

## Chapter D12

### Miscellaneous lubricant related information



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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 <https://www.kalsi.com/seal-handbook/>.

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## 1. Lubricant viscosity requirements

The hydrodynamic film thickness of a Kalsi-brand rotary shaft seal depends on various factors, including seal geometry, seal hardness, rotary speed, differential pressure, and lubricant viscosity<sup>1</sup>, which is temperature dependent. Viscosity recommendations for specific seal patterns and operating conditions are typically provided in Section C of this handbook. Contact Kalsi Engineering for additional assistance.

Viscosity requirements are highly dependent on seal type, heat transfer conditions, and other operating conditions of a particular rotary shaft seal assembly and are best determined by testing with the actual hardware. Higher viscosity lubricants may be needed to minimize asperity contact<sup>2</sup> in applications with slow shaft speeds, higher temperatures, or higher differential pressure. Well cooled high surface speed applications may develop enough film thickness with lower viscosity lubricants. Excessively high lubricant viscosity can promote increased running torque and heat<sup>3</sup>. Optimum viscosity can only be determined by rotary testing in the actual machine assembly, under thermal conditions that are a reasonable match to the actual application.

Lubricant viscosity increases as temperature decreases. To avoid excess startup leakage, cold climate applications may require high viscosity index<sup>4</sup> lubricants to avoid an excessive increase in lubricant viscosity, or pre-heating of the seal lubricant before operation, or higher differential pressure at the time of startup.

When low viscosity lubricants such as hydraulic fluid must be retained at high differential pressure in equipment such as hydraulic swivels, seals with more aggressive wave patterns (such as Enhanced Lubrication™, Hybrid, or Plastic Lined Seals™) are recommended. Hybrid Seals™ are suggested for oilfield rotary steerable tools that use relatively low viscosity hydraulic fluid at relatively high temperatures.

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1 Viscosity is a measure of resistance to flow. Low viscosity lubricants are thinner, and less resistant to flow. High viscosity lubricants are thicker, and more resistant to flow.

2 The term “asperity contact” is used to describe poorly lubricated contact between microscopic high points of the rotary seal and the shaft. Excessive asperity produces adhesive wear and additional seal generated heat. More viscous lubricants produce a thicker interfacial film, which helps to reduce asperity contact. As an intuitive example, imagine sliding down a steep slope covered with cement. Your skin would be less abraded if the cement was wetted with molasses, compared to being wetted with water. The higher viscosity of the molasses would provide a thicker film between your skin and the cement, compared to water, minimizing contact between your skin and the rough cement.

3 For example, in a 1,000 psi (6.89 MPa) lab test, an ISO 6800 viscosity grade lubricant produced about 54% more running torque than a typical test with an ISO 320 viscosity grade lubricant. This is because of increased shear stress due to increased viscosity.

4 The higher the viscosity index, the less the lubricant viscosity changes with temperature.

**Viscosity estimation at various temperatures**

Lubricant viscosity at various temperatures within a limited range can be estimated using the ASTM D 341 standard viscosity chart for liquid petroleum products, chart III. This chart has been computerized by Kalsi Engineering, and the resulting software (Figure 1) is available for free to Kalsi Engineering's customers. Table 1 provides sample output from the software to help the reader understand that lubricant viscosity changes significantly with temperature.

**Viscosity Calculator**

**Kinematic Viscosity**

Viscosity @ 40 C, cSt: 320

Viscosity @ 100 C, cSt: 35

Reference Temperature, C: 71, 150

Calculated Viscosity, cSt: 85.642, 11.987

Dynamic Viscosity

Specific Gravity: 0.87

Dynamic Viscosity in Reyns (lbf-s/in<sup>2</sup>): .0000108, .00000151

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**Figure 1****Viscosity calculator software**

Kalsi Engineering's free "Viscosity Calculator" software computerizes the ASTM D 341 standard viscosity chart for liquid petroleum products, chart III.

