Chapter A1

Introduction

Revision 5 January 10, 2019

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

NOTICE: The information in this chapter is provided under the terms and conditions of the Offer of Sale, Disclaimer, and other notices provided in the front matter of this handbook.

1. Purpose and basis of this handbook

Kalsi Seals® are typically used in relatively complex rotating machinery that is exposed to harsh conditions. In order to achieve maximum rotary seal performance, a systems approach is required for machine design. Any number of factors can influence seal performance, such as bearing implementation, heat transfer efficiency, shaft surface finish, reversing pressure conditions, shaft vibration and deflection, assembly techniques, differential pressure, extrusion gap clearance, pressure compensation, lubricant selection, threaded connection alignment, and chemical exposure – and more.

One thing that sets Kalsi Engineering apart from other seal companies is our ability to draw upon decades of seal testing and mechanical design experience to support customer applications. We wrote this rotary seal handbook to help our customers benefit from our experiences, with the desire that they may obtain the best possible seal performance. The knowledge in this handbook is the result of seal-related research and development projects that were funded by Kalsi Engineering and, in some cases, the United States Department of Energy. Our projects have included the design, analysis and field testing of surface and downhole research tools that were developed to provide Kalsi Engineering with direct feedback on seal and hardware performance. Figure 1 illustrates one such research tool, a sealed -bearing mud motor assembly.

Figure 1

Dr. Kalsi inspects a sealed bearing mud motor that Kalsi Engineering designed and manufactured as a research tool, to obtain firsthand information about downhole seal performance.

Contact Kalsi Engineering Search this handbook

2. What are Kalsi Seals?

Kalsi Seals are a family of rotary shaft seals for contaminant exclusion and lubricant retention in harsh service conditions such as environmental abrasives, high differential pressures, and high levels of shock and vibration. The seals are compact precision-molded polymeric rings. They incorporate proprietary features that dramatically improve seal and shaft life through hydrodynamic lubrication, providing economic and performance benefits that surpass many other types of rotary seals. Figure 2 shows the geometry of a representative Kalsi Seal. Kalsi Engineering's rotary seal product line was established to address the harsh and unforgiving conditions of the oilfield downhole environment. Kalsi Seals are available in a wide range of sizes, designs, and materials to satisfy a variety of application requirements.

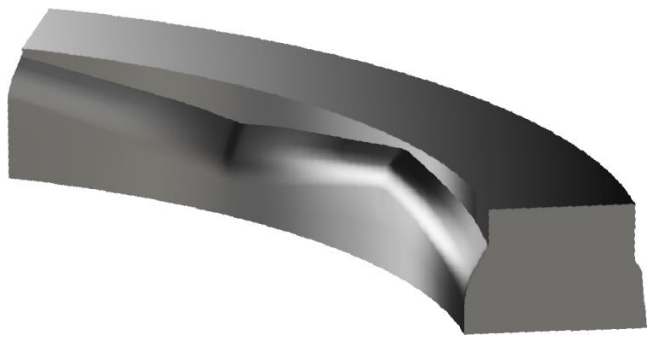

Figure 2

The dynamic sealing lip of a Kalsi Seal has waves that produce hydrodynamic lubrication, allowing the seal to operate at much higher pressure and speed combinations than conventional rotary seals. Several different seal configurations are available.

Typical applications include both low and high pressure installations, such as:

- Downhole drilling mud motors
- Rotary steerable drilling tools
- High speed coring swivels
- Rotary Control Devices (RCD's)
- Rotary valve actuators
- Rock drilling machines
- Slant hole drilling swivels
- Underwater vehicles
- Submerged dredge pumps
- Oilfield cement pumps
- Construction swivels
- Oilfield vacuum truck agitators
- Industrial slurry mixers
- Roller reamers
- Machine tools
- Hydraulic swivels
- Blasthole drilling
- Gun drills
- Side port swivels

Contact Kalsi Engineering Search this handbook

3. Kalsi Seal principle of operation

The Kalsi Seal™ is installed in a circular housing gland (Figure 3) that compresses it against the shaft, eliminating clearance and establishing static sealing in the same manner as other interference-type seals, such as O-rings. When the shaft rotates, the seal remains stationary and the seal-to-shaft interface becomes dynamic.

The dynamic sealing lip has a wavy shape on its lubricant side, and an abrupt circular exclusionary shape on its environment side. This unique geometry dramatically improves seal life by lubricating the dynamic seal-to-shaft interface while excluding environmental contaminates.

