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"Lubrication Practices for Heavy Movable Bridges"

by Brian H. O'Connor
Bergmann Associates, Inc.

LUBRICATION PRACTICES FOR MOVABLE BRIDGES

Written By: **Brian H. O'Connor**

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Brian H. O'Connor
Mechanical Engineer
Bergmann Associates
Hoboken, NJ
(201) 653-2898 ext 313

BRIEF HISTORY OF LUBRICATION

Since the beginning, nature has been applying lubrication in the form of synovial fluid, which lubricates the joints and bursas in an animal's body. Prehistoric man used mud and reeds to lubricate sledges for dragging game or timbers and rocks for construction. Animal fats were the first lubricants used on the bearing points of wagon axles.

The first major contributions to the study and development of lubricants was not performed until Osborne Reynolds developed fluid-film lubrication theory in 1886, following Beauchamp Tower's discovery of hydrodynamic lubrication (Tower studied railroad car journal bearings in England in 1885).

Animal fats continued in wide use until the petroleum industry arose in the 19th century, after which refined petroleum became the principle source of lubricants. The natural lubricating capacity of crude petroleum has been steadily improved through the development of a wide variety of modern machinery, and has in turn made possible the increase in speed and capacity of them.

More recently the science and technology of tribology, (study of interacting fricative surfaces in relative motion, to include effects of lubrication and wear) has provided lubricant manufacturers with the ability to produce the state of the art "High Performance Lubricants" available to us today. Lubricants, derived from the Latin verb *Lubricare,* meaning "to make slippery", are any substance – liquid, solid, or gas – introduced between two relative moving sliding surfaces intended to control friction and wear. However due to the standard practices of Movable Bridges (MB) this discussion will be limited to liquid type lubricants, more specifically grease and oil.

LUBRICATION; HOW IT WORKS

It is more than obvious to each of us that fundamentally grease and oil are identical to each other, in fact oil is the major constituent in grease; why wouldn't they be. This statement is 100% accurate if your only responsibility is to operate a particular device and know that it is performing satisfactorily without prematurely wearing itself out. If you are the designer, installer, mechanic, maintenance person, or even the owner, you need to know that this statement is just as WRONG as it is right. Designers and technical people alike need to know which medium is best suited for each application, and vise versa. However this decision would be difficult to be made correctly without a good strong understanding of the application, its environment and lubricants, the different mediums available, their mechanical properties, their chemical properties, compatibility with one another, practicality, availability, and even costs for that matter.

Lubrication Films. In engineering practice it is usually desirable to design a mechanism to operate with a fluid film separating the surfaces. **Hydrodynamic Lubrication** (also known as **full film**) occurs when the pressures developed in a converging fluid film are sufficient to support the load. For a hydrodynamic state to exist, the combination of speed (approximately higher than 25 feet per minute), load and viscosity of the lubricant must be in a specific range so that the internal pressure, created by converging surfaces, in the fluid becomes equal to or greater than the radial load. An increase in speed or viscosity will produce a thicker film, while increasing the load will decrease the film thickness. This condition is typically achieved in high-speed plain and thrust type bearings (e.g. internal combustion engines) and is rarely, if ever, generated on movable bridge applications.

In fact this condition does not occur in most machinery. Typically, as in the case of roller bearings and certain gears, the geometry of the surfaces and the normal range of loading are such that the oil film is squeezed until it begins to approach the dimensions of the surface roughness of the contacting parts. As a result, very high pressures develop and elastic yielding of the bearing material momentarily occurs as oil viscosity dramatically increases (keep in mind pressure is a function of viscosity). This condition is known as **Elastohydrodynamic Lubrication (EHL),** or **mixed film**, and is prevalent from the point when classical Hydrodynamic conditions no longer exist to when the oil film thickness is reduced to about 4 times the average surface roughness. On moving bridges this condition would exist in bearings on high to mid speed shafts (higher than 10 feet per minute) and between some high-speed gear engagements.

In certain applications, where the lowest possible frictional forces are required but the speed, load and viscosity relationships of the fluid are not balanced enough to support pure Hydrodynamic conditions, a **Hydrostatic** condition may be created. Hydrostatic bearings are supplied with lubricants under pressure from an external source. These bearings produce low friction and have high load capacity in addition to longer life. There benefits would be ideal for the large trunnion and thrust bearings found on movable bridges, however they require a greater maintenance effort and are costly.

When the oil film becomes thinner, as on slow moving roller and plain type bearings, including slower moving gears, surface asperities begin to rub increasingly against each other. Fluid films of molecular dimensions must be present to prevent damaging the high surface finishes. This condition is known as **Boundary Lubrication** and requires lubricants with additives to ensure adequate protection of moving parts. This is generally only acceptable for slow moving rotary and oscillating mechanisms and is common in moving bridge applications.

Each and every application will produce a specific film characteristic and will require particular lubricant types and properties for a successful operation.

LUBRICATING OILS; TYPES AND PROPERTIES

Oil Lubricant Types. It would not be practical or even possible to discuss the near infinite range of lubricant types and their properties. Despite how interesting some of them may be, in particular SAE multi-grade lubricants, this discussion will be limited to the types common with the movable bridge industry. *Animal and vegetable products* were some of the earliest lubricant stocks produced by man for the purpose of controlling wear and reducing load resistance. Though they have excellent lubricity, they lack chemical inertness and have a tendency to oxidize rapidly leading to the formation of sludge, lacquer, and potentially corrosive acids. Currently, they are sometimes used as additives to improve lubricity or to form soaps, which in combination with oils, set up grease structures. Pure fatty oils, yet still available, have been largely superseded by more formidable products and should be avoided on movable bridge applications.

Mineral oils, or more specifically *Petroleum oils* (refined petroleum fractions from naturally occurring hydrocarbons), have succeeded them. The success of the petroleum products is due partially to advancements in refinery techniques, but is better attributed to the mechanical and chemical properties that these paraffin-base and nephthene-base products have to offer. They are available in a much larger range of viscosity, have a lower volatility, are more chemically inert, better protect sliding surfaces against corrosion and are less expensive.

Synthetic lubricants are composed of synthesized hydrocarbons and have some properties that are similar to petroleum lubricants. Their inception has been brought about to meet the increased demands of technology rather than because of petroleum shortages. These lubricants offer improved properties like lower volatility, stability of viscosity over wider temperature ranges and better resistance to scuffing and oxidation. However these lubricants are not as readily available and generally are obtained at higher costs.

In addition to the previously discussed lubricant-types there are also *Solid lubricants*. These lubricants are made up of solids like graphite, molybdenum disulfide, polytetrafluoroethylene, babbit, silver and metallic oxides; and on movable bridges are usually seen as additives in greases and oils where boundary and mixed film conditions are common.

Lubricant Properties. There are a multitude of lubricant properties to be considered when designing lubrication systems and specifications. Since each application has its own special requirements it is imperative that "critical" properties be identified and satisfied first. Unfortunately it is only practical that commercially stocked products be used in bridge applications. As a result there may be properties of a particular product that may not be the best suited for the intended purpose. Designers may then be forced to compromise "non-critical" properties if a better product can not be found. None of this process may effectively be accomplished without a strong understanding of the application and function of lubricant properties. The following bullets will discuss properties and how they apply to bridge machinery.