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		Viscosity, cSt				
°C	°F	32 VG	68 VG	150 VG	320 VG	680 VG
0	32	270.5	676.2	1834.6	4382.5	10089.3
10	50	138.1	331.5	856.7	1997.8	4459.3
20	68	77.8	179.2	441.9	1003.4	2171.5
30	86	47.5	105.1	247.7	547.2	1148.5
40	104	31.0	66.0	149.0	320.0	652.0
50	122	21.4	43.9	95.1	198.7	393.4
60	140	15.4	30.6	63.9	129.9	250.2
70	158	11.6	22.2	44.8	88.8	166.6
80	176	8.9	16.7	32.7	63.0	115.4
90	194	7.1	13.0	24.6	46.3	82.8
100	212	5.8	10.3	19.0	35.0	61.2
110	230	4.8	8.4	15.1	27.1	46.5
120	248	4.1	6.9	12.2	21.5	36.2
130	266	3.5	5.8	10.0	17.4	28.7
140	284	3.0	5.0	8.4	14.3	23.2
150	302	2.7	4.3	7.2	12.0	19.1

Table 1

**Sample output from the Viscosity Calculator software**

This sample output from the Viscosity Calculator is based on the PAO synthetic hydrocarbon lubricants we typically use in our dynamic seal testing. This table is provided to help the reader understand that lubricant viscosity changes significantly with temperature.

**2. Elastomer compatibility with various lubricants**

Information about lubricant compatibility with various elastomers is often provided by the lubricant manufacturer as a courtesy. The website of Nye Lubricants, Inc. ([www.nyelubricants.com](http://www.nyelubricants.com)) provides a particularly useful compatibility chart for a variety of synthetic lubricants and elastomers. Lubricants that produce significant elastomer swelling should be avoided because they alter material properties, which can negatively impact the performance of rotary shaft seals.

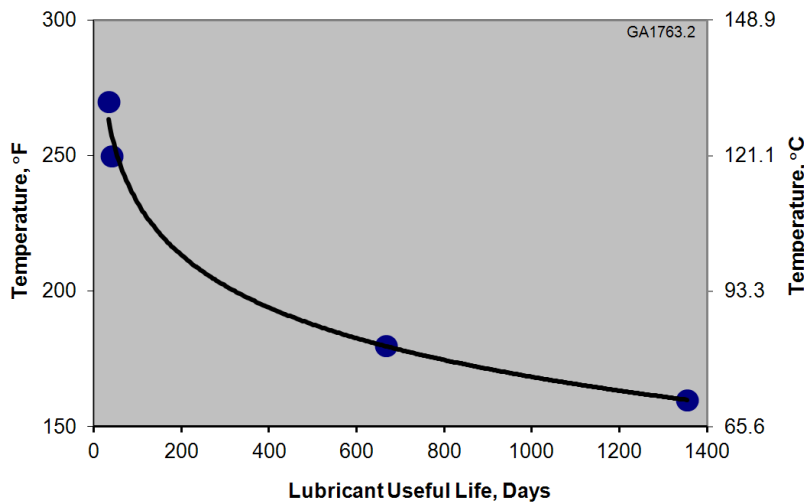
***Synthetic hydrocarbon lubricants are compatible with HNBR***

Most of Kalsi Engineering's high-pressure rotary seal testing with HNBR seals have been performed with polyalphaolefin (PAO) synthetic hydrocarbon (SHC) liquid type lubricants<sup>5</sup> which were developed for maximum film characteristics under extreme loads and elevated temperatures. Kalsi Engineering recommends such lubricants for most

<sup>5</sup> "Liquid type lubricants" refers to oils, as opposed to greases.

applications that employ HNBR seals, because they tend to have higher load capacity than the other lubricants that are compatible with NBR type elastomers.

