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LUBRICATION SURVEY FORM

Application type (bearing, chain, etc.): ________________________________

______________________________________________________________

Operating Temperature: ____________________________________________

______________________________________________________________

Operating conditions: ____________________________________________

______________________________________________________________

Speed: ______________

Estimated Load: __________

Environmental Conditions (dust, dirt, moisture): ______________________

______________________________________________________________

Sudden starts/stops: ______________________________________________

______________________________________________________________

Vibration: ______________

Lubrication Schedule (list type and amount of lubricant): ________________

______________________________________________________________

Method of application: ____________________________________________

______________________________________________________________

Additional Comments: ____________________________________________

______________________________________________________________
API – American Petroleum Institute
AGMA – American Gear Manufacturers Association
Asperities – The irregular features in a contact surface.
ASTM – American Society for Testing and Materials
Axial – Referring to the length of an object, for example an axial load on a shaft is parallel to the length (axis) of that shaft.
Boundary Lubrication – That condition in which the lubricant film is discontinuous.
Babbit – An alloy, or mixture of metals that is softer than the metal used in the rotating components. It has a lower coefficient of friction and acts as a sacrificial component in the moving assembly; it will not gall or score the shaft. It is named for its inventor.

**Coefficient of Friction** – The coefficient of friction is the ratio of the force required to move an object and the normal force or weight of an object. The coefficient of friction is dependent upon the nature of the material. Some coefficients of friction for various materials are:
- Bronze on bronze: 0.20
- Tool steel on tool steel: 0.42
- Mild steel on mild steel: 0.57
- Hard steel on babbit metal: 0.34

**Cone** – The inner part of an antifriction bearing

**Elastohydrodynamic Lubrication** – A mode of lubrication which relies on the deformation of the contact surfaces in conjunction with the viscosity of an oil at high speeds to establish a protective film.

**Fretting** – A condition of wear characterized by grooving or lines spaced at intervals around a shaft. It can be caused by oscillating motion with small amounts of play (approx. 1 micron) in the assembly. Usually design related.

**Galling** – Destructive wear of a metal surface characterized by large chunks of metal being removed.

**Hydrodynamic Lubrication** – That condition of lubrication in which a continuous film separates the moving parts.

**Idler** – A rotating element neither driving nor driven. It is simply used as a low friction support for a chain or belt.

**Kinematic** – Refers to viscosity measured by its rate of flow due to its mass.

**Lubricity** – A property of a lubricant to reduce friction beyond that expected by viscosity alone.

**Naphthenic** – Composed of compounds of a more cyclic and/or aromatic nature; low ashing.

**Paraffinic** – Composed of long straight chains of hydrocarbons.

**Poise** – A unit of dynamic (sheared between moving surfaces) viscosity measurement.

**Race** – The outer contact surface of a rolling element bearing.

**Radial** – Referring to something perpendicular to a rotating assembly; A Radial load is at 90° to the shaft.

**Rib-roller velocity** – the velocity of the rollers in an antifriction bearing which will help determine the lubrication requirements of a bearing.

**Shock Loading** – A condition caused by sudden startup or stoppage of equipment. Change in loading is rapid and places added sites on bearing and other parts.

**Spalling** – A condition of metal fatigue in which the surface of the metal flakes off.

**SAE** – Society of Automotive Engineers

**Stoke** – A unit of measurement for kinematic viscosity in units m²/sec

**SUS** – Saybolt Universal Second; yet another unit for measurement of fluid viscosity.

**SSU** – See SUS

**Timken** – Test Method named for bearing manufacturer of the same name (see Figure 6, page 8).
**Grease Chemistry**

In general, greases contain between 70-90% oil, 5-15% thickeners, and up to 10% additives. The oils and additives are essentially the same products used throughout the industry and previous discussions apply to the oil fraction of a grease as to oils in general. The thickeners, however, will affect the temperature and water resistant properties of a grease and therefore an understanding of thickening agents is necessary.

The thickener in a grease is usually a metallic soap, but nonsoap thickeners are used as well. The soaps used are made by the saponification of animal fat or the neutralization of fatty acids. Soap-thickened greases comprise about 85% of all greases in use. They are economical and offer good lubricity. The nonsoap thickeners are less frequently used. While they usually offer high melting temperatures, some (bentonite clays and silica gels) can leave a residue that can be abrasive to metal parts, particularly if the grease is not manufactured carefully.

Polyurea based greases are a newer technology in thickening agents. These greases offer high dropping points and good resistance to water washout, but they are marginally compatible with some soap based greases.

Soap based greases use a wide array of metallic soaps. Soaps are more often identified by the metal because it is the metal that determines the soap characteristics. A list of soaps is shown below:

- Lithium stearate
- Lithium 12-hydroxystearate
- Lithium complex
- Hydrated calcium
- Anhydrous calcium
- Calcium complex
- Aluminum
- Sodium
- Barium

In general, the complex greases have highest dropping points, with calcium and aluminum at the high end. For metallic soaps, calcium is highest in dropping point, with sodium and lithium at successively lower dropping points. The sodium based greases are often incompatible with other thickeners. Sodium greases offer less water resistance than other greases. This along with lower dropping points has made sodium greases less common of late.

Lithium greases are by far the most common of all greases and represent more than half of all greases used. Initially, lithium stearate was the most popular grease on the market, but it is being supplanted by lithium 12-hydroxystearate. The hydroxystearate soap imparts a higher dropping point. Lithium complex greases typically have dropping points of about 260°C (500°F).

Of the calcium based greases, the calcium complex greases have the best resistance to heat and water washout. The wear resistance and shelf life are improved at higher thickener levels.

Anhydrous calcium greases have good heat resistance, but not as good as that for lithium. The water resistance is fair to good. The least temperature resistance is obtained with calcium hydrated greases, because the thickener incorporates up to 2% water in its chemical makeup. The grease is compromised when the water begins to cook off at 80°C (about 175°F). Water washout resistance and low temperature handling are very good, however.