Viscosity. Viscosity, simply defined as a fluid's ability to flow, is by the far the most "critical" property of any lubricant. Hence, viscosity should be the principal element when selecting a lubricant for a particular application and warrants more than just a simple cursory review.

Viscosity is the primary factor in a lubricant's ability to:

- control wear and too reduce friction
- maintain particular film conditions
- Provide product retention
- Remove/dissipate heat from working parts
- Assist seal functions / minimize leakage
- Facilitate pumpability

The thicker the fluid, the higher resistance it will have to flow and subsequently will have a higher viscosity rating. Lubricant and machinery manufacturers primarily reference two systems for measuring viscosity, *Kinematic* (metric) and *Saybolt Universal* (American standard).

Kinematic Viscosity, in short, related to the time that a specific quantity of oil requires to flow through a standard size capillary tube at a specific temperature, as per the *American Society of Testing Materials (ASTM)* (D-445). Depending upon the consistency of the oil, tests are performed at either 40°C or 100°C, units are centistokes (cSt).

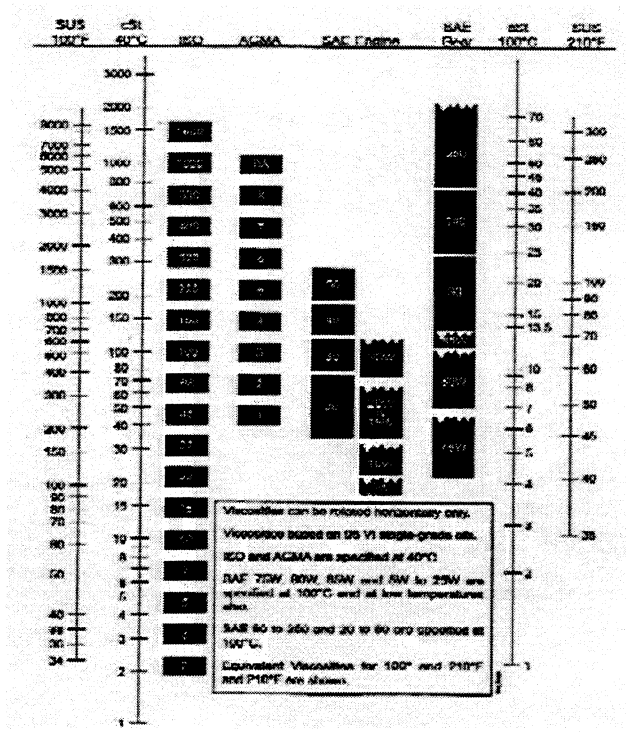
Saybolt Viscosity is the time, in seconds, required for 60 ml of oil to flow through a standard orifice under a standard falling head at either 100°F or 210°F, as per ASTM (D-88). The time measured in seconds is the viscosity of the oil in units of *Saybolt Universal Seconds (SUS).*

Typically, suppliers of lubricants and machinery will provide both ratings. Some of the less reputable products may not provide either. Any product that does not provide viscosity information should be discarded (there is a reason for it).

Another practice used by the industry that better correlates ranges of viscosity with the actual applications is called *Viscosity Grade* or *Viscosity Classification*. There are three relative to bridge applications. The two classifications for industrial oils are the *International Standards Organization (ISO)* and the *American Gear Manufacturers Association (AGMA)* systems. The third, which is generally used for automobile gear oil, is called the *Society of Automotive Engineering (SAE)* system.

Additionally, in lieu of a viscosity measure or viscosity grade, machinery manufacturers may provide a table of specific product recommendations. However, in this case, the recommended product must still be reviewed in detail so that all of its components are compatible with all of the application's criteria.

The following chart will compare the different rating systems and how they relate to Saybolt and Centistoke viscosity values.



The following table is similar to the preceding chart, however it is produced by the AGMA and gives numeric values. Notice the viscosity column consists of ranges not specific values.

Table 2 - AGMA GEAR LUBRICANT NUMBERS

AGMA STANDARD SPECIFICATION
INDUSTRIAL GEAR LUBRICATION
VISCOSITY RANGES FOR AGMA LUBRICANTS

Rust and Oxidation Inhibited Gear Oils AGMA Lubricant No.	Viscosity Range[1] mm²/s(cSt) at 40°C	Equivalent ISO Grade[1]	Extreme Pressure Gear Lubricants[2] AGMA Lubricant No.	Synthetic Gear Oils[3] AGMA Lubricant No.
0		32		0 S
1	41.4-50.6	46		1 S
2	61.2-74.8	68	2EP	2 S
3	90-110	100	3EP	3 S
4	135-165	150	4EP	4 S
5	198-242	220	5EP	5 S
6	288-352	320	6EP	6 S
7, 7 comp.[4]	414-506	460	7EP	7 S
8, 8 comp.[4]	612-748	680	8EP	8 S
8A comp.[4]	1350-1650	1000	8AEP	–
9	900-1100	1500	9EP	9 S
10	2880-3520	–	10EP	10 S
11	4140-5060	–	11EP	11 S
12	6120-7480	–	12EP	12 S
13	190 to 220 cSt at 100°C (212°F)[5]	–	13EP	13 S

Residual Compounds[6] AGMA Lubricant No.	Viscosity Ranges[1] cSt at 100°C (212°F)
14R	428.5 to 857.0
15R	857.0 to 1714.0

NOTES
1) Per ISO 3448, *Industrial Liquid Lubricants–ISO Viscosity Classification*. Also, ASTM D 2422 and British Standards Institution B. S. 4231.
2) Extreme pressure lubricants should be used only when recommended by the gear manufacturer.
3) Synthetic gear oils 9S – 13S are available but not yet in wide use.
4) Oils marked Comp are compounded with 3% to 10% fatty or synthetic fatty oils.
5) Viscosities of AGMA Lubricant Number 13 and above are specified at 100°C (212°F) as measurement of viscosities of these heavy lubricants at 40°C (104°F) would not be practical.
6) Residual compounds–diluent type, commonly known as solvent cutbacks, are heavy oils containing a volatile, non-flammable diluent for ease of application. The diluent evaporates leaving a thick film of lubricant on the gear teeth. Viscosities listed are for the base compound without diluent.

CAUTION: These lubricants may require special handling and storage procedures. Diluent can be toxic or irritating to the skin. Do not use these lubricants without proper ventilation. Consult lubricant supplier's instructions.

Extracted from ANSI/AGMA 9005-D94, *Industrial Gear Lubrication*

Grease products are rated by the *National Lubricating Grease Institute (NLGI)* system and will be covered in the next section.

Viscosity Index. Viscosity Index (VI) is an empirical number indicating the rate of change in viscosity of an oil within a given temperature change. A low VI signifies a relatively large change in temperature, whereas a high VI indicates a minimal change in viscosity with temperature. For most mechanical applications, where there is no actual heat source, a higher VI is the best. Internal Combustion engines however, need the highest VI possible.

Neutralization Number. Neutralization Number, also called *Total Acid Number*, is a measure of an oils acidic components. The number is expressed in milligrams of potassium hydroxide needed to neutralize the acid in on gram of oil. If oil sampling is performed this test will detect an oxidizing condition in the lubricant.