Such SHC lubricants are typically recommended for service temperatures less than 250°F (121.1°C) and have significantly shorter useful life at higher temperatures. For example, one manufacturer rates the useful life of its SHC lubricants as about 1,350 days at 160°F (71.1°C), 666 days at 180°F (82.2°C) and 33 days at 250°F (121°C); see Figure 2.



**Figure 2**

This graph shows how one lubricant manufacturer rates the life of its PAO SHC lubricant product line, as a function of temperature.

### ***Consult your lubricant manufacturer***

The extreme pressure (EP) additives in some SHC lubricants reportedly attack copper and silver-based metals at temperatures higher than 210°F (98.9°C). If you are using copper or silver-based materials or coatings, check with your lubricant manufacturer on this topic. Avoid lubricants containing amines when conventional FKM materials are being used. Consult your lubricant manufacturer for detailed lubricant information, including viscosity, service temperature range, and compatibility with elastomers and other materials.

### **3. Lubricants for mud motor bearings and rotary seals**

Lubricant selection is an important consideration for oilfield mud motor sealed bearing assemblies, due to the extreme operating conditions encountered by the rotary seals and

bearings. Adequate viscosity at operating temperature is important because both the bearings and the Kalsi-brand rotary seals rely on hydrodynamic lubrication to minimize wear. The lubricant viscosity used in mud motors is typically dictated by the bearings, and a relatively high viscosity may be required to satisfy bearing requirements.<sup>6</sup> The hydrodynamic pumping related seal leakage that occurs during rotation increases with lubricant viscosity, because film thickness increases (Handbook Section C).

Kalsi Engineering recommends that mud motor bearing assemblies and similar elevated temperature, high differential pressure, heavy bearing load applications use liquid type synthetic lubricants that are compatible with the seal materials.

#### 4. Be cautious when using grease with Kalsi Seals®

Liquid type lubricants are recommended for use with most<sup>7</sup> Kalsi-brand elastomeric rotary seals because, unlike some greases, they are not abrasive to the seals. Unlike liquid type lubricants, greases are not a Newtonian fluid, and pressure response may be sluggish when small passageways are involved. Many greases are non-Newtonian soap complexes with a variety of other constituents, such as graphite and Molybdenum disulfide. The soap complex acts as a carrier for the other constituents.

Kalsi Engineering has performed tests at speeds up to 346 ft/minute (1.76 m/s) with various grease type lubricants using 2.75" (69.85 mm) diameter, 0.335" (8.51 mm) radial cross section seals constructed from several different elastomeric materials. Some of the conclusions from this testing are as follows:

- The particles found in some greases can severely abrade and otherwise damage the elastomers used in rotary seals. Rotary testing is required to determine the suitability of any given grease. This damage is worse at higher temperatures, higher speeds, and higher compression levels. Various damage mechanisms have been observed with greases, from simple third body abrasive wear to bizarre crack initiation and propagation.
- Softer durometer HNBR seal materials are typically better able to resist grease particle-induced rotary seal abrasion, compared to harder durometer HNBR seal materials. The -30 FKM seal material wore severely with every grease it was tested with.

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<sup>6</sup> Commercial lubricant filling systems are available that have heaters to lower the viscosity of high viscosity lubricants, for ease of filling.