Aluminum based greases, although not very common, have good stability over a high temperature range, with high (260°C/500°F) dropping points. The water resistance is excellent, but the lithium complex greases offer comparable performance at a lower cost.
THE PRACTICE OF lubrication is an ancient one. Water was probably the first lubricant. When primeval man used water or ice to ease the sliding movement of heavy objects, the idea of lubrication was born. He later found that certain plants and animals contained oily secretions or had natural oils in their tissues. It was found that these oils had the advantage of a low evaporation rate, and the coefficient of friction was lower than that for water.

What our Neanderthal ancestors were trying to do was to reduce friction, how they did it was not as important as the need to do it.

**What is Friction?**

Simply put, friction is the resistance to motion caused by the direct contact of parts. In typical operations, friction must be overcome by the addition of force or energy.

Friction is a measurable phenomenon and it is usually measured and expressed as a coefficient of friction. The coefficient of friction is the ratio of the force required to move an object to the normal force or weight of that object.

Friction in machinery manifests itself in several ways:

- Power losses
- Lower efficiency
- Generation of heat
- Wear
- Equipment Failure/Seizure

At the microscopic level, friction is caused by the direct contact of asperities. All surfaces, even the truest and most highly polished surfaces, have a rough nature (Figure 1). They are composed of minute projections and depressions, or “hills and valleys”. These surface irregularities are called asperities and can interlock to impede the sliding movement of parts (Figure 2a on page 4). The asperities also reduce the actual contact area available for load carrying. When the parts move, some of these asperities are deformed and may be subjected to very high localized temperatures. The asperities cold flow or “weld” together and increase the resistance to motion. The welded asperities then shear as the relative motion of surfaces continues. The surfaces do not shear cleanly, but yield a rather jagged profile less uniform than the initial surface. Small amounts of material are transferred from one surface to the other, and some small amount of material may be eroded from both metal surfaces.

This is a continuous process repeated millions of times over a contact or bearing surface. It is these weld/shear cycles that result in the phenomenon of wear. As the welds increase both in number and in frequency, seizure can occur. This is a catastrophic mode of failure.
The best way to reduce wear, seizure, and friction is to prevent asperity contact. A lubricant is a substance which accomplishes this. A lubricant is usually a fluid, although it may also be a solid or semisolid, that flows between contact surfaces to form a film. Under the best of conditions, the moving parts do not actually make contact, but glide on this film (Figure 2b). Friction is greatly reduced, because the resistance to movement is determined primarily by the viscosity of the lubricant. Wear is also reduced due to the elimination of asperity contact. Finally, with reduced friction, the amount of heat generated is greatly reduced. Heat reduction is a very real benefit, because:

- Working tolerances are maintained
- There is less fatigue of metals and other bearing materials
- The life of the equipment is extended

Figure 2

a. Asperity contact of dry surfaces
b. Separation of surfaces with lubricant film
In order to recognize the proper lubricant viscosity, it is essential that the relationship between viscosity units be understood.

The table in Figure 3, (page 6) lists the common viscosity measurement standards and schematically shows how the scales relate. It is interesting to notice that an SAE 50 crankcase oil, SAE 90 weight gear oil and an ISO 220 lubricant can all have the same viscosity.

Oils with the letter “W” in their rating have been tested at low temperatures as well as at 40°C (100°F) and 100°C (212°F). The cold testing specifies the maximum viscosity measured and these materials are known as multigrade oils (e.g. SAE 80W-150, 20W-50).

As an example, let’s say that a maintenance engineer has read an equipment manufacturer’s recommendation for an ISO 68 viscosity grade lubricant. A prospective replacement has a viscosity of 65 cP. The question is, will this oil be a suitable replacement in terms of viscosity?

First, we know that an ISO 68 lubricant has a viscosity that can range from 61.2 - 74.8 cSt. If we can obtain specific gravity data from the Material Safety Data Sheet (MSDS), we can convert from centipoise to centistokes.

From the MSDS, we find that the specific gravity is 0.87

Converting to cSt

65 cP = 74.7 cSt vs.

0.87 72.80 cSt for ISO 68

This viscosity is at the upper limit for an ISO 68 viscosity grade lubricant. Therefore this 65 cP lubricant will be acceptable.
**Viscosity Detailed**

The most empirical of measurements is the Saybolt Universal Viscosity. It involves the time it takes for a defined amount of sample to flow through out of a standard container with a precisely measured hole in the bottom (Figure 16 on page 25). The measurement is usually taken at a controlled temperature, usually 38°C (100°F) or 100°C (212°F). Viscosity is reported in Saybolt Universal Seconds or SUS, although the abbreviation SSU has also been used.

A more accurate measure of viscosity is kinematic viscosity. It is reported in units of centistokes (cSt). Again, measurements are taken at 40° and 100° C. Kinematic viscosity is called the ISO (International Standards Organization) system. ISO viscosity grades are determined by the measurement of kinematic viscosity at 38°C (100°F). ISO viscosity grades are listed in the table above.

It is interesting to note that the ISO grading has gaps into which a lubricant might not conceivably fit. However, due to the increasing adherence to ISO procedures and documentation, it is likely that this system will see increasing use in industry.

<table>
<thead>
<tr>
<th>ISO Grade</th>
<th>Viscosity Range cSt @ 38°C (100°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1.98 - 2.42</td>
</tr>
<tr>
<td>3</td>
<td>2.88 - 3.52</td>
</tr>
<tr>
<td>5</td>
<td>4.14 - 5.06</td>
</tr>
<tr>
<td>7</td>
<td>6.12 - 7.48</td>
</tr>
<tr>
<td>10</td>
<td>9.00 - 11.00</td>
</tr>
<tr>
<td>15</td>
<td>13.50 - 16.50</td>
</tr>
<tr>
<td>22</td>
<td>19.80 - 24.20</td>
</tr>
<tr>
<td>32</td>
<td>28.80 - 35.20</td>
</tr>
<tr>
<td>46</td>
<td>41.40 - 50.60</td>
</tr>
<tr>
<td>68</td>
<td>61.20 - 74.80</td>
</tr>
<tr>
<td>100</td>
<td>90.0 - 110.0</td>
</tr>
<tr>
<td>150</td>
<td>135.0 - 165.0</td>
</tr>
<tr>
<td>220</td>
<td>198.0 - 242.0</td>
</tr>
<tr>
<td>320</td>
<td>288.0 - 352.0</td>
</tr>
<tr>
<td>460</td>
<td>414.0 - 506.0</td>
</tr>
<tr>
<td>680</td>
<td>612.0 - 748.0</td>
</tr>
<tr>
<td>1000</td>
<td>900.0 - 1100</td>
</tr>
<tr>
<td>1500</td>
<td>1350 - 1650</td>
</tr>
</tbody>
</table>