Total Base Number. Total Base Number is a measure of alkaline components in oils. The number is the weight in milligrams of Hydrochloric Acid required to neutralize one gram of oil.

Oxidation Stability. Oxidation Stability is the resistance a lubricant has to oxidize. Oxidation is chemical process that will break down a lubricant when exposed to elevated temperatures in the presence of oxygen and catalytically active metals or metallic compounds. The oxidation process becomes critical when oil is operating above 150°F, and will approximately double for each 18°F increment. Under EHL film conditions this critical temperature is very obtainable, even under ambient conditions without a heat source. As a result of oxidation a lubricant may develop an increase in viscosity, become acidic, become sludge-like and/or produce varnish. However, normally the process is very slow and on regularly maintained systems it usually does not become a problem.

Rust Prevention. Rust Prevention indicates the ability of a lubricant to prevent corrosion of ferrous parts in the presence of water or a moisture-laden atmosphere. Most lubricants can not adequately prevent rust without the aid of rust and corrosion protection additives especially when parts are only intermittently wetted with oil.

Demulsibility. Demulsibility, or *Water-Separation* properties are the ability of an oil to separate from water. Its measure will indicate how well an emulsion of oil and water will take to separate before excessive quantities accumulate and lead to rust and/or lubrication problems. This property may be particularly important in an application that is exposed to water run off, driven rain, or even in areas of high humidity.

Cloud Point. Cloud Point is the low temperature at which oil will begin to crystallize and become hazy, or wax-like, in appearance. This temperature is important because it indicates the point where the lubricant may begin to clog filters or small orifices in parts.

<u>Pour Point</u>. Pour Point is the low temperature point at which a lubricant CAN flow from its container. This temperature point is important, for the same reasons that Cloud Point is important, for oils that do not wax or where wax crystallization is not visible.

<u>Lubricity</u>. Lubricity, or *Oiliness,* is essentially the *Film Strength* of a lubricant, which is an indication of how well it can lubricate, or in other words how slippery a condition it can create. In Boundary Film conditions it is critical that the correct lubricant be used. Not all oils have the properties to maintain adequate lubrication performance under these extreme conditions. One very important test for movable bridges evaluates the load-carrying capacity under heavy-duty conditions. It's known as the *Timken OK Load Test* (ASTM D2782 for oil and ASTM D2509 for grease) and was devised by the Timken Bearing Company.

Lubricant Additives. Many applications require lubricants with properties that differ from the naturally occurring properties of Paraffinic or Naphthenic base stocks, or their blends. As a result, to impart new properties or to improve existing properties, an *Additive*, which is a chemical compound, is introduced to the product.

With all the different kinds of additives and their different combinations, or "additive-packages", the process of selecting a product can become ambiguous. To aid in this process an understanding of the advantages and disadvantages, as well as the side effects, of additives must be ascertained. An important note to keep in mind is that additives usually are not stable over the entire temperature and shear-rate ranges considered acceptable for the base stock oil application. Because of this, additive type oils must be carefully monitored to insure that they are not continued in service after their principal capabilities have been diminished or depleted.

The following discussions will give some insight as to the different types of additives and their applications.

<u>Oiliness Agent</u>. Oiliness Agents are used to increase the lubricity, or film strength, which is intended to prevent wear and scoring under thin film (EHL) or boundary lubrication.

<u>Extreme Pressure</u>. Extreme Pressure (EP) agents are intended to reduce friction and control wear under heavier loads at higher temperatures. Typically they are compounds of sulfur or phosphorus that chemically react with metal surfaces to form oil-soluble surface films which act to prevent metal to metal contact. See the section on "Grease Lubricant Additives" for a further discussion.

<u>Anti-Wear</u>. Anti-wear agents are very similar to EP additives. For mild sliding polar materials such as fatty oils, acids and esters form adsorbed films in the metal surfaces.

<u>Tackiness Agents</u>. Tackiness agents are used in applications to increase adhesion and improve retention on contacting surfaces.

Anti-Foam. Anti-foam agents control foam caused by aeration. Typically silicone oil is used to break up larger surface bubbles while polymers are introduced to decrease the small bubbles entrained in the oil.

Rust Inhibitor. Rust Inhibitors provide protection to ferrous materials against rusting. Depending upon the agent in use either a water-resistant film is created at the surface or by neutralizing corrosive acids.

Anti-Oxidation. Anti-Oxidants, also called *Oxidant Inhibitors*, function by neutralizing metal catalyst, or by breaking down or modifying peroxides (oxidizing products) to render them inert.

Corrosion Inhibitor. Corrosion Inhibitors protect metal parts of chemical attacks from contaminants. They can either chemically neutralize metal surfaces so that they are less reactive, or they may simply maintain an oil film as a protective coating. These agents are generally successful and should be considered in most applications.

Emulsifiers. Emulsifiers retain solutions of oil and water from separation.

Demulsifiers. Demulsifiers enhance the ability of a non-water-miscible fluid to separate from water with which it is mixed. The higher the demulsibility rating, the more rapidly the separation will occur.

Dispersant/Detergents. Dispersant agents retain insoluble oil oxidation products in a homogeneous solution preventing the formation of harmful buildups like sludge and or varnish. Since the materials cause the oil to carry a higher than normal amount of the breakdown products in a fine suspension, they may cause an accelerated deposition rate or foaming when they have been depleted or degenerated by contamination action. Ingestion of water in humid environments, or by direct exposure to rain run off, may cause markedly harmful effects.

Pour Point Depressant. Pour Point Depressants are polymers that depress the formation of wax crystals at low temperatures enabling better flow in those regions.

Petroleum Manufacturers and the Machinery Industry do not always agree on the effectiveness of all additives. It is important to keep in mind that marketing efforts may influence what goes into a lubricant regardless of how effective that particular component may be. And although the function of the additive may appear to create a "wonder lubricant" they actually may have an adverse effect on other properties of the host. Many application experts now feel it's best to keep it simple, the fewer additives the better. If a particular product needs to many additives it just may be that the base oil may not be fit for the job. Still in all, a reputable lubricant manufacturer, not a supplier, is the best source of information regarding additives. However, it must be accepted that the interrelation of variables prohibit precise recommendations or predictions of fluid durability and performance. Monitoring should be performed to insure that the final selection performs optimally.

LUBRICATING GREASES; TYPES AND PROPERTIES

In movable bridges there are many devices where an oil type lubricating system would be just to complicated, or costly. For the most part, these particular devices, by application or service requirements, warrant a grease type lubricant.

Although in some regards they are very similar to oils, their application, and less obviously the way they function, make them quite unique. Greases are essentially lubricating oils with relatively small dispersions of a thickening agent that when mixed together create solid or semi-solid structures. These stiff mediums serve as a time-release mechanism that discharge, or "bleed", lubricating oils during shearing actions. Though the thickener very often has lubrication properties of it's own, oil bleeding from the bulk is the actual functioning element. As the shear pressure begins to fracture the grease structure, the grease begins to bleed like a sponge being squeezed of water. Unlike oil systems this relatively small amount of mobile lubricant is all that is needed for a satisfactory operation. Most commonly greases are employed where:

- complex oil circulation systems and sumps are not practical.
- lubricant must adhere or be retained on parts or contacting surfaces.
- enhanced sealing action is required due to dirty/moist environment.
- an increased protection against rusting of ferrous materials is required.
- full-film lubrication is not possible.