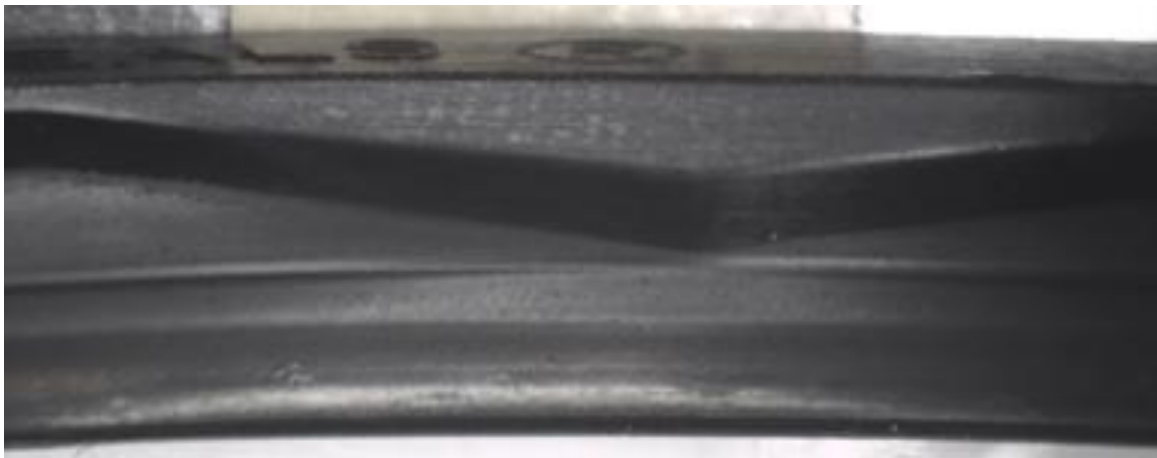
<sup>7</sup> Kalsi-brand high performance washpipe packing is used with grease. The fabric reinforced construction of packing limits the wear associated with the use of grease.

- Lithium based greases have provided a little better performance than many calcium complex-based greases.
- When basic 0.335" (8.51 mm) radial cross section Kalsi Seals are used with grease, the recommended 0.289" (7.34 mm) minimum groove width for liquid type lubricants at temperatures up to 300°F (148. 9°C) is too small and causes shorter seal life; the minimum recommended groove width is 0.295" (7.49 mm).
- Rotary seals operating with heavy greases generate much more torque and heat than seals operating with a suitable liquid type lubricant. This extra heat is detrimental to seal performance and life.

If grease is necessary in your application, testing at actual service temperatures and speeds is recommended to determine rotary seal performance with your specific grease. Beware that grease constituents and performance may vary from batch to batch.

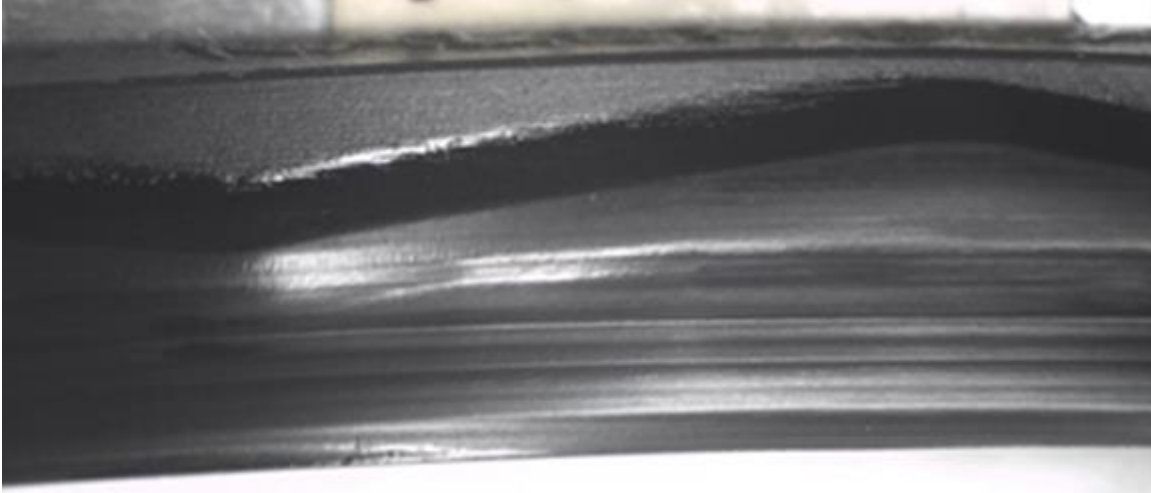
***Test specimens from recent testing with grease***

Figures 3 to 7 show Wide Footprint Kalsi Seals™ from rotary testing that was performed with three different greases. All tests were performed at 345 ft/minute (1.75 m/s) with a target bulk lubricant temperature of 162°F (72.2°C). As can be seen from the photos, all the greases had an abrasive effect on the seals, but the Valvoline multi-purpose grease was less abrasive than the other two.