SAE viscosity grades can be rated by whether the measurement is made at 38°C (100°F) or -9.4°C at (15°F). Materials rated at -9.4°C (15°F) are designated W (for winter). An oil with a viscosity 20W-50 has the same viscosity as a 20 weight oil measured at -9.4°C (15°F) but with the viscosity of a 50 weight at 38°C (100°F).

Absolute viscosity is often seen in the field and is typically measured using viscometers which contain rotating elements to measure the viscosity of the fluid. The unit of measurement is the Poise or, more commonly, the Centipoise (cP) where 100 Centipoise = 1 Poise.

These are the major organizations which have some standard method for viscosity measurement and classification. ISO – International Standards Organization, AGMA – American Gear Manufacturers Association, ASTM – American Society for Testing and Materials, SAE – Society of Automotive Engineers, IP – DIN (German), API – American Petroleum Institute.
IN THE SELECTION of a lubricant, one must be sure to match the characteristic of the lubricant to operating conditions. The major properties to consider are listed below:

- Viscosity/Viscosity Index
- Antiwear Properties
- Extreme Pressure (EP)
- Lubricity
- Oxidation Resistance

Other characteristics of note include:

- Water Washout Resistance
- Specific Gravity
- Foaming
- Penetration (greases)
- Dropping Point (greases)
- Shear Stability
- Grease Pumpability
- Other Properties
  - Pour Point
  - Flash and Fire Points

Finally, it should be noted that good lubricants are not born. The final product performance will be determined by its additives. A well-refined and formulated petroleum product can be made to outperform an unmodified synthetic.

**Viscosity**

Viscosity is the resistance of a fluid to flow. It is probably the single most important property of a lubricant. The viscosity of a lubricant varies significantly with temperature, so when specifying or comparing a lubricant viscosity, care must be taken to note the temperature at which the viscosity was measured. Oils are loosely classified as light, medium, or heavy. Light oils flow freely, while the heavy oils flow slowly, if at all. Light oils are typically used under conditions of higher speeds and lower loads. Lighter oils are also useful at lower environmental temperatures where a heavier oil may congeal and fail to flow freely into the contact area. An oil can be a mixture of heavy and light oils blended to achieve the desired weight.

Heavy oils are used at lower speeds and heavier loads. The higher viscosity prevents oil from being squeezed out of the contact area under heavy loads. High operating temperatures will often require a heavier oil so that a lubricating film can be maintained. This is because the viscosity of a lubricant will tend to decrease as temperature rises.

The viscosity of an oil is measured using a wide variety of instruments with an annoying number of systems for rating and classification of any given oil. This can lead to much confusion when selecting the right viscosity lubricant for an application. A convenient conversion chart is given on page 6 (Figure 3) and a more extensive discussion of viscosity measurement can be found in the appendix.

The main point to remember is that viscosity, no matter how it is measured, is dependent on temperature and any comparison of viscosities should be done with measurements at the same temperature. It is absolutely necessary to be aware of the units used to measure viscosity and to be able to convert between systems to match viscosity requirements.
Viscosities can be related horizontally only.

Viscosities based on 95 VI single-grade oils.

ISO are specified at 40°C (104°F).

AGMA are specified at 37.8°C (100°F).

SAE 75W, 80W, 85W and 5W & 10W specified at low temperatures. Equivalent Viscosities for 100 & 210°F are shown.

SAE 90 to 250 and 20 to 50 specified at 98.9°C (210°F).
**Modes of Lubrication**

There are a few different modes of lubrication:
- Hydrodynamic
- Mixed film
- Boundary
- Elastohydrodynamic (EHD, EHL)

**Hydrodynamic lubrication** is the preferred method of lubrication because there is no asperity contact in this mode. There is therefore virtually no wear in this lubrication mode. In this region, the moving parts are kept totally apart. Friction is lowest in this mode.

As loads increase however, lubricant is squeezed from between the parts and the film is discontinuous. This regime is one of **Mixed Film Lubrication**. There is asperity contact, and a lubricant with good extreme pressure characteristics will prolong bearing life.

**Boundary lubrication** is what occurs when the oil supply is discontinuous, or the loads on the surfaces are high enough to squeeze out the lubricant film and allow metal to metal contact. There is lubricant present, but there is not a continuous film present on the moving surfaces. The coefficient of friction is highest in this mode of lubrication. Under these conditions a lubricant with good lubricity will leave microscopic quantities of lubricant tenaciously bound to the metal surface and this will help to minimize wear at the sliding surface interface.

**Elastohydrodynamic lubrication** is not as obvious a mode of lubrication, but it is an important factor in the lubrication of rolling element bearings and sliding surfaces under very heavy loads.

There are two main mechanisms by which elastohydrodynamic lubrication (EHD) works. The first is that the apparent viscosity of a fluid increases as the pressure on it rises. Under extremely high pressures, some fluids can actually solidify. This mechanism serves to reduce lubricant squeeze out and maintain the film between the moving elements, thereby preventing asperity contact. The second mechanism is the elastic deformation of the metal to increase the surface area and spread the load. The surface returns to its original configuration when the load is released. These two mechanisms combine to reduce wear and extend the service life of bearings and gears.

**Figure 15**
Regimes of lubrication in a plain bearing
Polyalkyleneglycols are made by polymerizing simple glycols or alkylene oxides, and can be further classified as to their solubility in water. Insoluble polyglycols are used more in gear boxes and as heat transfer fluids. The water soluble types are used primarily as metalworking fluids, but they also are formulated for use as fire resistant hydraulic oils.