Based on the mobile lubricant principles the actual lubricating oils in greases are very similar to those in liquid lubricants. Most importantly is the viscosity, base oil viscosity in grease should be determined the same as for liquid lubricants, for all practical purposes, there should be no difference. One thing that is very much different is the flow characteristics of grease. Grease unlike oil is a Non-Newtonian fluid, in other words its *Apparent Viscosity*, while in pure grease form, is a function of its rate of shear. Unlike oils, which are Newtonian, where the faster they are pushed the more resistance they will have to flow.

Grease Lubricant Types. Grease are manufactured with one, or a combination, of a variety of lubricating oils mixed with one, or a combination, of an even larger variety of thickening agents called *"Soaps"*. Grease-base-oils, which represent approximately 90% of the compound, are the pure forms of standard oil type lubricants (not to insinuate that greases are free of additives); they include Animal/Vegetable, Mineral/Petroleum, and/or Synthetic oil types. As a result, all natural lubricating oil properties discussed previously apply to base oils as well.

Essentially, grease types are categorized by the make-up of their thickening agent, which can be divided into two general groups, *Conventional Soap* and *Non-Soap* type thickeners. Conventional Soap thickeners, the most common, are typically processed out of five different metallic elements; calcium, sodium, aluminum, lithium, and barium, used either singly or in combination. More recently, complex versions of the calcium, aluminum, and lithium types have been introduced.

Complex Soaps are created when the soap crystal or fiber is co-crystallized with a complexing agent, the result is a higher load carrying capability at higher operating temperatures, than the pure form, and are well suited for many MB applications.

Non-Soap thickeners, or Non-Metallic Soap thickeners, which are less common, can either be *"Organic"* or *"Inorganic"*. Non-Soap organic compounds are oxidatively and thermally stable thickeners usually made of Fats and or Fatty Acids.

Polyurea is an organic type thickener, which is formed by the reaction of various amines and isocyanates. It gives exceptionally long durability in high-speed bearing operating at high temperatures.

Inorganic type non-soap thickeners are manufactured out of either petroleum or synthetic liquids that are capable of creating very stable products. However, they are hydrophilic and will absorb water on their surfaces, so they require an additive to impart water repellent properties. The following is a brief summary of grease types that are commercially available.

<u>*Conventional Soap Grease Bases*</u>

Calcium Base. Calcium grease also referred to as cup grease normally contains water to stabilize the compound. The max continuous usable temperature is approximately 160°F, beyond that and the water is lost and separation of the components will begin. They show good resistance to water washing and have been successful in both dry and wet operations that only experience moderate temperatures. Its low cost is a major advantage.

Sodium Base. Sodium grease at one time had been recognized for having a superior dropping point, in the 350°F range, and operating temperatures, in the 250°F range. This was higher than any other available product until the introduction of Lithium. Also, sodium grease is not water-resistant and is poorly suited for wet or continuously moist environments. Although, ironically, it does have some inherent rust inhibiting characteristics that are superior to other types of grease that are not provided with corrosion inhibiting additives; mechanical stability is only average at best. They're not very suitable for high loads or high shear rates.

Lithium Base. Lithium grease, which is presently the most available of all greases, provides fair water resistance characteristics, but with excellent thermal and mechanical stability. It was, and still is, one of the first successful *General- Purpose Greases*.

Aluminum Complex Base. Aluminum Complex, like all complex compounds, is an excellent general purpose lubricant. This compound provides outstanding protection against rust, without additives, and has excellent water-resistance properties. Its mechanical stability is very good, along with its reactivity.

Lithium Complex Base. Lithium Complex maintains a high dropping point, with good water-resistance and good pumpability that provides long bearing life. Its mechanical stability is excellent, however it's not a completely inert medium and in some applications may require oxidant inhibitors, maintenance efforts should be punctual. This base is most known for it's successful service in automobile front wheel-bearings and is suitable for MB applications.

Non-Soap Grease Bases (Inorganic)

Clay Base. Clay base greases are thickened with non-melting, water-resistant thickeners, where the apparent viscosity of the greases is affected very little with increasing temperature. Their benefit is that they bleed very little as compared to soap type greases, but are poor rust and oxidant inhibitors. These greases are usually only employed in extreme temperature environments and are not well suited for MB applications.

Non-Soap Grease Bases (Organic)

Polyurea. Polyurea, despite inferior mechanical stability test results, has lasted ten times longer than lithium grease when subjected to the 300°F Navy rig bearing test. Furthermore, in the much higher shear rates that are normal for antifriction bearings, polyurea has performed without leakage or other stability problems. This grease is an excellent combatant against fretting corrosion and is suitable for MB applications. Chemically it's more stable than Lithium Complex.

> (**NOTE**: The properties of Polyurea are a prime example of how functional/performance tests performed in a lab have the potential of being misconstrued to simulate specific field service conditions.)

Grease Lubricant Properties. As with oil lubricants, there are a multitude of functions that a grease product is required to perform, and then some. Those properties however are not as clearly understood as with oil products. In order to specify or employ the correct grease for a particular application their purpose and abilities, along with application requirements, must be clearly understood. Equally important, since grease products used in MB applications are essentially Commercial (off-the-shelf) items, it is likely that not all of the properties in a particular product will be required for the intended purpose. Likewise, it is equally probable that a product may lack a certain property, thereby not completely satisfying field conditions. If the ideal product is not available you must identify those "critical" and "non-critical" properties and prioritize. The following information will aid in the process.

Grease products are composed of a Base Oil and a Thickener that are usually accompanied by additives. In designing a grease specification the two *MOST IMPORTANT* properties to consider are the thickener's *Consistency*, which is the most recognized aspect of a grease and is how they are classified by the *National Lubricating Grease Institute (NLGI),* and Base Oil viscosity, particularly when operating under Boundary or Mixed-Film conditions. Ironically, base-oil information, as important as it is, is usually not specified on product containers. However this information is paramount and can either be obtained from product spec sheets or by directly contacting the manufacturer. Remember that bleeding oil from the grease bulk is the actual lubricating function, not the thickener. Determining the proper viscosity will be discussed later. The remainder of this section will discuss grease properties as described by manufacturers and as listed by the NLGI Grease Application Guide.

Consistency. Consistency or *Firmness* of grease is the principal reason why grease is chosen over oil for a particular application. It is a measure of how fluid or firm the bulk is. Consistency is determined by the depth at which a Cone penetrates into a grease sample, as described by the Cone Penetration Test (ASTM D217). In this test a standardized cone is dropped into a sample for a period of 5 seconds at 77°F. The rating is the actual depth of penetration in tenths of millimeters. Two versions of the test exist, there is the "Standard Penetration" or Unworked (described above) and there is the "Worked Penetration Test" where the sample is double stroked 60 times at 77°F in a churn before testing. Worked penetration better simulates product performance and is the principal measure used to categorize grease grades by the NLGI.