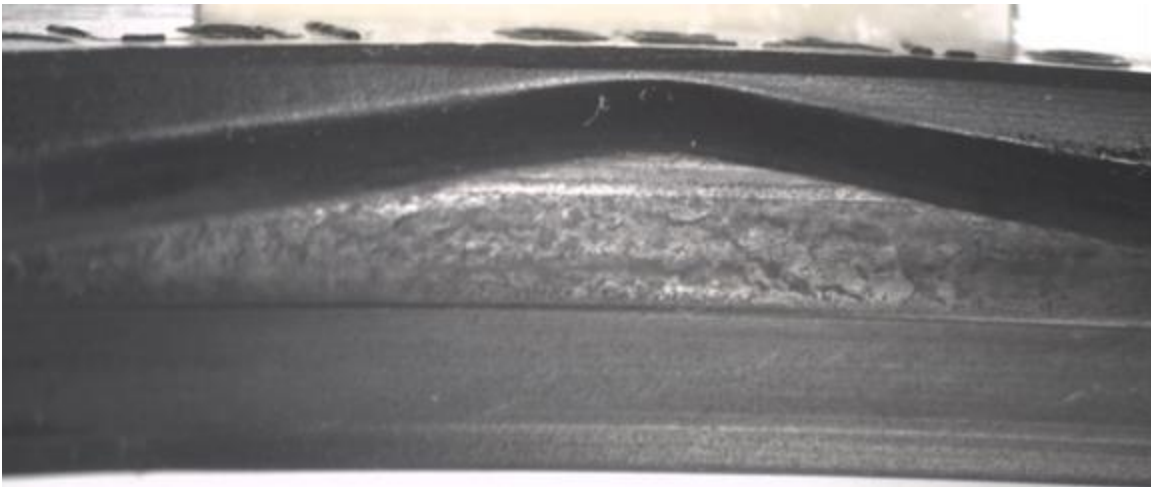
**Figure 3**

This worn PN 507-5-11 seal ran for 28.4 hours with a grease that was developed for, and works well with, fabric reinforced oilfield washpipe packing. The bulk temperature was 160 to 190°F (71.1 to 87.8°C), the grease pressure was 47 psi (342 kPa), and the surface speed was 345 ft/minute (1.75 m/s).



**Figure 4**

This worn PN 507-5-11 seal ran for 107.5 hours with Royal Purple #2 grease. The bulk temperature was 162°F (72.2°C), the grease pressure was 90 psi (0.62 MPa), and the surface speed was 345 ft/minute (1.75 m/s).



**Figure 5**

This worn PN 507-5-11 seal ran for 111 hours with Valvoline multi-purpose grease. The bulk temperature was 162°F (72.2°C), the grease pressure was 80 psi (0.55 MPa), and the surface speed was 345 ft/minute (1.75 m/s).





**Figure 6**

This worn PN 507-5-30 seal ran for 100.3 hours with Valvoline multi-purpose grease. The bulk temperature was 162°F (72.2°C), the grease pressure was 50 psi (345 kPa), and the surface speed was 345 ft/minute (1.75 m/s).



**Figure 7**

This worn PN 507-5-30 seal ran for 138.3 hours with Valvoline multi-purpose grease. The bulk temperature was 170°F (72.2°C), the grease pressure was 80 psi (0.55 MPa), and the surface speed was 345 ft/minute (1.75 m/s).

## 5. Biodegradable lubricants

A certain amount of Kalsi Seal™ testing has been performed with biodegradable lubricants; call for more information. For a better understanding of biodegradable lubricants, see Society of Tribologists and Lubrication Engineers (STLE) Preprint No. 97-WTC-20, titled “Biodegradable Lubricants”.

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