While these materials offer excellent viscosity index and lubricity characteristics, they are not practical for use over 200°C (390°F) because of oxidation and high evaporative losses at high operating temperatures.

Finally, silicons offer excellent high temperature stability with excellent viscosity index. Unfortunately, silicone oils exhibit very poor antiwear properties which are difficult to improve because of poor solubility and compatibility of additive packages.

### C. Vegetable Based

In terms of performance, vegetable based lubricant stocks are superior in lubricity and EP to many petroleum bases. Up until the end of Word War I, aviation and other high performance racing engines used castor oil in their crankcases because of the exceptional lubricity this oil offered. In fact, low cost petroleum base oils of lesser performance were often fortified with less available animal and vegetable additives in order to make them suitable for the application at hand. They are used widely in the metalworking industry. Other than availability, one disadvantage of these natural oils is their tendency to form waxes at low temperatures. Also, oxidative stability is not as good as that of petroleum based oils.

Today, vegetable based lubricants are enjoying renewed popularity because they do something that petroleum and most synthetics cannot, and that is to degrade rapidly in the environment. As industries all over the world seek to reduce the environmental impact and overall hazards of their industrial operations, “natural” lubricants will be able to deliver good performance at a cost favorable when compared to that of synthetics. The added expense of vegetable based lubricants can be offset by the savings in disposal costs. Vegetable based lubricants are essentially nonhazardous and can be incinerated or disposed of more economically than their petroleum counterparts.

More important is the reduction in environmental damage should the material find its way into the environment. In some locales, governments have mandated the use of fully biodegradable lubricants in delicate ecosystems. Thankfully, the use of a vegetable based lubricant need not mean giving away anything in performance.

The vegetable based lubricants will be useful over the same temperature range as petroleum oils, but are indicated for use in areas where release could pose a health or environmental hazard.
**Lubricant Characteristics**

**Viscosity Index**

The viscosity of a lubricant will change with temperature, increasing at low temperatures and dropping at higher ones (Figure 4). It can be said that the best lubricant in an application is the lowest viscosity which will prevent damage at the highest normal operating temperatures. This allows the best energy savings while providing the required protection. The viscosity index (VI) is an empirical number designed to indicate the amount of viscosity change over a given temperature range. A higher viscosity index oil tends to thin less with increasing temperature. Higher quality oils tend to have greater viscosity indices. Improving the viscosity index can be achieved by use of VI enhancers.

Synthetic lubricant base stocks tend to have higher viscosity indices.

Viscosity index can be obtained by the measurement of viscosity at 40°C and 100°C (measurements are made at 100°F and 212°F in the English System). The difference is then used for comparison in a book of tables to obtain the viscosity index. This number cannot be used as a measure of any other property of a lubricant.

**Antiwear Properties**

Good antiwear properties are what you get when you collectively have good extreme pressure characteristics and good lubricity in a lubricant. Good antiwear characteristics mean that metals are coated and/or kept apart thus preventing metal fatigue and the generation of wear particles and loss of tolerances between the moving parts.

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**Liquid Viscosity**

- A thin material has low viscosity
- A thick material has high viscosity

**Temperature Effects Viscosity**

- Temperature increase means a viscosity decrease and temperature decrease means a viscosity increase

**Figure 4**

Liquid Viscosity
**Extreme Pressure**

Extreme Pressure additives in a lubricant increase its load bearing capacity. Under heavy loads, extremely localized areas of very high temperature are produced. At these high temperatures, the additives react with the metal surface and form compounds which fill in the surface asperities. With a more even surface, a more uniform lubricant film can be maintained and friction thereby reduced.

There are a couple of different methods for the measurement of extreme pressure performance. One method employs the 4-ball testing apparatus (ASTM D 2783). The test is run with increasing load placed on the top ball throughout the test (Figure 5). Eventually the balls will weld together, and it is the weight at which this occurs that is reported as the weld load. The higher the number, the more pressure a lubricant can withstand. The other test commonly used (for greases only) is the Timken method (ASTM D 2782). This method employs a rotating drum impinging on a flat surface (Figure 6). Load is placed on the drum and the “OK load” is the highest weight that can be applied to the drum without causing a wear scar. This test can be run to weld point as well.

It should be noted that high weld loads by themselves do not indicate a good lubricant. Antiseize compounds have very high numbers for instance but are generally too abrasive to be used as lubricants.

Other ASTM tests that use the 4-Ball machine are ASTM D 2266 that measures the scar diameter and ASTM D 2596 that measures weld load index.
As mentioned in the body of the manual, base stocks alone do not create a good lubricant. That being said, there are pros and cons associated with the general use of each.

### A. Petroleum

Crude oil is, by itself, useless as a lubricant and must be refined in order to obtain base stocks. Petroleum base stocks are typically classified as either paraffinic or naphthenic. It should be noted that while there are two distinct types of base stock, all base oils are a mixture of both. A particular oil may be predominantly one type or the other, but it is not paraffinic or naphthenic exclusively.

Paraffinic oils are composed primarily of straight chain hydrocarbons. These materials have certain characteristics due to their structure:

**PARAFFINIC**

**Advantages**
- High viscosity index
- High flash points
- Good film strength
- Good oxidation stability

**Disadvantages**
- High wax content
- Carbon residue (varnish)
- Low wettability to metal
- High pour points

**Uses**
- General purpose lubricants
- 2-cycle oils
- Way oils
- Chain oils
- Pneumatic oils

Naphthenic base stocks have a higher content of cyclic hydrocarbons such as naphthalene and cyclohexane.

The characteristics of naphthenic base stocks are:

**NAPHTHENIC**

**Advantages**
- Solubility of additives
- Good detergency
- Low carbon residue
- Low pour points

**Disadvantages**
- Low viscosity index
- Lower oxidation stability
- Low flash point
- Wettability to metals
- Seal swell

**Uses**
- General purpose lubricants
- 2-cycle oils
- Way oils
- Chain oils
- Pneumatic oils

### B. Synthetics

Synthetics are formed in a reaction process. There are several different types.