Since grease consistency may be effected by minor changes during processing, temperature cycling, time in storage, exposure to environment, and the amount of handling it may receive, the NLGI has established consistency numbers, or *Grades*, based on penetration ranges rather than specific values. Grades begin at 000 and go to 6, thin to thick, respectfully. Each grade represents 30 penetration points with gaps between them, for errors supposedly.

NLGI GREASE CONSISTENCY NUMBERS

NLGI Number	ASTM Worked Penetration
000	445-475
00	400-430
0	355-385
1	310-340
2	265-295
3	220-250
4	175-205
5	130-160
6	85-115

Note: The grades are defined as ranges of the values of the 60 stroke worked penetration, in tenths of millimeters, as determined by ASTM D 217, *Cone Penetration of Lubricating Greases.*

Worked Stability. Worked Stability, also referred to as *Mechanical Stability* or *Consistency Stability*, is the ability to withstand repeated working with minimum change in it's structure or consistency. Worked grease will usually soften, some may harden depending upon formulation and service conditions. Although, since test results are given in percentage points it can not be determined from the results which way the sample responds.

To determine Worked Stability a worked sample is measured for cone penetration as described above, afterwards the same sample is worked for 10,000 strokes and measured for cone penetration again (ASTM D217-A). See the following table for standardized ratings.

Worked Stability Final Reading – Initial Reading = % Change	
Percent Change	**Rating**
1 to 5%	Excellent
5.1 to 15%	Good
15.1 to 30%	Fail
30.1% +	Poor

<u>*Temperature Stability*</u>. Temperature stability evaluates the performance of a grease at elevated temperatures. Because grease does not exhibit a true melting point, some definitive temperature where a sudden change in state is experienced, performance is determined by two values; Dropping point and Maximum Usable Temperature. *Dropping Point* (ASTM D566) is a measure of the temperature at which there is a total breakdown of a product's ability to lubricate. However, long before this point the grease has already begun to oxidize and too bleed-off oil. *Maximum Usable Temperature* is the point at which oil bleed-off and oxidation becomes aggravated by temperature conditions.

> **Note:** Dropping Point and Max Temperature are the results of controlled laboratory tests under ideal conditions. Their values will depreciate due to service conditions and age of product.

<u>*Oxidation Stability*</u>. (Same as "Oxidation Stability" in Oil Lubricant Properties section) Good oxidation stability is imperative in applications that are open to moist environments (e.g. large trunnion-type bearings) and where EP additives are employed.

<u>*Load Carrying Capacity*</u>. Load Carrying Capacity is a property of particular importance in MB applications. Particularly where operating systems are running under Boundary Film Conditions. This information will indicate grease's ability to control Wear Rates and establishes Lubricant Life Cycles under both light and heavy loading. There are three standardized tests used: *Timken EP Lubricant Tester, Falex Tester*, and *Four-Ball EP Lubricant Tester*. Base-oil viscosity will have a profound affect on a lubricant's ability to carry loads.

<u>*Protection Against Rust*</u>. Protection Against Rust describes the ability of grease to prevent the formation of rust on ferrous materials. A product may use on of two different methods to accomplish this. Either the grease may be required to establish and maintain a protective film over material surfaces shielding them against exposure to oxygen, or a rust inhibitor may be used to neutralize a reactive condition. The latter method will also enhance the product's Oxidation Stability. Good rust protection is imperative in applications that are open to moist environments (e.g. large trunnion-type bearings and or open gears) and where EP additives are employed.

Slumping. Slumping is the ability for a product to not hold form under it's own weight. It is some times referred to as "falling in" and will vary with temperature. For the most part, it's a function of it's NLGI Consistency Rating.

Channeling. Channeling is the ability that a product has to hold form under it's own weight, or not slump. It's NLGI Consistency Rating is a factor, as are temperature variations.

Water Resistance. Water Resistance describes the ability for a grease to resist being washed away by direct washing/spraying of water which is conducive to the effects of driven rain. Good water resistance is critical on open racks and pinions that are out in the open. It may also be of importance to some trunnion applications that are exposed to rain run-off.

Oil Separation. Oil Separation, also refer to as *"Bleeding"*, may be slightly ambiguous in that a grease needs to bleed, but shouldn't bleed excessively. In many applications bleeding is the way in which a grease supplies oil product into interacting surfaces. However, excessive bleeding is essentially wasted oil product and will shorten grease service life.

Storage Stability. Storage Stability is an evaluation of the effects on grease stored over time. Many grease products can soften and or bleed over time, while others may become stiffer. Storage life may depreciate depending upon the type of thickener and various facility conditions: temperature, humidity, amount of handling, etc. Simply consult the manufacturer to determine storage life.

Pumpability in Central Systems. Pumpability can be described as a grease's ability to perform during pumping operations. Should a grease be to thin it might be forced to separate. If it's to thick it may overload the pump or even block system; operating temperatures are a factor as well.

Compatibility. Compatibility is an assessment of how a particular grease type will interact with other greases of different thickener types. A respectable percentage of thickener types react adversely when mixed with different thickeners. Non-compatible greases when mixed together may solidify or loosen and bleed out base oil.

The following table is the Grease Application Guide produced by the NLGI. It is a good source of information for the different property characteristics that are inherent in the different thickener-types. Keep in mind that the data is generalized and that actual grease properties will vary with specific manufacturing processes, oxidation stability, NLGI grease classifications, base-oil viscosity, and even product age.

Making a correct grease application recommendation was made much easier with the introduction of multi-service greases. With the exception of extreme conditions such as water wash, high and low temperatures, and chemical contamination, most multi-service greases, regardless of thickener type, will perform satisfactorily in the majority of applications. This Guide takes some of the mystery out of making grease recommendations.

	Thickener Type									
Properties	Aluminum	Sodium	Calcium-Conventional	Calcium Anhydrous	Lithium	Aluminum Complex	Calcium Complex	Lithium Complex	Polyurea	Organo-Clay
Drop. Pt.(°F)	230	325-350	205-220	275-290	350-400	500+	500+	500+	470	500+
Drop. Pt.(°C)	110	163-177	96-104	135-143	177-204	260+	260+	260+	243	260+
Max. Usable Temp.(°F)	175	250	200	230	275	350	350	350	350	350
Max. Usable Temp.(°C)	79	121	93	110	135	177	177	177	177	177
Water Resistance	Good to Excellent	Poor to Fair	Good to Excellent	Excellent	Good	Good to Excellent	Fair to Excellent	Good to Excellent	Good to Excellent	Fair to Excellent
Worked Stability	Poor	Fair	Fair to Good	Good to Excellent	Good to Excellent	Good to Excellent	Fair to Good	Good to Excellent	Poor to Good	Fair to Good
Oxidation Stability	Excellent	Poor to Good	Poor to Excellent	Fair to Excellent	Fair to Excellent	Fair to Excellent	Poor to Good	Fair to Excellent	Good to Excellent	Good
Protection Against Rust	Good to Excellent	Good to Excellent	Poor to Excellent	Poor to Excellent	Poor to Excellent	Good to Excellent	Fair to Excellent	Fair to Excellent	Fair to Excellent	Poor to Excellent
Pumpability in Central Systems	Poor	Poor to Fair	Good to Excellent	Fair to Excellent	Fair to Excellent	Fair to Good	Poor to Fair	Good to Excellent	Good to Excellent	Good
Oil Separation	Good	Fair to Good	Poor to Good	Good	Good to Excellent	Good to Excellent	Good to Excellent	Good to Excellent	Good to Excellent	Good to Excellent
Appearance	Smooth and Clear	Smooth to Fibrous	Smooth and Buttery	Smooth and Buttery	Smooth and Buttery	Smooth and Buttery	Smooth and Buttery	Smooth and Buttery	Smooth and Buttery	Smooth and Buttery
Other Properties		Adhesive and Cohesive	EP Grades Available	EP Grades Available	EP Grades Available, Reversible	EP Grades Available, Reversible	EP Antiwear Inherent	EP Grades Available	EP Grades Available	
Production Volume/Trend (1)	No Change	Declining	Declining	No Change	The Leader	Increasing	Declining	Increasing	No Change	Declining
Principal Uses (2)	Thread Lubricants	Rolling Contact Bearings	General Uses for Economy	Military Multiservice	Multiservice Automotive & Industrial	Multiservice Industrial	Multiservice Automotive & Industrial	Multiservice Automotive & Industrial	Multiservice Automotive & Industrial	High Temp. (frequent re-lube)

