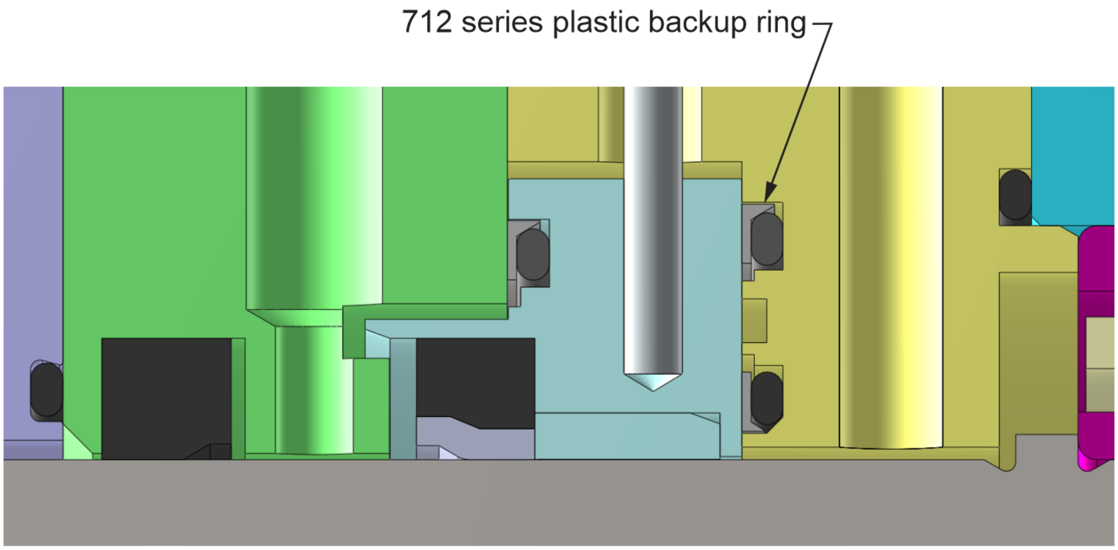

Figure 3

Plastic backup rings for the force balancing face seals

In high pressure swivels, 712-series plastic backup rings are used to bridge the face-type extrusion gaps of the force balancing seals. These plastic backup rings protect the rubber element of the balancing seals from high pressure extrusion damage.

8. Bearing housing design

By being separate from the pressure-containing housings, the bearing housings are immune to pressure induced expansion. This preserves the intended fit between the bearings and the housings, which helps to minimize runout of the mandrel.

The bearing housing should be designed with sufficient strength and bolt retention to handle anticipated mechanical loads. The bore that receives the outer bearing races should be designed with both the bearing manufacturer's recommended fit and any anticipated pressure related expansion of the inner races in mind.

When rotary seals are used to retain the bearing lubricant, the bearing cavity should be vented, to prevent pressure buildup that could damage the seals.

9. Housing interface design

Several of the housing end surfaces are sealing surfaces for face seals and must have a suitably smooth surface finish. A 32 micro-inch AA or better surface finish is recommended. The end surfaces impact overall alignment of the housings, and must be machined parallel to one another, and square with critical bore surfaces.

The housings are aligned to one another by overlapping piloting surfaces. The MMC fit of the pilots should correspond to the MMC RC 3 class of fit, however the LMC fit can be looser than the LMC RC 3 class of fit, so that tolerances can be looser than RC 3 tolerances. The axial length of the overlap of the piloting surfaces should be kept short, to prevent the possibility of misalignment-related binding due to the “sticky drawer” effect. A concentricity tolerance should be provided between the housing pilots and critical interior surfaces, such as the extrusion gap bores, and the bearing housing bore that receives the outer races of the bearings.

If desired, the housings may incorporate indexing features, to ensure that they are assembled in proper angular alignment. One practical indexing method is axially oriented indexing pins and corresponding recesses in mating parts. Another practical indexing method is slightly uneven angular spacing of bolt holes, so they only line up when the housings are in the correct angular orientation.

10. Miscellaneous high pressure swivel considerations

Optional barrier seals

In applications where the conducted fluid may contain a wide variety of chemicals, it may be desirable to incorporate a lip-type barrier seal that faces the conducted fluid. This barrier seal can be made of a different material than the partitioning seal, to resist a different spectrum of chemicals. When a barrier seal is used, the region between the barrier seal and the partitioning seal is filled with lubricant, and pressure balanced to the conducted fluid. Information on the use of barrier seals is provided in chapter D10.

Mandrel diameter implications

The journal bearing clearance of the floating metal backup ring must increase with increasing mandrel diameters, to accommodate factors such as differential thermal expansion between the mandrel and the backup ring. Because the journal bearing clearance must be bridged by the pressure retaining seal, this means the pressure capacity of this swivel design decreases with increasing mandrel diameter.

Pressure staging

If the pressure of the fluid being conducted through the swivel is greater than the pressure capacity of the pressure retaining seal, the pressure can be staged across more than one pressure retaining seal. The general concept of pressure staging is described in chapter D18, along with methods for staging lubricant pressure.

Potential simplifications from the illustrated high pressure swivel design

As a simplification, the grooves for the partitioning seals can be formed in the central housing, eliminating the need for partitioning seal housings. In small diameter swivels, this simplification may increase the difficulty of installing the partitioning seals in the grooves.

This simplification also eliminates the possibility of replacing the partitioning seal carriers when groove features become worn or damaged.

As a simplification, when the highest pressure capacity and longest life is not needed, the floating metal backup rings can be eliminated and the extrusion gaps for the pressure retaining seals can be defined by the bulkhead housings. In smaller diameter swivels that use Plastic Lined Kalsi Seals as the pressure retaining seals, the bulkhead housings may still need to be separable from the partitioning seal housings to facilitate seal installation. In larger diameter swivels, it may be possible to incorporate the groove for the partitioning seal and the groove for the pressure retaining seal in a single housing. Contact Kalsi Engineering for guidance.