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Effects of wet lubrication on Bal Seal® spring-energized seal performance

Technical Report

TR-10 (Rev. C; 07-28-15)

(100-41-2)

19650 Pauling
Foothill Ranch, CA
USA 92610-2610
t +1 949 460 2100
f +1 949 460 2300
www.balseal.com

VIDA Building, 1st floor
Kabelweg 57
1019 GW Amsterdam
The Netherlands
t +31 20 638 6523
f +31 20 625 6018
www.balseal.nl

Suite 901, Chinachem
Century Tower
178 Gloucester Road,
Wanchai, Hong Kong
t +852 28681860
f +852 22956753
www.balseal.com.hk

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1.0 Summary

This report outlines the selection and use of wet lubricants and how these lubricants affect Bal Seal® spring-energized seal performance.

2.0 Introduction

Using wet lubricants in conjunction with Bal Seal® spring-energized seals not only enhances the seal performance but also improves the overall performance of the equipment in which a Bal Seal® is placed. This report focuses on several types of oils, methods of lubrication, properties of wet lubricants (i.e., viscosity, wettability, surface tension, demulsifying properties, and oxidation resistance), and the effect of wet lubrication on Bal Seal® performance.

3.0 Purpose of Lubrication

3.1 Keeping Surfaces Separate

The main purpose of lubrication is to keep moving parts separated, thus lowering friction and wear. This is accomplished by creating a thin film of lubrication between moving parts.

3.2 Heat Distribution

When moving parts come in contact with each other, heat builds up due to friction. This results in poor performance or failure of parts. Lubrication keeps these parts separated and helps dissipate heat by transferring it throughout the lubricant film and taking it away from part surfaces.

4.0 Types of Oils

4.1 Hydraulic Oils

Hydraulic oils, usually turbine-grade oils (i.e., SAE 10 or 20), are used as a power transmission medium.

4.2 Turbine Oils

Turbine oils are premium, highly refined, pale oils with a high demulsibility, usually SAE 10 grade.

4.3 High-Speed Oils

High-speed oils are generally low-viscosity oils. Low viscosity provides lower shear force, reducing wear to metal surfaces and to the seal’s surfaces.

4.4 Silicone Oils

Silicone lubricants display good thermal and oxidation resistance characteristics. They are best used in high temperatures, up to 400 °F (204 °C) and higher with special blends, as they have one of the best viscosity indexes of all synthetics. However, most silicone polymers display low adhesion qualities and high shearing, leading to rapid degradation.

4.5 High-Pressure Oils

High-pressure oils are used in applications of 100–100,000 psi (6.89–6894.75 bar). The purpose of these lubricants is to reduce wear and friction while lowering compressibility. Low-viscosity oils are selected for high-pressure applications; however, the surface tension of the lubricant must also be considered. High surface tensions lead to poor wetting, resulting in boundary lubrication.

4.6 Fluorine-Based Oils

Fluoropolymer (CTFE) oils are fluorine-based oils and are primarily used due to their non-volatility characteristics. They are best used where the possibility of ignition is present.

4.7 Properties of Typical Lubricants

Type of Oil	Viscosity (cST) at 100 °C	Viscosity Index	Surface Tension	Military Specification
Hydraulic oil	4.9 Min.	113	N/A	MIL-PRF-5606
Turbine oil	4.90–5.40	103	N/A	MIL-PRF-23699
High-speed oil	5.2	103	N/A	No Specification
Silicone oil	50	424	N/A	No Specification
High-pressure oil	12.9	103	29.5 dynes/cm @ 100 °F (37.77 °C)	MIL-PRF-6085
Fluorine-based oil	N/A	N/A	15 dynes/cm @ 100 °F (37.77 °C)	No Specification

cST = centistokes

5.0 Methods of Lubrication

5.1 Hydrodynamic Lubrication

The sealing surfaces are separated continuously by a lubricating film (under pressure) whose thickness is greater than the average surface roughness of the metal sealing face (see Figure 1).