Notes (1) Lithium grease over 50 percent of production and all others below 10 percent. (2) Multiservice includes rolling contact bearings, plain bearings, and others.

Grease Lubricant Additives. Greases in their pure forms, as with lubricating oils, do not always maintain the most desirable property characteristics for their intended purpose. As a result, manufacturers may introduce an *Additive* to either enhance an insufficient property or to impart new ones, or they may introduce an *Inhibitor* to retard the effects of a destructive type property. In general many of the Additives that are employed in oil lubricants are common to grease lubricants as well, and serve the same purpose. Anti-wear additives, extreme pressure additives, demulsifiers, metal wetting additives, corrosion inhibitors (film or passive), oxidation inhibitors, solid lubricants, and tackiness agents are some of the more important ones. Due to their specific importance in greases only tackiness agents, extreme pressure additives, and solid lubricants will be discussed in this section. Refer to the "Oil Lubricant Additives" section for discussions on the others.

<u>Tackiness Agents</u>. Tackiness Agents are used to enhance product adhesion or to "make it stick". There are a number of different agents used to accomplish this. The most used is a residual asphaltic compound commonly known as *Crater Compound*. Anyone that has ever worked with it knows how well it works. However it's resistance to oxidation is very low and it does not function well in cold environments.

<u>Extreme Pressure Additives</u>. Extreme Pressure Additives are by far the most recognized and controversial grease additives. These additives provide increased protection against friction and wear, SPECIFICALLY during poor film conditions. Poor film conditions are unstable boundary-type film conditions where physical metal to metal contact is either sustained or occurs intermittently. Generally, the grease consistency and or base-oil viscosity is not able to maintain film integrity due to either; excessively high or fluctuating loads, vibrations or impacts, slow machinery speeds (e.g. during start-up or creep speed operations), or

degradation of product properties (i.e. by contamination, oxidation, or "aged" product depleted of base-oil). Under these conditions it is imperative that EP additives be available to control the effects of friction and wear.

Also, it is important to understand that it is not necessarily a particular additive that qualifies a product as an EP lubricant, as much as it is a rating. To qualify as an EP lubricant the product must produce a minimal result in either the *Timpken OK* or *Four-Ball Test*.

Many different types of EP additives are used in grease products. Most of them are compounds of sulfur or phosphorus that form oil-soluble surface films. Consequently these compounds, by their nature, are very reactive and have the ability to create a corrosive environment; temperature and moisture will act as a catalyst. Therefore it is just as important, when selecting an EP product, to select a product that has excellent oxidation and rust stability. Normally their useful service life will expire prematurely with respect to the host product.

Furthermore, EP additives are intended for gear and sliding-type bearing applications, not for frictionless bearings. Currently the Automobile Industry is in contention with the Petroleum Industry to have these additives removed from wheel-bearing greases. They claim that EP additives attribute to premature bearing failure brought about by the degradation of the rolling elements and their races. According to the NLGI, specific testing conducted by the Automobile Industry does support their claim. However, the exact reason goes unconcluded. Some experts feel that by the nature of their function EP's compromise the integrity of polished and hardened roller/race surface finishes under extreme conditions. Due to this newest information one would be best advised to reframe from the use any EP additives where their service is not absolutely essential.

Solid Lubricants. Solid Lubricants, or *Dry Lubricants*, are used to control friction and wear under extreme conditions where there may have been a total breakdown of a films ability to lubricate and or where a loss of lubricant has occurred. Generally they are not used to produce EP products, although they may enhance EP ratings. These lubricants adhere in some degree by mechanical or molecular action. There is no chemical reaction so they typically do not create corrosive conditions, as EP's may. The most common used are molybdenum disulfide, graphite, polytetrafluoroethylene, and/or metal oxides. These additives are well suited for open gear, large trunnion, and open sliding applications. They most never should be used in frictionless-type bearing applications, especially in conjunction with EP products. In these applications they could be considered as a contaminant for their abrasive nature, material surfaces are to hard.

SELECTION OF LUBRICANTS

For the most part choosing between oil and grease in a MB application is a no-brainer. Grease, hands-down, is the preferred method of lubrication for the majority of the mechanical devices due to its simplicity, service requirements and relative cleanliness. Oil usage, the majority of the time, is limited to enclosed gearboxes, some radial-bearing applications and center pivot bearings on swing bridges. For this reason the remainder of this paper will concentrate more on grease products and their application, although oils will be mentioned from time to time.

Selecting any kind of lubricant requires the consideration of several factors. The most important of which are the:

- desired/anticipated mode of film condition (full, mixed, or boundary film)
- relative speed of moving parts
- types and size of loads
- operating temperatures

Other factors include, but are not limited to:

- realistic time frame between service intervals
- extreme temperature conditions
- presence of contamination (to include foreign matter and moisture)
- possibility of metal to metal contact (impacting, vibrations, loss of lubricant)
- inherent effectiveness of sealing functions
- system's cost or customer's preference

In general oils are best suited for applications where higher surface speeds are expected to create full or mixed film conditions, as they are balanced with load conditions. Also, oils are used where operating temperatures are high, above 180°F so that heat may be carried away with system flow.

Grease on the other hand is more functional under boundary or mixed film conditions created by slower speeds and higher load relationships. Since grease has retention it has the ability to stick to interacting surfaces which also gives good protection during irregular loading (i.e. vibrations, impacting, start-ups, metal to metal contact). The downside is that they do not function well where high operating temperatures are experienced and for the most part, are not filterable. However they serve as excellent sealing devices themselves and in many applications do not require oil-tight sealing. Due to their simplicity they are more cost effective to design, build and operate than oil systems and usually require less frequent servicing.