**Polyalphaolefins (PAOs)** are pure hydrocarbons made by the reaction of an alphaolefin with ethylene, followed by polymerization with additional ethylene units. PAOs are closest in chemistry to paraffinic lubricating stocks. As such, this material offers excellent viscosity indices (130-150 typical) and good oxidative and thermal stability. Their limitations, other than cost, are poor detergency and possible seal incompatibility. The most widespread use of PAOs is as automotive engine oils. In industrial applications, they are used as wide temperature range gear and circulating fluids or greases.

**Organic esters** are the earliest synthetic lubricants, developed during World War II. There are two types of esters, based on the number of acids substituted on the alcohol base unit. Diesters are made by reacting a dibasic acid (two reactive sites) with two alcohol molecules. Polyesters react a number of monobasic acid molecules with alcohols of two (glycol) or more (polyl) reactive sites. The main advantages of esters are:
- Good oxidative stability
- Good thermal stability
- Good antwear properties
- Low vapor pressure
- Excellent detergency
- Low residue (varnish) formation
- Good Lubricity

The main disadvantage of these materials is the possible attack of materials used in seals and sealing devices. Beside being used as jet engine and turbine oils, their main usage in industry is for the lubrication of chain drives, compressors, and wide temperature range oils and greases.

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**21**
How often is the chain cleaned and lubricated?
Many maintenance crews are only now beginning to realize the effect of regular cleaning and relubrication on chain life. Cleaning should be more frequent in extremely dusty or dirty conditions. Many operators simply use heavier applications of lubricant to try to flush dust or dirt from the chain.

To what contaminants is the chain exposed? As mentioned above, chains exposed to dust or dirt require more frequent lubrication. Moisture or chemical fumes will demand more than just an oil for adequate protection. A tacky lubricant will act as a barrier to contamination while retaining the thinner lubricant in the pin and bushing area.

How long does the chain last? (What is the typical service life?) Knowing the typical service life at the outset will help gauge the effectiveness of the lubrication program as well as point out any defects in equipment or flaws in operating procedures. A sudden drop in chain life can be caused by anything from a defective chain to a simple lapse in lubrication.

What type of lubricant is typically used? Some people lubricate their chains with used oil and while dirty oil is better than no oil at all, it is hardly the optimum. Fresh oil of the right type will contain the additives needed to protect against wear or link seizure and can carry contaminants away from the pin area instead of introducing them.

Although at first the topic of lubrication may seem quite complicated, there is actually a fairly standard set of questions you will need to answer in order to choose the proper lubricant. For those new to the subject, a questionnaire is provided in the appendix to ensure a solid start. Hopefully this manual has served its purpose of providing the reader with an understanding for the basis of the questions asked.
**Lubricity**

The lubricity of a lubricant refers to how well the product reduces friction beyond what would be indicated by its viscosity alone. In other words, how well it clings to a surface once in operation. It is a property that can be enhanced by the selection of additives or by blending different base stocks. The test typically used to measure this is the Falex Pin & Vee (ASTM D 3233, Figure 7). In this test, a pin (usually steel) is rotated between two blocks at constant speed (290 rpm) while an increasing load is applied to the Vee blocks. Typically, the pins seize, and the force at which this occurs is reported. Another useful number to know is the degree of pin wear that occurs should the instrument go to full load (usually about 2041 kg or 4500 lbs.). The better lubricants will be able to post larger forces before seizure occurs.

![Exploded view of Vee Blocks and Journal arrangement, Falex Lubricant Tester](image)

**Oxidation Resistance**

Oxidation is not to be confused with corrosion resistance. Corrosion refers to the effect of a lubricant on metal surfaces, such as copper. Oxidation is a chemical process in which the lubricant is altered by exposure to oxygen in the air. The process is accelerated by increasing temperatures, moisture, some types of metals or contaminants. The significance of oxidation of a lubricant is that as oxidation progresses, the viscosity of the oil can change substantially (it usually thickens), degrading lubricating capabilities. Varnishes and sludge can form which can plug oil lines and orifices. Many of the oxidation products formed are acidic and can attack or corrode metal surfaces.

Oxidation resistance of a base lubricant can be measured three ways, bomb oxidation; that measures pressure change upon oxidation over time, change in viscosity on oxidation and acid number change. The bomb method is used for greases and the other two methods are used typically for oils. It is desirable to have as little change as possible for all three methods.

**Water Washout Resistance (ASTM D 1264)**

Water washout resistance is a characteristic which pertains more to greases than oils. The test involves a hot water spray (38°C [100°F] or 80°C [175°F]) directed onto a test bearing charged with a specific weight of grease sample. The trend in testing is toward the more severe condition at 80°C (175°F). The number reported is the percentage of weight change at the end of the test. If a grease is to protect an assembly where water is a contaminant, then good water washout resistance is essential.
**Specific Gravity**

Specific gravity of a lubricant is the ratio of the density (weight per unit volume) of the lubricant to the density of water at the same specific temperature. Therefore the specific gravity of water is 1. Materials with a specific gravity lower than 1 will float on water, materials with specific gravities greater than 1 will sink. Specific gravity will likely come into play when purchasing or storing material. API gravity is put forth by the American Petroleum Institute and it is a different numbering system to measure the same thing. With this scale, water is assigned a specific gravity of 10. If a lubricant is more dense than water, the API gravity will be less than 10. Materials less dense than water will have values greater than 10.

**Foaming**

A lubricant that is used in high speed conditions, such as in gearboxes, should have good resistance to foaming. Antifoaming can be incorporated into a lubricant, but it should be noted that foaming is usually indicative of a mechanical or design problem. In pressurized lubrication systems, an air leak at the inlet can cause air to be beaten in under pressure and dissolved into the lubricant at the pump. When the pressure is released, the entrained air will bubble out, resulting in foam.

