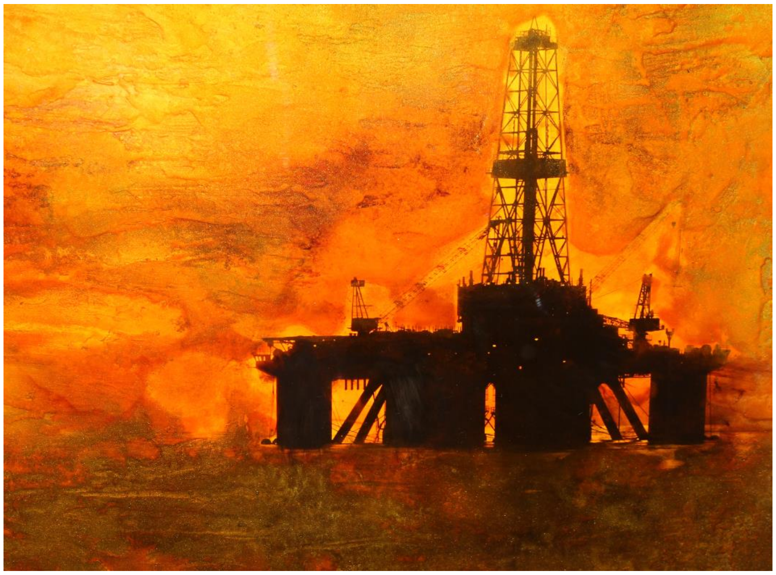
Chapter A3

Kalsi Seal application examples



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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

Kalsi Seals are widely used in the harsh, unforgiving conditions of oilfield drilling and production, where reliability is critical. These seals have made a number of equipment innovations technically and economically feasible. They are also employed in difficult rotary sealing applications in other industries, such as construction swivels, rock drilling machines, machine tools, and submersed dredge pumps. Examples of several sealing applications are described in this chapter.

2. Mud motor seals

How sealed bearing mud motors work

Mud motors (Figure 1) are used for various drilling tasks such as straight hole, horizontal, directional and short radius oilfield drilling, river crossings and other utility drilling. They are connected to the drillstring to rotate and steer the drill bit. Rotation is provided by a power section, which is typically a progressive cavity positive displacement motor that uses the flow of the drilling fluid to produce rotation. Drilling loads are reacted between the drillstring and the drill bit via the sealed bearing assembly.

A small bend angle between the power section and the bearing assembly gives mud motors the ability to selectively drill curved or straight holes. Drillstring rotation produces a straight, slightly oversized hole. If the drillstring is not rotated, the hole curves in the direction of the bend. The driller references data from a measurement while drilling (MWD) tool in order to steer the mud motor to the target zone.

Advantages of sealed bearing mud motors are:

- Compact size, which facilitates short radius drilling
- Greater efficiency, due to reduced bearing friction
- Lower repair and maintenance costs

Challenges faced by mud motor seals

Sealed bearing-type mud motors have several rotary seal locations, and all are critical to reliability. Two locations are exposed to severe abrasives, and all locations are subject to shaft motion resulting from drilling forces and power section rotor thrust and nutation. Each seal location also has its own unique challenges, including high differential pressure at the fixed location seal, and reversing pressure and sliding motion at the piston-mounted seals. The lack of reliability and short life of conventional seals had previously limited the acceptance of sealed bearing mud motor bearing assemblies, but the Kalsi Seal has allowed sealed bearing assemblies to attain widespread use. The reliability, ease of maintenance, and economics of the Kalsi Seal have been proven by the significant population of motors that use them today. Kalsi Seals represent the state of the art in mud motor seals. Runs in excess of 500 hours have been achieved by several customers.