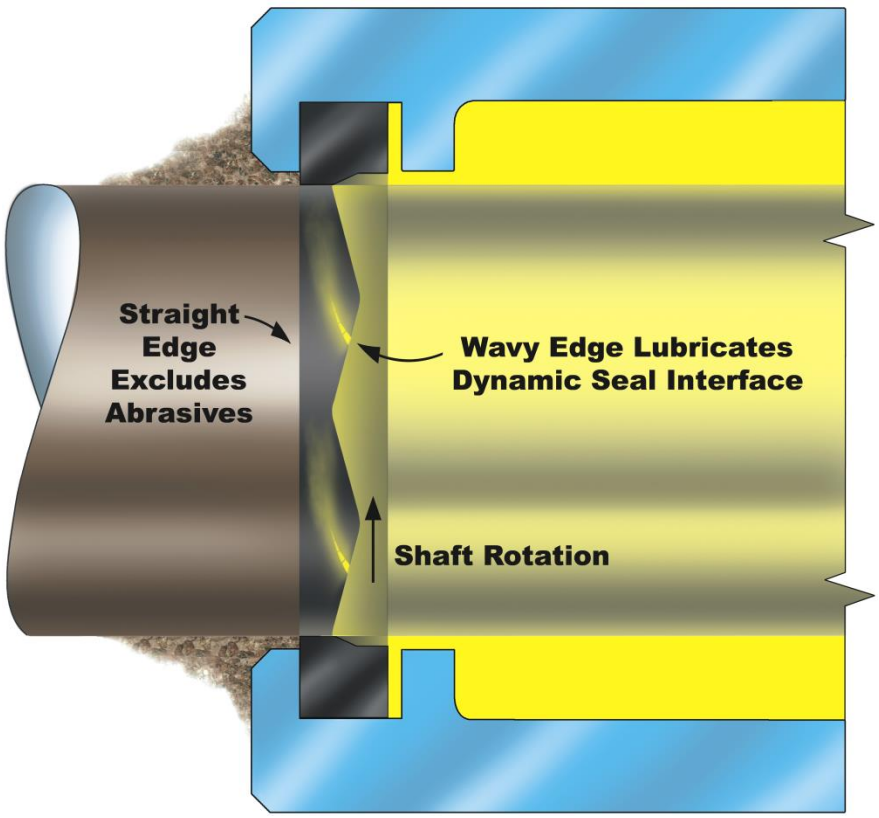

Figure 3

The unique geometry of the Kalsi Seal wedges a hydrodynamic film into the dynamic seal to shaft interface during rotation to reduce friction and wear while excluding abrasives.

As rotation occurs, the rotational velocity of the shaft drags a thin lubricant film past the wavy edge and into the dynamic sealing interface (Figure 3). This hydroplaning effect lubricates the seal and shaft surfaces, and prevents the typical dry rubbing wear and high friction associated with conventional rubber (Figure 4) and plastic seals. This prolongs

seal and shaft surface life, and makes operating at higher speed and pressure practical. For a slow motion animation of Kalsi Seal lubrication, visit our website.

The hydrodynamic wedging action causes a controlled hydrodynamic pumping related lubricant leakage rate during rotation. When rotation stops, the hydrodynamic action stops, and a static sealing relationship is reestablished due to the initial compression of the seal. The interfacial lubricant film thickness decays gradually when rotation stops, due to squeeze film effect.

Hydrodynamic leakage and film thickness during rotation are dependent upon a number of factors, including rotary speed, lubricant viscosity, differential pressure, hardware design, and seal geometry.

The leakage of most types of Kalsi Seals is minute, being in about the same range as typical mechanical face seal leakage. Certain types of Kalsi Seals, such as the Enhanced Lubrication Seal, are designed to provide increased hydrodynamic leakage for those applications where such performance is desirable. Regardless of which type of Kalsi Seal is employed, a suitably sized lubricant reservoir must be provided to accommodate the hydrodynamic pumping related leakage (Chapter D11).

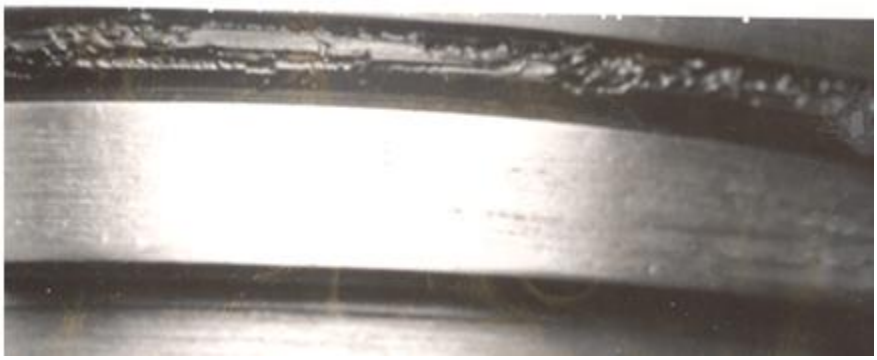

Figure 4

Conventional seals, such as this O-ring, suffer from heat and wear damage if rotated with significant differential pressure.