**Other Properties**

The pour point of a lubricant is the lowest temperature at which the oil will flow. The pour point can provide an estimate of the low temperature properties of an oil. Flash and fire points yield fire safety data for storage, and in use. The flash point is the minimum temperature at which the lubricant will give off vapors that will ignite when a small flame is passed over the surface of the lubricant. The fire point is the lowest temperature where an oil ignites and burns for at least 5 seconds.
<table>
<thead>
<tr>
<th>METHOD OF LUBRICATION</th>
<th>FORCED LUBRICATION</th>
<th>PUMP SPRAYS OIL ON CHAIN</th>
<th>DRIVES – HIGH HORSEPOWER AND SPEED</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUTOMATIC</td>
<td>OIL DISC</td>
<td>OIL DISC THROWS LUBE UP ON CHAIN</td>
<td>DRIVES – MODERATE TO HIGH HORSEPOWER AND SPEED</td>
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<tr>
<td></td>
<td>SPLASH</td>
<td>CHAIN DIPS INTO OIL</td>
<td>CONVEYORS AND ELEVATORS</td>
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<td></td>
<td>DRIIP CUP</td>
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</tr>
<tr>
<td>SEMI-AUTOMATIC</td>
<td>MANUAL</td>
<td>PRESSURE LUBRICATION</td>
<td>CONVEYORS, ELEVATORS, DRIVES</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BRUSH OR OIL CAN</td>
<td></td>
</tr>
<tr>
<td>NON-AUTOMATIC</td>
<td>MANUAL</td>
<td>APPLICATION OF LUBRICANT</td>
<td>Kind of Equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CONVEYORS, ELEVATORS, DRIVES</td>
</tr>
</tbody>
</table>

**Figure 13** Chain Lubrication Methods
Bushings are pressed into the rollers and these roller assemblies fit over the pins at each end of the side or link plates. For proper lubrication, the load bearing surfaces and moving parts must be coated. If pins and bushings are unlubricated, they begin to wear. As these parts wear, the effective pin to pin distance increases, resulting in the “chain stretch” so commonly encountered. Chain stretch of 2.5 to 3% is generally considered the limit; at this point, the chain should be replaced. Chains, however, are often repaired by adjustment of tensioning mechanisms or in extreme cases by removal of links. This is not a true repair, because the pins continue to wear and in time become too thin to support the encountered working loads. The chain then breaks, which can be inconvenient due to the unexpected down time.

In successfully lubricating a chain, one must consider the type of chain as well as the operating conditions (load, sliding surfaces, speed, etc.) and environmental factors such as dust, dirt, moisture.

The most important parts of the chain to lubricate are the pins and bushings. This is where the chain flexes and is also where the load is carried. These parts are fit to close tolerances and a good lubricant must:

- Be of low enough viscosity to penetrate the narrow spaces between pins, rollers, and links.
- Have sufficient film strength or EP capability to prevent pin wear under load.
- Resist sling off and, if required, water washout.
- Be stable at the temperature of application.
- Be able to clean built up residues from the inside and outside of the chain.

Lubrication methods for chains fall into three categories:
- Manual
- Semi-automatic
- Automatic

Figure 13 illustrates each method and indicates where each is commonly found. As mentioned in the body of the manual, the speed of the chain coupled with its size usually determines the lubrication method.

Where to lubricate a chain is an important factor in chain life. Where an oven is involved, the best locations for lubricating are before the chain enters the oven, and once again just outside the oven. If only one lubrication point can be used, lubricating just after the chain exits the oven has the advantage of cooling the chain. The chain also should be lubricated wherever there are sliding tracks.

Some other considerations in the lubrication and troubleshooting of chain drive applications are listed below.

**What is the condition of the chain?** The best lubricant in the world will not renew a badly worn chain.

**Is the chain running at the right tension? (i.e. Is the chain tight or loose?)** An improperly adjusted chain can place excessive loads on bearings and cause bearing failure as well as premature stretching of the chain.

**How far does the chain travel (chain length)?** Long chains may require idler gears for support of the chain. These assemblies may require additional lubrication.

**What is the maximum operating temperature for the chain and how long is the chain seeing this temperature?** If the chain goes into an oven, what is its residence time? A chain subjected to elevated temperatures for prolonged periods is more likely to cook the lubricant than one that sees high temperatures for only a few seconds. Continuous temperatures in excess of 150°C (300°F) will require the use of a synthetic material.

**Where is lubricant to be applied?** Application should be performed on a sprocket or sheave because this is where the chain flexes most. This will allow lubricant to work into the pin and bushing area.

**What is the load on the chain?** Extremely high loads may require more frequent lubrication or a high EP lubricant.
**Lubricant Types**

**Liquids**

By far the most common liquid lubricant is petroleum or mineral oil. The main reason for this is its availability. Petroleum base oil stocks are refined from crude oil deposits found beneath the earth’s surface. Main advantages are:

- Ready availability
- Low cost
- Many excellent additives are available
- Seal compatibility

In many cases, mineral-based lubricants continue to be an excellent low cost answer to lubricating problems.

The main disadvantages to mineral oils are:

- Tendency to varnish
- Lower viscosity index, necessitates changing oils and fluids with varying environmental and operating conditions.
- Not as biodegradable as natural products or some synthetics.
- Can contain hazardous ingredients not removed in the refining process.

**Synthetic** oils are the result of reacting lower molecular weight compounds and turning them into larger molecules of desired properties. Because synthetics have a uniform and controlled chemical structure, their properties are predictable. Some properties such as viscosity index and oxidation stability, are greatly improved. There are several different synthetic lubricants which are derived from various basic molecules:

- Polyalphaolefins
- Organic esters
- Polyols
- Silicones

In recent years, synthetic lubricants have seen increasing use. The advantages to using synthetic lubricants become evident under conditions of high speeds or extremes of temperature.

The main advantages of synthetic lubricants are:

- Broader temperature range
- Chemical resistance
- Oxidative stability
- Service life
- High viscosity index

The main disadvantage of synthetic lubricants is their higher cost. In some cases, a synthetic lubricant can have a cost as much as ten times that of a petroleum based lubricant. Synthetic lubricants are not generally available in the volumes that petroleum based products are. Depending on the type of synthetic lubricant seals may be attacked, causing leaks. The additives used in synthetic lubricants are usually adopted from petroleum based technology and these additives may not be as soluble or compatible in synthetic base stocks.