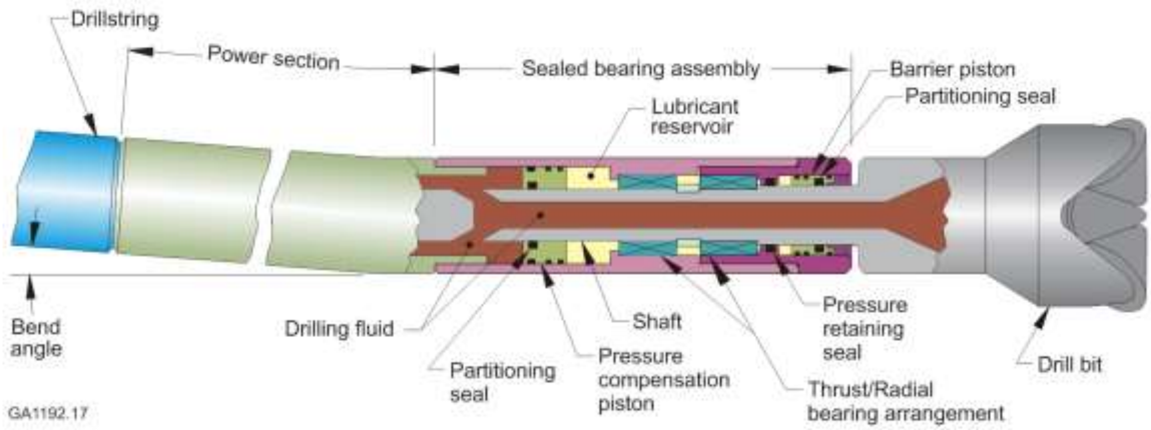

Figure 1

Schematic of a typical oilfield downhole drilling mud motor

Mud motor piston seals

The pressure compensating piston balances the lubricant reservoir pressure to the high pressure of the drilling fluid within the drillstring bore. The optional barrier piston balances the barrier lubricant to the pressure of the drilling fluid within the annulus of the well, providing a clean lubricated environment for the fixed location rotary seal. The barrier piston also limits the lateral deflection of the shaft. Because of the reversing pressures experienced by the rotary seals, axially constrained or axially spring loaded Kalsi Seals are recommended for mud motor piston sealing.

Mud motor high pressure seal

When the surface mud pumps are running, the drilling fluid flows down through the drillstring and mud motor power section, exiting into the annulus of the well through the jets (not shown) in the drill bit. The annulus pressure is substantially lower than the drillstring bore pressure due to the pressure drop that occurs as the drilling fluid passes through the drill bit jets[1]. This differential pressure is borne by the fixed location Kalsi Seal. The return flow of the drilling fluid in the annulus carries drilling cuttings to the surface. The drilling fluid flow through and along the outside of the assembly provides cooling to the bearings, rotary seals, and drill bit.

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1 The formula for determining pressure drop across the bit is provided on page 256 of Preston L. Moore's book "**Drilling Practices Manual"**, Second Edition, (Tulsa, OK: Pennwell Publishing Co., 1986.).

3. Seals for advanced rotary steerable drilling systems

Various companies have developed advanced rotary steerable drilling systems for the oilfield that accurately steer the rotating drill bit to the desired coordinates within a geological formation using surface commands. A typical rotary steerable tool incorporates a drill-string driven rotary shaft that rotates the drill bit. Various types of actuation systems are used steer the assemblies.

Rotary steerable tools eliminate the sliding drillstring mode associated with conventional mud motor steering methods. Since the drillstring continually rotates, such systems provide better hole cleaning and less chance of differential sticking. This allows extended reach wells and complex well trajectories to be drilled more efficiently, with less risk and significant cost savings. Rotary seals are a critical element these expensive systems, and Kalsi Seals provide the reliability necessary to protect the complex internal components.

4. Centrifugal pump seal cartridge

Figure 2 illustrates a patented centrifugal pump seal cartridge that is used on charging and mixing centrifugal pumps on oilfield well-cementing trucks. This same basic technology is applicable to other centrifugal pump applications.

A pressurized lubricant (typically 60 psi) is introduced between the pair of Kalsi Seals. During rotation, the High Film Seal (Figure 3), acting like a miniature pump, pressurizes, lubricates and flushes a pair of conventional lip seals that face the pump casing and impeller.