4. Kalsi Seal product overview

The Kalsi Seal product line consists of a number of rotary shaft seal styles that address a variety of sealing challenges. Custom cross-sectional sizes can be engineered for unique applications, and specific features can be tailored to the application if necessary.

Kalsi Seal™ Product Overview

	**Wide Footprint Seal™** – An improved product intended for direct interchange with Standard Kalsi Seals™, to achieve longer life in pressurized lubricant applications. The improved geometry provides increased abrasive exclusion and additional sacrificial material to accommodate wear.
	**Axially Constrained Seal™** – Developed for excluding abrasives in non-pressurized applications, and in applications with low levels of reversing pressure. Also useful for retaining pressurized lubricants up to approximately 750 psi. This geometry does not require spring loading in any situation.
	**Standard Kalsi Seal™** –A general-purpose hydrodynamic seal for pressurized lubricant retention and abrasive exclusion that is used in a variety of low to high differential pressure applications. It can also be used to retain non-pressurized lubricants if axially spring loaded.
	**Enhanced Lubrication Seal™** – An aggressive hydrodynamic wave geometry that provides enhanced lubrication. Particularly useful when low viscosity lubricants, high temperatures, poor heat transfer conditions, or high differential pressures are encountered. Compared to Standard and Wide Footprint Kalsi Seals™, an Enhanced Lubrication Seal allows significantly higher speeds in low differential pressure conditions with low viscosity lubricants. Enhanced Lubrication Seals are available with single and Dual Durometer construction, and in various lip widths.
	**Chamfered Enhanced Lubrication Seal™** - A subset of Enhanced Lubrication Seals. They were designed for applications where the pressure of an abrasive environment is higher than the pressure of the seal lubricant. Kalsi Engineering refers to this condition as "reverse pressure". This breakthrough allows the seal to be used in equipment that has a simple gravity fed lubricant reservoir.
	**Hybrid Seal™** – Hybrid Seals™ mix enhanced lubrication waves with more conventional waves to temper the hydrodynamic pumping-related leak rate while still providing a torque advantage over Standard Seals. Hybrid Seals were developed to provide reduced running torque and seal generated heat in oilfield tools, and are also useful in a variety of other applications.
	**Plastic Lined Seal™** – A seal directed at increased high different pressure sealing capacity and reducing breakout torque. This geometry has a plastic layer at the dynamic interface, and an elastomer energizing section forming the seal body. The use of a plastic liner allows high pressure extrusion resistance and has a lower coefficient of friction thereby reducing breakout torque compared to elastomer only Kalsi Seals®.
	**Dual Durometer™ construction** – A seal for pressurized lubricant retention that employs dual hardness construction to reduce interfacial contact pressure, and allowing a hard extrusion resistant compound to be used at the dynamic sealing lip. Depending on compound selection, it can be configured to seal higher pressures than a Standard Seal, or run at lower torque and higher speeds. It provides good abrasion resistance when differential pressure is maintained.
	**High Film Seal™** – A special purpose seal that incorporates an extremely aggressive unidirectional hydrodynamic geometry for pressurized lubricant retention and abrasive exclusion in applications that can tolerate or exploit a very high hydrodynamic pumping rate. It can lubricate with fluids as thin as water.

Contact Kalsi Engineering Search this handbook

	**Filled Seal™** – A more economical dual material seal design for high speed pressurized lubricant retention. Permits higher speeds than conventional Dual Durometer Seals™. Not recommended for abrasive applications. When combined with the enhanced lubrication wave pattern, leakage and torque are similar to a solid cross-section High Film Seal, but in a bi-directional rotation design.
	**Grooved Seal™** – A special purpose seal that incorporates a flexing lip for reduced torque in medium differential pressure applications. Not recommended for abrasive exclusion, or very high or low differential pressures.
	**KLS®** – A spring-loaded high-pressure lip seal. Can withstand up to 1,000 psi reverse pressure differential.
	**BDRP™ "Bi-Directional Rotation and Pressure" Seal** – Developed specifically to be hydrodynamically lubricated when high differential pressure acts from either side and when rotating in either direction.
	**Kalsi Packing™** – High performance washpipe packing for power swivels and top drives. This packing provides additional interfacial lubrication during rotation, providing reduced operating temperature and longer life.

In general, the larger seal cross-sections are preferred whenever sufficient space is available. For a given amount of percentage compression, a larger cross-section has more dimensional compression, is more tolerant of variations in gland depth, and less prone to slippage. For a given amount of dimensional compression, a larger cross-section has a lower percentage of compression, which reduces interfacial contact pressure and seal-generated heat.