In hydrodynamic lubricating conditions, friction is determined almost solely by the lubricant viscosity. Because no other factors affect friction, (e.g. roughness of the metal sealing surface), it is typically lowest under this type of lubrication.

5.2 Mixed Lubrication

With increased pressure and/or decreased lubricant viscosity, partial contact of the seal and metal sealing surface occurs (see Figure 2).

Lubricating thickness (H) is generally equal to the average roughness of the metal sealing surface (Ra). Friction is partially due to shearing of the lubricant film and contact between the seal and metal sealing surface.

5.3 Boundary Lubrication

The thickness of the lubricating film is generally less than the average roughness of the metal sealing surface (see Figure 3).

There is almost continuous contact between the seal and metal sealing surface. Wear can be rapid and is similar to dry, non-lubricated conditions.

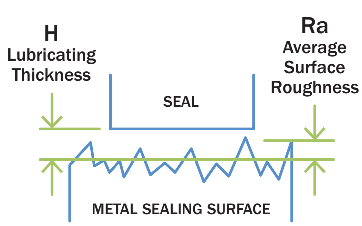

Figure 1.
Hydrodynamic Lubrication

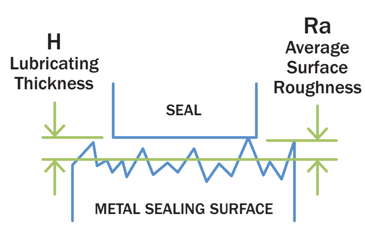

Figure 2.
Mixed Lubrication

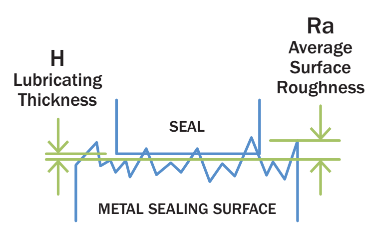

Figure 3.
Boundary Lubrication

6.0 Properties of Wet Lubricants

6.1 Viscosity

6.1.1 Measuring Viscosity

Viscosity is measured by observing the time required for a certain liquid to flow through a short tube with a small bore. Viscosity can be measured in centistokes (cST) at temperatures of 100 °F (37.77 °C) and 210 °F (98.88 °C).

6.1.2 Effects of Temperature Change

Change in temperature inversely affects lubricant viscosity. As temperature increases, liquid viscosity decreases. The viscosity index (VI) is a means of measuring the change in the viscosity of a liquid due to temperature change. A viscosity index of 100 or above represents high resistance to change in viscosity due to temperature fluctuation, and viscosity index of 0 represents low resistance to viscosity change.

6.1.3 Effects of Viscosity on Friction

The fluid viscosity and any friction affect each other. As friction increases, temperature increases, causing a breakdown in viscosity. High-viscosity fluids tend to cause more friction, raising the temperature; therefore, when selecting a lubricant, it is imperative to choose a viscosity that is high enough to lubricate well, but low enough to keep friction to a minimum.

6.1.4 Classification of Viscosity

The Society of Automotive Engineers (SAE) system is a method of grading lubricants according to their viscosities (see Tables 2 and 3). A difference of 10 in the SAE number represents a 50% viscosity increase over the previous number. (Example: SAE 30 is 50% more viscous than SAE 20).

Table 2. SAE Viscosity Classification

SAE Viscosity No.	Viscosity Range in Centistokes (cST)			
	Min. at 0 °F	Max. at 0 °F	Min. at 210 °F	Max. at 210 °F
Crankcase Oils				
5W		869		
10W	1,303	2,606		
20W	2,606	10,423		
20			5.73	9.62
30			9.62	12.93
40			12.93	16.77
50			16.77	22.68
Transmission Oils				
75		3,257		
80	3,257	21,716		
90			14.24	25.0
140			25.0	42.7
250			42.7	

Table 3. Viscosity of Fluids

Fluids	Temp °F (°C)	Viscosity (cST)
Water		
	2 (–16.66)	1.792
	50 (10.00)	1.308
	68.4 (20.22)	1.000
	100 (37.77)	0.679
	150 (65.55)	0.432
	212 (100.00)	0.284
Air		
	32 (0.00)	0.0171
	150 (65.55)	0.0201
Gasoline, Specific Gravity: 0.70		
	32 (0.00)	0.05
	150 (65.55)	0.25