A Filled Kalsi Seal is used on the air-side of the cartridge to retain the pressurized lubricant while operating with low torque and low hydrodynamic pumping related leakage. Seal cooling is provided by a shaft-driven rotating fan, a thick mounting flange that transfers heat to the pump casing, and heat draw through the shaft to the slurry-immersed pump impeller.

Comparable designs are possible for pumps where the stuffing box and rear wear plate are integral. The cartridge overcomes the key limitations of conventional cement pump sealing, and has the following advantages:

- Provides a longer-lasting air-side pressure-retaining seal,
- Automatic pressurization and flushing of the lip seals during rotation, as a result of the High Film Kalsi Seal,

- Meters the flow of lubricant across the lip seals during rotation,
- Provides a liquid-tight seal when rotation is stopped,
- Provides improved heat transfer and reduced seal temperature, resulting in significantly longer life than conventional sealing arrangements.
- Reduces pump maintenance costs.

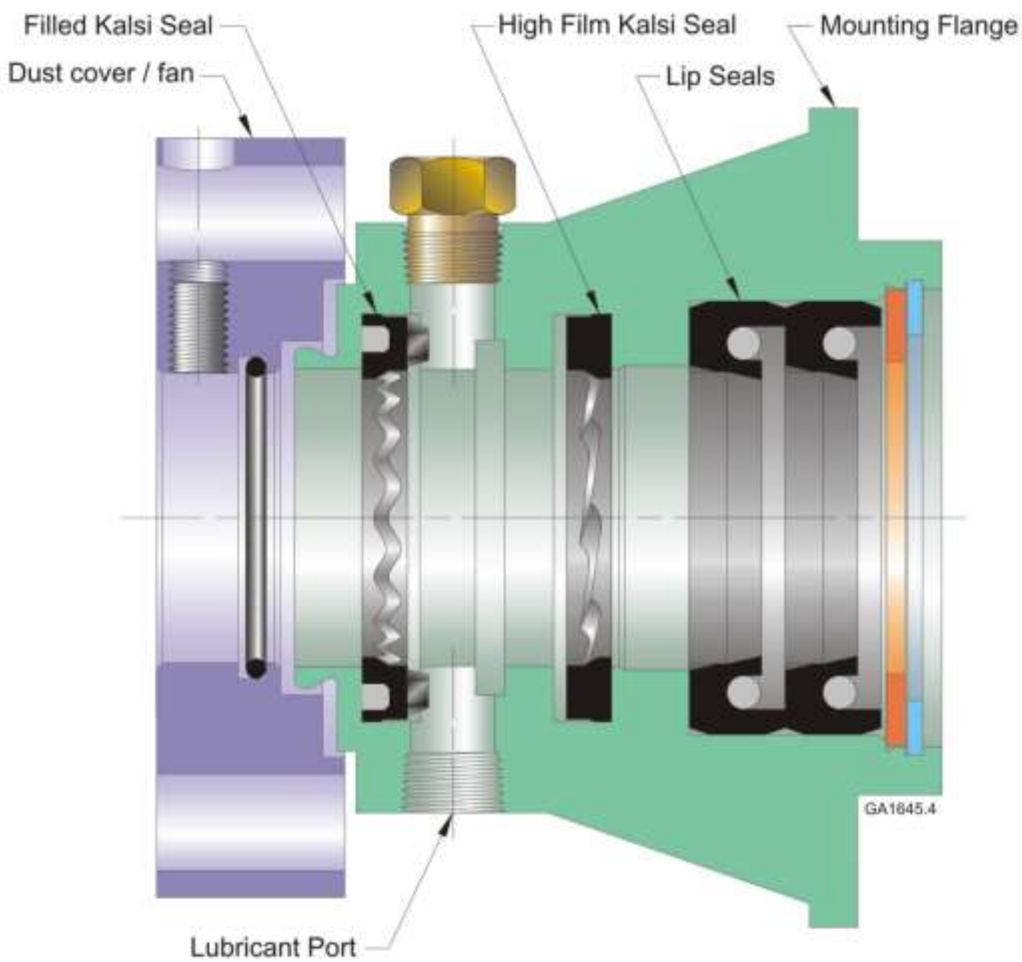

Figure 2

Centrifugal pump seal cartridge

In the cement pump seal cartridge, a Filled Kalsi Seal retains the pressurized lubricant, and a High Film Kalsi Seal flushes and lubricates a pair of lip seals that face the pump casing. Seal cooling is provided by fan driven air flow, by immersion of the end of the shaft in the cement, and by contact between the mounting flange and the pump casing.