5. Kalsi Engineering company background

Kalsi Engineering, Inc. was founded in 1978 to provide consulting engineering services in the areas of research and development, design, analysis, and testing of mechanical equipment and structures. The company facilities (Figure 5) are located in the Houston, Texas metropolitan area. The founder and President of the company, M. S. Kalsi, PhD, P.E. was the director of research and development for a well-known valve manufacturer prior to starting Kalsi Engineering. He became interested in the field of elastohydrodynamic lubrication while pursuing his masters and doctorate degrees. His fundamental research led to the basic lubrication concept employed by the Kalsi Seal product line. The company's pioneering efforts and commitment to continued research and development have resulted in a variety of rotary seal products that extend the

performance envelope well beyond the original design. Performance has been verified by years of laboratory and field tests and commercial use.

Figure 5

Kalsi Engineering, Inc. is located in the Houston, Texas metropolitan area

Kalsi Engineering's facilities are located in Sugar Land, Texas, and house our consulting engineering offices, mechanical testing laboratories, flow loop, and Kalsi Seal operations. Our highly experienced staff of mechanical engineers has a variety of complementary skills and industry backgrounds. We are well versed in classical solid mechanics/stress analysis and thermo-fluid analysis. Kalsi Engineering uses state of the art design, analysis and testing software to support our activities.

6. Continuing seal research and development

Our research and development mission is continual product improvement directed at the needs of new and existing rotary seal markets. Products are developed and refined using state-of-the-art analysis techniques and rigorous testing. The performance of existing products is continually evaluated in our well-equipped seal testing laboratory (Figures 6 and 7),

Figure 6

Kalsi Engineering has an experienced team of engineers, analysts, and technicians who are committed to rotary seal research, development, and testing.

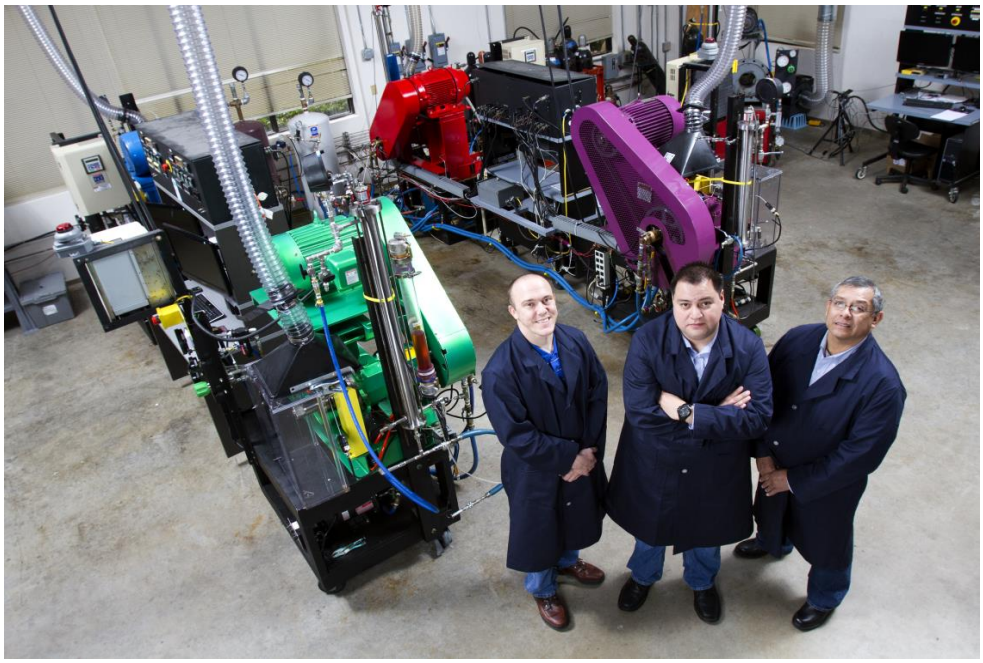

Figure 7

Computer-controlled rotary test fixtures are available to evaluate seal performance with customer-specified lubricants, process fluids, temperatures and other application-specific conditions. The fixtures are color coded for reference purposes. That is our seal testing team in the foreground.

Contact Kalsi Engineering Search this handbook

7. Consulting engineering capabilities

The Kalsi Engineering staff has an outstanding and diverse engineering background, with a record of accomplishments in developing practical and cost effective solutions to mechanical engineering problems in a wide range of applications in the power generation, oilfield, petrochemical, aerospace, defense, manufacturing and mining industries. The company's core capabilities include structural, fluid and thermal analysis, mechanical design and product development, tribology, and testing.

Kalsi Engineering is recognized worldwide for technical excellence. Our numerous industry milestones, guidelines, technical publications, new products, and patents continue to provide long-term benefits to our clients and to the industries we serve. Visit our web site at www.kalsi.com for additional information.