It can not be emphasized enough that the most important aspect to be considered while selecting any lubricant, whether it be oil or grease, is its base-oil *Viscosity*. Should a type of lubricant not yet be determined, or more specifically the film condition, viscosity properties that are available in the different products may facilitate the decision. If all other variables are known, which is the usual case, and it's the viscosity that must be determined there are tons of empirical data produced by responsible organizations in the form of tables and charts that are easy to use. To name of few is the NLGI, AGMA, ABMA (American Bearing

Manufacturers Assoc.), ISO, and or the ASTM. These organizations normally use a *Speed Factor* (Bore Dia. x RPM) in conjunction with a series of graphs that may incorporate operating temperatures and or load factors to determine viscosity ratings. The resultant value is only a base line, loading conditions or other variables may influence the final selection. Of course nothing could replace the advantages of good field-testing provided the opportunity was there. A mathematical analysis is also a possibility, but with all of the available empirical data it's not warranted.

For Grease products the NLGI Consistency rating is as equally important as base-oil viscosity. Consistency ratings are for the most part independent of base-oil viscosity and should be selected based upon application requirements. Things to be considered are operating temperature ranges, pump-ability, channeling, slumping, retention, sealing requirements and churning to name a few. Most MB applications work well with NLGI 1 or 2 consistencies. Non-enclosed linear sliding bearings may consider a No. 3 grease for increased water wash stability. A lubrication expert or NLGI application guides are a good source of information for specific recommendations.

Thickener types are the second most important consideration in selecting grease products. Lithium and Lithium Complex soaps make excellent greases and are well suited for most every MB machine component. Also since these soaps are so widely produced they come in a variety of base-oil viscosity, grease consistencies and with different additive packages. Polyurea is just as good, if not better in some aspects, but is not compatible with many other bases. Furthermore it is not as available as the Lithium's, as well as being more costly. For more information refer to NLGI Grease Application Guides.

Additives and Inhibitors are the third most important aspect to be considered. Their intricacies and how they relate with each other and their environment has been briefly discussed in previous sections. More discussions will be covered in the following sections. Should more information be required consult any of the above listed organizations, or a person whom is a known expert in this area. Equipment manufacturers are not always the most knowledgeable about additive specifics and grease manufacturers tend not to disclose potentially adverse side effects of their recommendations (e.g. EP phenomenon).

Lubrication of Mechanical Devices

Movable Bridges use grease to lubricate a number of different types of bearings and gears. Common bearings are radial bearings, both plain and friction-less roller type, linear bearings, and thrust type bearings used on center pivoting swing bridges. Gears are usually the open-gear simple spur-type or bevel where the grease product actually adheres to the contacting surfaces. Herringbone, helical, spiral bevel, and in some rarer cases worm gears are also used, but are normally associated with enclosed gearboxes that are oil lubricated. Couplings will also be discussed in this section.

Plain Bearings, or *Sleeve Bearings,* are common in MB trunnion bearings for Vertical Lift bridge sheaves and for Bascule mains. Due to the high loads, slow operating speeds and need for product retention (no mechanical seals) grease is most always used. Their size and large bearing clearances provide for aggressive convergence zones that smear ultra thin films of fresh product into the contact area. Consequently, it is important the bearing be kept full of fresh clean grease and be periodically cleaned of old grease. The disadvantage of these bearings is that they are impossible to conveniently disassemble for cleaning and have the tendency to retain old product despite the best re-lubrication efforts. Old grease will eventually breakdown and may become reactive and oxidize, solidify, bleed out, and/or produce lacquer or varnish type coatings on journal surfaces. These coatings are destructive in that they may prevent certain additives from developing oil-soluble surface films (e.g. EP agents). A good design will provide lubricant in an area of low pressure as close to the contact area as possible, not directly into it, in addition to locations elsewhere around the annular area.

The best grease product for these devices should posses the highest base-oil viscosity possible be EP rated and contain solid lubricant additives for added protection. In addition these products should have good oxidation and rust stability for increased service life. NLGI Consistency rating should be high enough to maintain product retention, yet low enough to prevent cold temperature problems and to allow for slumping during all operating conditions. Slumping is necessary for bulk located higher up in the bearing to fall into the convergence zones located directly adjacent to the contact area.

Friction-less Roller Bearings are found throughout various locations in MB machinery. Many of them serve as support bearings for machine line shafts, pinion shafts, electric motor housings, in enclosed gear reducers, and more recently have been employed on Bascule bridges replacing the conventional Plain-type trunnion bearings. Of course depending upon speed and radial load, these bearings can operated under full, mixed, or boundary film conditions and can be lubricated with either oil or grease lubricants.

Grease lubricated roller bearings operating under mixed film conditions are the most common to MB applications. Greases provide lubricant to the rolling element in the form of a thin film of oil that is squeezed out of the product by shearing forces. This oil film is subjected to extremely high pressures within the contact zone and for an instant undergoes a dramatic increase in viscosity. This enables the lubricant film to with stand the high contact stresses while preventing metal to metal contact between the rolling surfaces. Also, these high contact pressures will elastically and momentarily deform the rolling surfaces momentarily thereby enlarging the contact area that is directly responsible for supporting the load.

As a freshly charged bearing begins to rotate, grease is slung from the rolling elements and is pushed out to the housing. A small portion of it remains inside the bearing itself where shearing will take place releasing the oil lubricant. The discharged bulk of the lubricant will build wall-like damming structures along bearing sides, which consequently will cover existing (perhaps expired) grease product and help trap the newly released oil product. As bearing elements continue to rotate the newly created grease dam will now need to slump back in towards the rolling element at a very controlled rate (ideally, slow enough to last until the next service). Impinging product will then be pulled back in and behind a passing roller where the cycle will begin again. To ensure the longest possible life, by the mechanics of this process it is important that roller bearings are never over filled and should be periodically cleaned out before it's cavity is filled completely; consult bearing manufacturer.

Always consult manufacturer when selecting grease products for roller bearings, as well. These devices need a NLGI consistency rating that will provide good channeling as well as be able to slump throughout the entire operating temperature range. Base oil viscosity needs to be just heavy enough to develop film integrity, yet light enough to prevent adverse temperature conditions and churning. In oil lubricated bearings oil levels should be just high enough to submerge half of the lowest bearing to prevent churning and foaming. Avoid the use of EP additives and never deploy Solid Lubricant additives, they are a contaminant in this application; consult manufacturer and or the NLGI.

Linear Bearings are used in MB applications in numerous forms. Mostly they serve as span guides, centering devices, lifting wedges, nose-locks, or even tail-locks to name a few. What the majority of them have in common is that they usually are open-type bearings, operate at slow speeds, experience high loads, are directly exposed to the outside elements, oscillate and have bushings that are typically made of bronze. Because they operate with such slow speeds and high loads, boundary-type film conditions are guaranteed. Their function by design along with their need to withstand direct exposed to rain, water run-off, and/or scraping-off requires a special purpose grease that is extremely tenacious in nature. *Crater Grease*, sometimes called *Grease Tar*, are residual asphaltic compounds and are well suited for applications of this nature. These compounds are usually brushed or sprayed on with solvents; pay attention to health warnings. Due to their specific nature there are not a lot of varieties available. Consulting a local distributor for product recommendations would be sufficient in this case.

Some Linear bearings are designed to operate using more standard type grease products. In these applications a NLGI No. 2, 3, or even 4 EP rated greases with solid lubricants, good channeling, minimal slumping, tackiness agents, water stable, that are oxidation and rust stable are best suited. Due to the harsh environment frequent servicing is advised for optimum life.