Figure 3

Photograph of a High Film Kalsi Seal for clockwise shaft rotation

In the cement pump cartridge, a High Film Seal is used to flush and lubricate a pair of lip seals which face the cement slurry within the volute of the pump.

5. Coring swivel washpipe seal assembly

High pressure, high speed coring swivels present another extreme challenge to rotary seals, with speeds of 298 to 497 ft/minute (1.52 to 2.53 m/s) and pressure up to 3,000 psi (20.7 mpa). In this severe application, conventional chevron-type washpipe seals were unable to survive for more than eight hours. When Kalsi Seals were implemented in a washpipe assembly (Figure 4) designed and licensed by Kalsi Engineering, Inc., a seal life of over 1,400 hours was achieved in the first field use.[2] Although several seal advances have occurred since then, the same hardware configuration is still in use.

The assembly incorporates a spring-loaded compensating piston that amplifies the lubricant pressure slightly above the drilling fluid pressure. This promotes maximum seal life by keeping the upper seal straight in the gland. The upper rotary seal serves as a partition between the high pressure drilling fluid and the clean lubricant, and the lower seal retains the pressurized lubricant. The assembly mounts to a conventional gooseneck. The internal components are designed to align with the washpipe when the unit is installed. This feature allows a very small extrusion gap clearance to be used, which promotes high pressure sealing performance.

Other washpipe sealing arrangements have been made that are capable of handling even higher pressure; see IADC/SPE Paper No. 59109 and U.S. Patent 6,007,105.

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2 To learn more about the development and initial field use of the coring swivel, see the article *"Hybrid Rigs Developed for Continuous Coring Exploration"*, **Oil & Gas Journal**, April 27, 1992.