**Lubricants from animal and particularly vegetable base stocks** are the oldest lubricants known to man. They were widely used in the industrial revolution for lubricating steam engines, textile equipment, and many other applications. Until petroleum based products became available in the volume required for the growing industry worldwide, animal and vegetable based materials provided excellent lubricity and extreme pressure characteristics with low toxicity. Petroleum oils could be produced more economically because of the quantities available. The main advantage of animal/vegetable products is that they provide excellent natural lubricity and are readily biodegradable. This is advantageous in areas sensitive to lubricant contamination.
**Semisolids (Greases)**

Grease is essentially an oil with a thickening agent added. Grease will stay on the part to be lubricated where an oil might be washed or slung off in use. Greases are also used in applications where an oil might drip or run out causing hazards to workers or the environment. Greases are also used in places that are hard to reach and as a result, are lubricated infrequently. At high operating temperatures, grease can dissipate more heat and provide a more robust lubricating film. Grease can also provide a barrier against corrosion of an assembly. The properties of a grease will vary depending on the thickeners used and the additive packages used in the base oil. A more detailed discussion of greases can be found in the Appendix.

**Solids**

Although lubrication is usually achieved by fluids, solids can be used to reduce friction and wear. Solids can be used by themselves, or suspended in a base oil or grease. Some of the more common materials used as solid lubricants are listed below:

- Graphite
- Molybdenum disulfide
- Polytetrafluoroethylene (PTFE, Teflon®)
- Mica
- Zinc oxide
- Lead
- Copper

Most of these compounds have a layered (laminar) microscopic structure. In use, the layers are loosely bound and will slip over each other easily under lateral force. The heavy metals and PTFE, however, work by cold flowing and filling asperities. Malleability of heavy metals and low coefficient of friction for PTFE are operative once the asperities are filled.
While no lubrication is disastrous for a bearing, excessive lubrication of a bearing can cause damage as well. The increased drag caused by excessive lubricant can raise temperatures to the point where the operating tolerances of the bearing are exceeded leading to wear and premature failure.

The best lubricant for a bearing depends on a number of factors, as mentioned earlier but linear velocity is most important.

The factors in the next column would also indicate the use of grease rather than oil.

**When to use grease vs. oil:**
- When oil may drip or run out
- Possibility of contamination
- High Loads
- Possibility of oil sling off
- High resistance to water washout required
- Infrequent lubrication intervals
- High temperatures
- No housings to hold lubricant

The temperature of oil from the hottest bearing should be considered the system operating temperature.

### Speed

<table>
<thead>
<tr>
<th>JOURNAL</th>
<th>ROLLING ELEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>slow</td>
<td>oil*</td>
</tr>
<tr>
<td>moderate</td>
<td>oil</td>
</tr>
<tr>
<td>fast</td>
<td>oil</td>
</tr>
</tbody>
</table>

* For very low speeds or intermittent operation, a grease can be used

** Except for needle bearings; on these an oil should be used

**Chains**

Chains are used to transmit power over distances greater than are practical with shafts and gears. There are a great number of chain drives in industry from conveyors, to hoists, to transmissions. Chains carry heavy items like automotive bodies, fabric, plasterboard, lumber, coal, and a myriad of other things through assembly plants. They are used to power saws, shearing equipment, camshafts, and in many other appliances.

Regardless of the application, chain drives are mechanisms with parts that work at close tolerances. Because chain drives are durable and reliable, they are often thought of as needing no maintenance. If chains are lubricated at all, it is often an afterthought rather than a preventative program using the correct lubricant.

Proper lubrication is important in assuring long chain life with less noise and lowest operating cost. The main purpose of a lubricant is to reduce friction and wear between moving parts. The lubricant used should act as a barrier to rust and corrosion, dissipate heat, and if possible, to lessen shock or impact induced wear from contact with sprockets. These factors can each contribute to accelerated chain wear and premature chain failure. A typical roller chain consists of links with pins and rollers.
How often to lubricate open gears? This is a question to which there is no simple answer. For the most part, one can notice the obvious signs that lubrication is required. Corrosion of exposed surfaces, excessive noise, squeaks, chattering, and heat buildup can be used as indicators. Lubricating a gear assembly too often is not nearly as bad as insufficient lubrication. It is difficult to damage an open gear by over lubricating. There is no excessive drag from shearing lubricant since there is no housing involved. An excessive amount of lubricant falling from the gears is indicative of excessive lubrication or a poorly designed product.

Bearings

A bearing is a mechanical element which supports a rotating shaft and controls its motion. The other functions of a bearing are:

- Distribution of load
- Friction control
- Lubricant film maintenance in contact area

Bearings represent one of the largest uses of lubricants in the industrial environment. They come in many sizes and configurations, but most generally, they are either plain or antifriction type. Plain bearings are often called journal bearings, while antifriction bearings are more often referred to as rolling element bearings (Figure 9).

Plain bearings are the simplest type of bearing. They look like a sleeve along the shaft (Figure 10). Their large contact area provides a high load capacity, and if hydrodynamic lubrication conditions can be maintained the frictional resistance and bearing life can be excellent. The main disadvantage of this bearing is that it can be difficult to maintain adequate oil supply to the bearing. Once a plain bearing is oil starved, it wears rapidly to failure.

Rolling element bearings, are precision units manufactured to close tolerances. Examples include ball bearings and needle bearings. A rolling element bearing consists of two raceways or races, separated by a set of rolling elements. These rolling elements can be balls, needles, or cylinders. Some examples of rolling elements are shown on the next page in Figure 11. These bearings can typically support greater loads than journal bearings. Rolling element bearings are commonly found in lower speeds and higher loads than journal bearings.