Thrust bearings are most commonly used for the larger center pivot bearing used on swing bridges. These large bearings consist of two spherical discs, one is bronze and the other is steel. The upper disc is a convex shaped while the lower disc is concave shaped with a slightly larger radius of curvature. This slight difference in curvature, amongst other things, provides for a centralized contact area at bearing center with convergence zones surrounding and immediately adjacent. Due to their inability to be opened and disassembled and cleaned, oil bath systems are normally used. Oil level is maintained at some point above the highest elevation of the upper disc so that the entire interface is submerged. Oil is usually drained from center of the lower bearing. Oil grooves are provided in the bronze disc to provide lubricant coverage, which also facilitates settling out of contaminants into the lowest point.

These bearings commonly experience extremely slow speeds and are required to support millions of pounds, boundary film conditions are guaranteed. The proper oil lubricants for thrust bearings will have a high viscosity, but not excessively high to where it will restrict good penetration into the contact area. The selected oil should also have excellent lubricity, good rust and oxidation stability, and be EP rated. Solid lubricant additives should also be considered.

Open Gears are employed in the majority of MB machinery. Usually they are the straight spur-type common to the rack and pinions on swing bridges, vertical lifts and bascule leafs. Bevel gears used to change direction of transmission shafts are not nearly as common, but can be open as well.

In either type, tooth engagement cycles see both sliding and rolling actions. Their relative surface speeds are slow by gear standards with moderate to high loads being transmitted. Gear sets are intermittently lubricated which presents a "feast-or-famine" condition. Therefore, on the faster moving vertical lift racks, thick full films may exist at time of application, but will quickly diminish to mixed or boundary films once bulk is squeezed out. Slower moving Bascule and Swing racks will experience a similar event, however they are more likely to approach truer boundary-type film conditions.

Additionally, their need to withstand direct exposed to rain, water run-off, resist oxidation and rust and/or scraping-off by meshing teeth requires a special purpose grease. Base-oil viscosity should be the highest obtainable and should include EP additives. Due to the nature of the application the product should be a residual asphaltic compound. These compounds are extremely tenacious in nature and are brushed on or sprayed on with solvents; pay attention to health warnings. The NLGI, AGMA, and ISO are good sources for additional information.

Couplings. There are a few different coupling styles that are employed on bridge machinery. Those of them that require lubrication should use the manufacturers recommended product. If not, a product with excellent centrifuge stability will prevent bleeding and product separation. This is of particular importance on applications that employ brake-wheel couplings. Centrifugal forces will eventually move oil bleed-out onto brake wheel surfaces hindering their ability to perform.

SERVICING LUBRICANTS

One frequently asked questions is "When should I re-lubricate?" This is not always a very easy question to answer. How often to service and change lubricants depends on a variety of factors, but none is more important than the experience of a good maintenance person or engineer that is proficient in this area.

At any rate, one good place to start is on the limitations of the grease product itself. Since grease soaps are not totally inert they will tend to oxidize in storage and deplete themselves by bleeding-out base oil. This is the storage-ability of the product and is typically in the range of two years for most soaps. Therefore, 2 years is the absolute longest any grease product should be around, whether it's in service or not. If it is in service, the existing product should be entirely cleaned out and recharged with new grease. It would not be possible to make specific recommendations in this paper. There are way to many variables within the devices themselves not to mention unique environmental conditions.

Cleaning Lubricated Parts. One very important servicing issue is the proper method of cleaning lubricated devices. Always, always, refrain form the use of solvents for cleaning purposes. The absolute best method of cleaning any device is by mechanical means. And never touch highly polished running surfaces with your hands, use rubber gloves. Perspiration and hand-oil will contaminate and attack surface-finishes; guaranteed.

Should a situation arise where the device can not be easily disassembled try flushing the device with light mineral oil, heated oil will work even better (120°F). If there is any residue or stiff grease that's tough to remove try soaking parts with the oil at that temp or higher if possible, for a few hours or even a day if need be.

On parts that still present a problem Kerosene is very effective in loosening thick black clogged product, soaking with it will help. Afterwards flush continuously with light mineral oil before re-lubricating.

Some deposits are so hard and thick they appear like plastic. This is the only time solvents should be considered; when all else fails. Once the fouled product has been removed allow solvent to evaporate, hair dryers work perfect. Then flush continuously with light mineral oil until all solvent residue has been removed and re-lubricate. It is imperative no solvent is left to contaminate fresh lubricant. If unusual bleeding occurs shortly after a solvent was used in the cleaning process, it may indicate that the new grease has been contaminated. Try pumping it through or remove and replace with fresh grease again.

TROUBLE SHOOTING/INSPECTING LUBRICANTS

There are few important observations that could be made while inspecting or trouble shooting machine components, to include their lubricants. This information can be valuable in detecting and preventing future problems or to resolve existing ones. Some of the things to look for are:

- Excessive oil-bleed or pooling on or around grease lubricated bearings. This may be an indication that the wrong grease product is being applied, product is expired, bearing may be running hot, or product is contaminated.

- Color changes in the grease product. Darkening indicates the product has been contaminated or is oxidizing.

- Changes in grease consistency. Hardening may indicate the product is expired or depleted of oil, not suitable for temperature condition (if cold), or if there has been a change in product it may indicate incompatibility.

- Operating noise levels of individual components. Abnormally loud devices may indicate that it is poorly lubricated or that it has experienced a respectable degree or wear and needs a thicker lubricant.

- Odor of lubricant. Unusual smells may indicate burnt lubricant or an oxidizing condition.

- Varnish or lacquer formations on bearings race. Both are a product of an oxidizing condition. Varnish is generally associated with contamination or expired product, while lacquer is a result of an overheating condition. Lacquer is harder than varnish.

- Small dark tarnished areas or spots on bearing surfaces. May indicate formation of rust due to insufficient rust inhibiting property, product breakdown, wrong product or contamination.

- Leaking reducer seals. Leaks on older units may indicate that seals are simply wearing, a heavier grade oil may resolve the problem. Although it is possible that there is a compatibility issue with seal material.

These are just a few of the more obvious and common signs.

Most lubrication problems are easily resolved with minimal effort. On the other hand some problems can be much more complicated and may require an extensive effort. Part of exercising a good preventive maintenance effort is staying alert and paying attention to the slightest details of each component. Keeping things clean and monitoring each device as frequent as possible during operation is a good practice. An excellent way to monitor a device is to lay a hand on it during operation. You will become accustomed to the way it heats and vibrates during operation enabling you to detect any early signs of problems.

CONCLUSION

In short, one simply needs to be aware of what good lubrication practices are and how they are influenced by application requirements and environmental conditions. The information contained in this paper is a product of the most current information available, and over 15 years of practical machinery experience. The idea here is not to teach an individual the science of lubrication, but to familiarize them with the principals and maybe to stimulate a more informed thought process. Let's face it, Movable Bridges are massive robust machines that are extremely resilient, even to the neglect of maintenance. However, hypothetically speaking, if next year only 3 bridges instead of 5 will require extensive repairs, due to enhanced lubrication practices, it would be worth it.

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