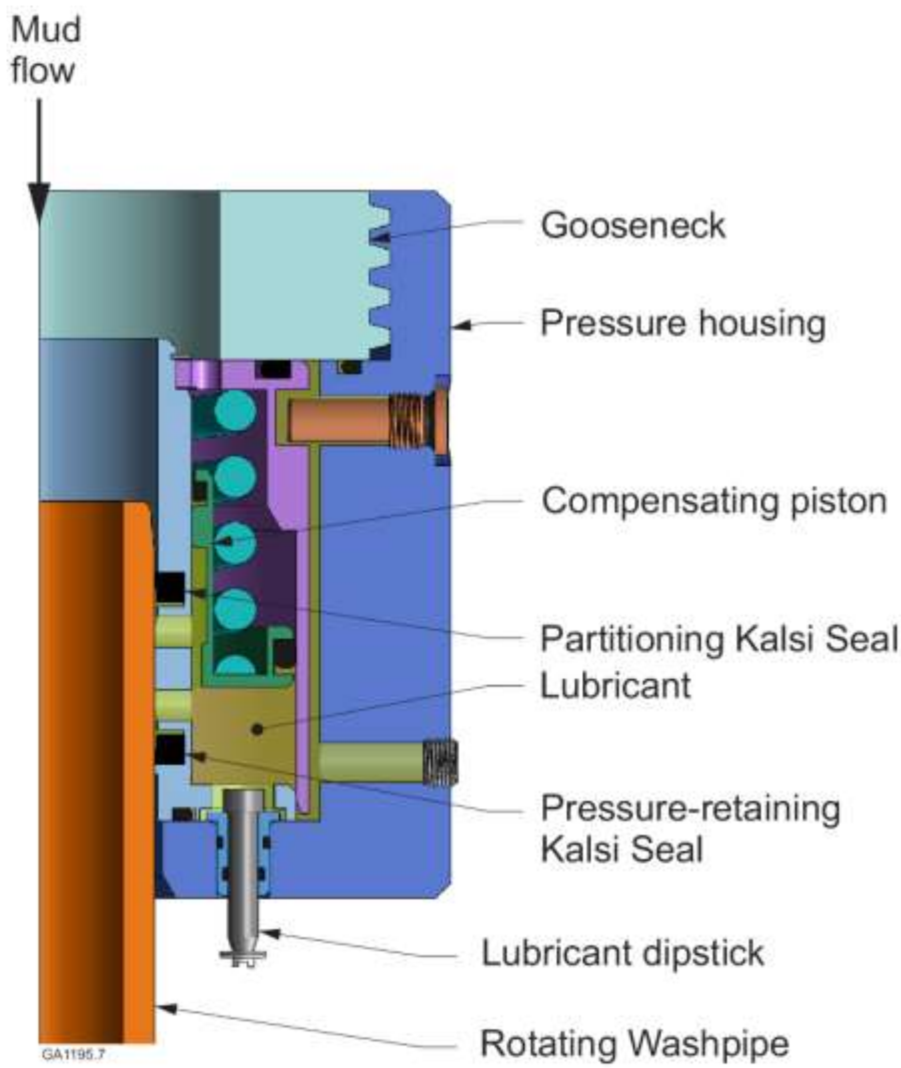

Figure 4

High pressure, high speed coring swivel

In the coring swivel seal assembly, the upper Kalsi Seal partitions the lubricant from the mud, and the lower Kalsi Seal retains the pressurized lubricant. A spring-loaded piston amplifies the lubricant pressure above that of the mud pressure to improve the abrasion resistance of the upper Kalsi Seal. Seal cooling is provided by the mud flow through the hollow rotating washpipe.

6. Underwater vehicle seals

Kalsi Seals are used in various underwater vehicles, including the US Naval Undersea Warfare Center NUWC LIGHT lightweight torpedo prototype (Figure 5). A Kalsi Seal protects the propulsor bearings from saltwater exposure. Kalsi Engineering also participated in the design of the pressure-compensated sealed bearing assembly that guides the rotating propulsor.