6.2 Wettability

In sliding systems operating under hydrodynamic conditions, viscosity is the most important bulk physical property to consider when selecting a lubricant. However, in some cases, another property exists that can prevent achieving full lubrication. This property is known as the wettability (or oiliness) of a lubricant. This is a property that enables a lubricant to form a uniform film over the whole surface to be lubricated. If the surface tension of a lubricant is high, the wettability will be low, causing bare spots in the surface to be lubricated. Bare spots are non-lubricated areas that can cause higher friction and undue wear; therefore, it is important to review the surface tension and wettability of a lubricant before using it in a certain situation.

6.3 Surface Tension

Another property of liquids is surface tension. A small sample of a liquid placed on a flat surface will tend to remain in the shape of a sphere. This is due to an amount of free energy at the liquid's surface. A certain amount of work has to be done to overcome this energy at the surface in order to spread the liquid. The resistance to this work (i.e., surface tension) is measured in dynes per centimeter. Surface tension can prohibit the fluid from spreading easily and evenly. This is of great importance in lubricants. High surface tension can keep the lubricant from forming a uniform film on the bearing surface. Some surface tensions of typical fluids are shown in Table 4.

Table 4. Fluid Surface Tension in dynes per cm

Fluids	dynes/cm
Mercury	487.0
Water	72.0
Olive oil	34.7
Mineral oil	32.0
Lubricating oil	29.5
Ethyl alcohol	22.0

6.4 Demulsifying Properties

Certain processes in machinery involve the use of water and steam. Depending on the chemical composition of the lubricant, emulsions may form when the lubricant comes in contact with the water. An emulsion occurs when two or more liquids are mixed that ordinarily would not mix together. Demulsibility is the quality of a lubricant to break down or resist formations of emulsions. When applying a lubricant to a situation where water may be present, it is important that the lubricant has good demulsibility.

6.5 Oxidation Resistance

It is required that a lubricant maintain its basic chemical properties (to remain stable in its chemical composition) when used in machinery. Changes in a lubricant's properties while in use are caused by dilution, contamination, etc. However, most changes can be traced to its molecular structure, which is primarily changed by oxidation of the lubricant (exposure to air or oxygen during operation). Due to the complex chemical composition of hydrocarbon oil, the exact nature of products formed by oxidation is difficult to identify; however, it is believed that organic peroxides are the first products formed by oxidation. These peroxides are corrosive to various bearing metals and lead to further oxidation. Good oxidation resistance is important for lubricants, especially for those that may come in contact with oxygen or air. Specific additives and corrosion inhibitors have been designed for use with lubricants to help retard oxidation (e.g., rust preventatives, pour-point depressants, and corrosion inhibitors).

7.0 Fluid Lubricants and Bal Seal® Spring-Energized Seal Performance

Wet lubrication can significantly improve Bal Seal® spring-energized seal performance, depending on the lubricant, pressure, temperature, and speed of the application. Best results are obtained when hydrodynamic lubrication exists at pressures up to 7 psi (0.54 kg/cm²). Refer to Table 5 for potential speed at various pressures in oil lubrication. Lubricants with low viscosity and low shear force properties should be used, i.e., SAE 30 or MIL-PRF-5606 hydraulic oil.

Table 5. Pressure vs. surface speed for PTFE Bal Seal spring-energized seals in lubricating oil in hydrodynamic service.

Max. Pressure psi (kg/cm²)	Max. Surface Speed ft/min (m/sec)
7 (0.49)	1000 (5)
5 (0.35)	2000 (10)
3 (0.21)	3000 (15)
1 (0.07)	5000 (25)

SAE 30 oil @ 70 °F (21 °C), using SP 45 Bal Seal spring-energized seals.
Recommendations in hydrodynamic service media.

8.0 References

Marks, Lionel S., *Marks' Handbook* (Textbook Edition)