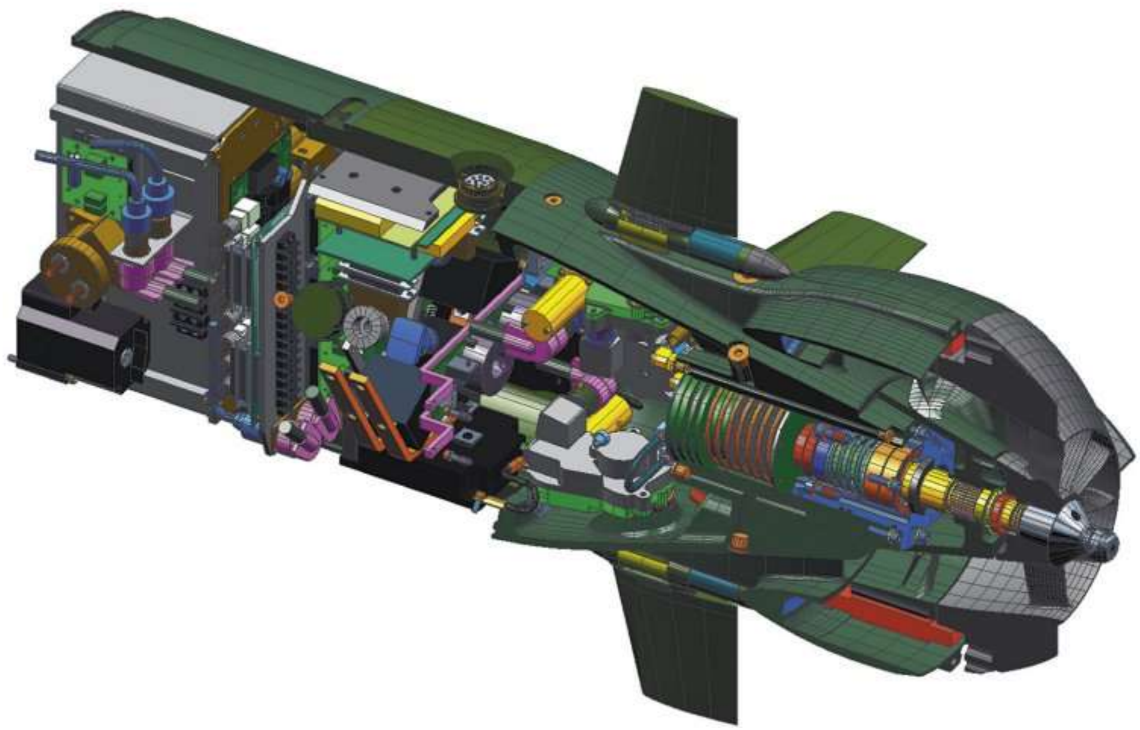

Figure 5

Underwater vehicle shaft seals

Kalsi Seals are used in underwater vehicles, such as the NUWC LIGHT lightweight torpedo prototype shown here.[3]

In the initial test program, the same Kalsi Seal was used in 40 successful runs at the NUWC Newport range. When finally disassembled, the bearing oil was still clean, and the seal and mating rotor surface had an unworn appearance. For additional information on the NUWC LIGHT project, see Jane's International Defense Review magazine, Volume 40, September 2007.

3 Image provided courtesy of the Naval Undersea Warfare Center.

7. Submerged dredge pumps

Submerged dredge pumps are used to excavate sediment from harbors, channels, and other waterways to maintain appropriate water depth. Such pumps are a critical sealing application because of the high cost and downtime associated with replacing the large diameter impeller shaft bearings when they become flooded with abrasive-laden salt water. Since the pumps are filled with lubricant, environmental concerns also exist when seal failure causes the pump lubricant to be dumped into the waterway. Pump operating conditions include significant shaft surface speed (800 ft/minute typical), dirty water conditions (sand & gravel), shaft impact loads from encounters with various sizes of submerged objects, and environmental pressure due to the submerged depth of the pump.

8. Rotating control devices

Rotating control devices[4] are oilfield devices that reduce formation damage in oil well drilling (compared to over-balanced drilling) by maintaining the pressure of the annular column of drilling fluid at a pressure below, or comparable to, that of the reservoir. The reduction in formation damage helps to optimize the production potential of the well. Drilling with an underbalanced pressure condition allows the evaluation of well effluents while drilling. It also reduces differential sticking, and allows less expensive drilling fluids to be used.

Kalsi Seals have been used in lubricant overpressure-type rotating control devices since 1993. Since then, a series of seal and hardware improvements have been developed that allow a higher dynamic pressure rating, cooler operation, and lower breakout torque.

Design advances have also been made for rotary control devices that use simple gravity-type lubricators. One example is the Chamfered Enhanced Lubrication Seal. This seal has been tested with 500 psi mud pressure with a gravity-type lubricator at 540 ft/minute. See the Catalog and Technical Data section of the handbook for more information.

9. Rotary valve actuators

A Kelly Valve is a ball valve that is installed in-line with the drillstring. When used as an upper Kelly Valve, they are closed when needed to control the pressure of a blowout. When used as a lower Kelly Valve, they are closed to prevent drilling fluid loss

4 Also known as rotary control devices, RCDs, rotating heads, rotating blowout preventers, rotary blowout preventers, rotating drilling heads, rotary BOPs, and rotating diverters.

during periods when the Kelly is disconnected. When open, they allow free flow of the drilling fluid. Kelly Valves are also referred to as a “Kelly Cock” or a “Drill Pipe Safety Valve”.

A rotary valve actuator (Figure 6) is used to open or close the Kelly Valve during drillstring rotation. As shown in the schematic below, a hydraulically operated rack and pinion arrangement is used to turn the stem and ball of the Kelly Valve. The hydraulic fluid pressure is transmitted to the valve actuator via three rotary seals that are mounted in a non-rotating seal housing. In other words, the rotary valve actuator incorporates a compact hydraulic swivel.

Kalsi Seals provide a significant advantage in swivel-type applications such as this because of their cool operation and long sealing life. This advantage is achieved via a special lip design that introduces a thin film of hydraulic fluid between the lip and the mating shaft surface during rotation, allowing the lip to hydroplane. This minimizes friction, which reduces heat and wear.

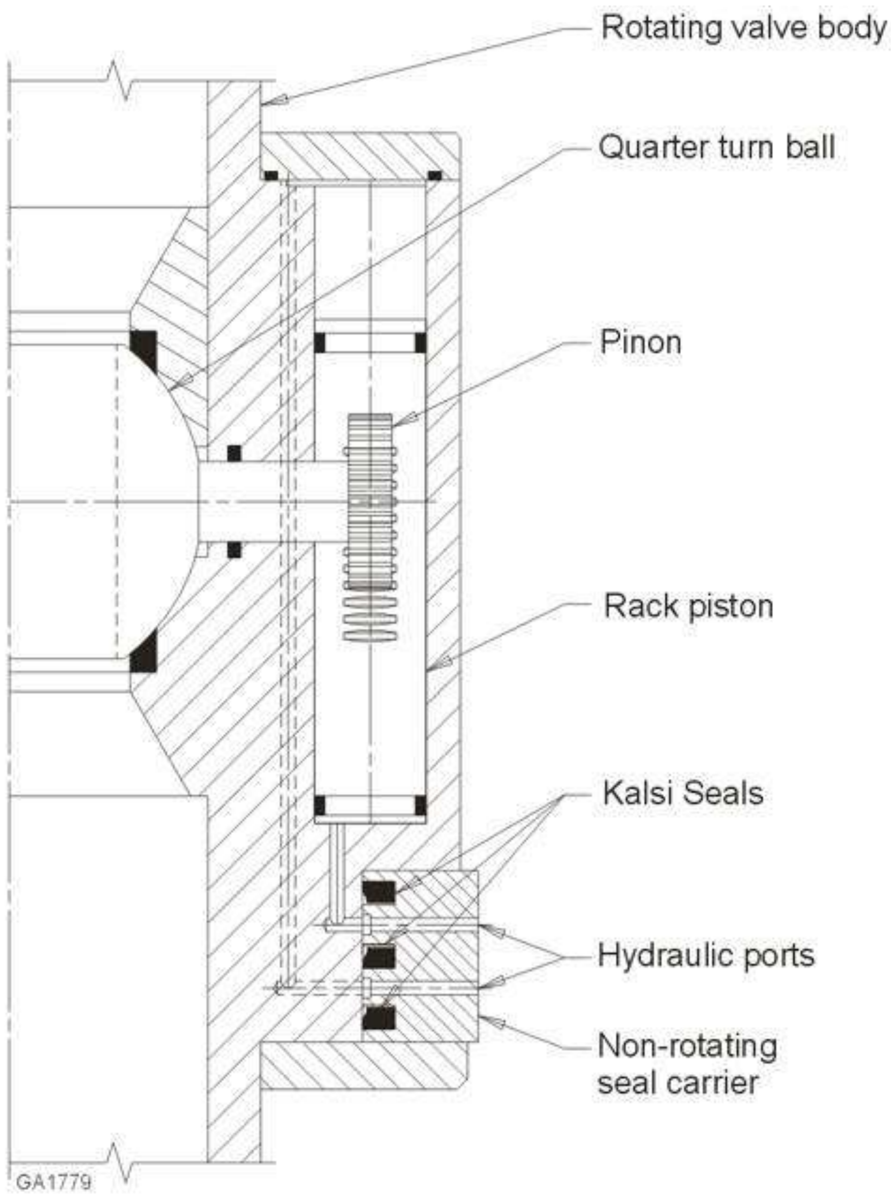

Figure 6
Schematic of an oilfield kelly valve actuator