Rolling element bearings are the most commonly found in the industrial applications you will encounter. No matter what the bearing or application, the bearing will fail eventually. The metal work hardens, becoming increasingly brittle until the surface material flakes off or spalls. Other factors include improper installation, excessive temperatures, shock loading, etc. It is interesting to note that about 64% of bearing failures are lubrication related.
There are several factors to consider in the selection of the proper lubricant. A manufacturer's recommendation should always be the starting point. The most important things you need to know if you do not have this are listed below.

- Operating speed of bearing, chain, or equipment
- Load (type and magnitude)
- Bearing type (if applicable)
- Temperature
- Method of lubrication
- Operating Environment (is there dirt?, water?, etc.)

**Speed**

Speed as it relates to lubrication is actually composed of both the revolutions per minute and the size of the chain, bearing or moving part.

A chain is considered slow moving if the chain is running at speeds up to 24.4 m (80 ft) per minute for a large chain (over 25 mm [1 in] distance between links) and up to 106.7 m (350 ft) per minute for a small chain (similar in size to a bicycle chain). A fast moving chain would be running at speeds greater than 260 m (850 ft) per minute for a large chain and over 808 m (2650 ft) per minute for a small chain. Anything in between would be considered to be running at a moderate speed. A large manufacturer of chains has traditionally given the following recommendations. Chain lubrication is almost always done with oils rather than greases, the main difference as far as lubrication needs (exclusive of temperature considerations) is in the method of lubrication. Slower moving chains can be lubricated manually or by drip oils. Chains running at a moderate speed should be run through an oil bath. Chains moving at a high speed should have pressurized oil misting systems providing frequent lubrication.

These recommendations are general and not absolute. It is understood that each application is unique and there are exceptions to every rule.

For a bearing, you also need to know both the size of the bearing and the speed in rpm. Rollers in a 12.5 cm (5 in) bearing operating at 1200 rpm are moving a lot faster than those in a 2.5 cm (1 in) bearing at the same speed. So, to calculate linear velocity which takes into consideration both, use the following equation (this is actually an approximation of a more complicated equation)*:

\[
\text{Linear Velocity} = \left(\frac{D}{\pi}\right) \times \text{rpm}
\]

The diameter (D) is the outside diameter of the inner race or cone (see Figure 9).*

After calculating the linear velocity, you can use the following approximation:

- Slow = less than 4572 cm/min (1800 in/min)
- Moderate = 4572-25400 cm/min (1800-10,000 in/min)
- Fast = greater than 25400 cm/min (10,000 in/min)

Although when you are talking about extremely large bearings (over 10 cm [4 in]) other factors come into play, in general greases are recommended for velocities up to 19050 cm/min (7500 in/min) with lighter i.e. NLGI 1, 0, being recommended at velocities over 16510 cm/min (6500 in/min). Generally, velocities ranging from 19050 to 29210 cm/min (7500 to 11500 in/min) should be bathed in oil to ensure proper lubrication, and finally, velocities in excess of 29210 cm/min (11500 in/min) are best lubricated with circulating oil systems, with a cooler being installed at speeds approaching 48260 cm/min (19,000 in/min). In general, higher speeds require thinner greases and thinner base oils to prevent channeling and resultant lubricant starvation or excessive heat generation due to fluid friction. Table A on the following page is included as a quick guideline.

**Load**

Assume loads of 14 kg/cm² (200 psi) or less to be light and loads of 35 kg/cm² (500 psi) or more to be extreme duty service. Any shock loading at all or sudden stopping and starting should be considered severe service. It can be assumed that larger bearings (over 5 cm or 2 in.) are carrying heavy loads, otherwise there would not be the need for a very large bearing.

The molybdenum disulfide in molygreases provides that solid, high EP film in instances where the grease may get squeezed out upon startup.

**Temperature**

The operating temperature of the mechanism to be lubricated is important for two reasons. First, because the viscosity of a lubricant will go down under increasing temperatures, it is important that the one chosen will retain a sufficient film to adequately reduce the friction. Second, there are definite temperature limitations to different base stocks and if exceeded, you will form varnishes which can actually do more harm than good.

Generally, petroleum based lubricants should not be used above 150°C (300°F) on a regular basis. Ester based synthetic lubricants can be used to 230°C (450°F) and polyol esters to 270°C (520°F). Silicones can be used to 205°C (400°F). Other specialty synthetics such as fluoroelastics can go as high as 230°C (450°F).

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* The more accurate roller rib velocity is used by bearing manufacturers and is reported in feet (or meters) per minute. This number is calculated as \( D \times \pi \times \text{rpm}/12 \).
Synthetics tend not to char or varnish the way petroleum based oils do and because of this they will not form hard deposits which can accelerate wear. The temperature of a bearing can be measured in different ways, but one of the simplest is to measure temperature at the housing using a thermocouple type thermometer. There are also handheld remote sensing devices utilizing a laser. One important thing to remember when measuring bearing temperatures is that when doing a comparison study of lubricants, it is always best to measure against a bearing in the same location operating under identical conditions. Anything less will not be a true indication of lubricant efficiency.

**Method of Lubrication**

The type of lubricating system may dictate a particular lubricant be used. For example, a bearing enclosed in a gearbox can use oil, but the same bearing out in an open setting must have a grease to prevent lubricant loss due to leakage. Higher speed bearings out in the open may require a tacky lubricant to prevent sling off of applied lubricant. Automated dispensing systems are becoming increasingly common. They deliver an appropriate amount of lubricant at crucial times to extend the working life of a component. Because of the accurate metering, less lubricant is required to perform the lubrication in the long run. It is very important to use a lubricant in these systems with excellent oxidation resistance so that gummy deposits do not build up in the mechanisms.

**Operating Environment**

Service in water spray or humid conditions will require a higher viscosity oil or, better still, a grease to form an effective barrier against moisture and any other contaminants (i.e. dust).

**Summary**

The industry demand for the continuous improvement in lubricants is driven by the greater speeds, increasing loads, and higher operating temperatures of modern machines. The globalization of the economy means that machines are being pushed like never before to increase speeds of production. The ultimate truth is that proper lubrication is:

- The right lubricant
- In the right place
- In the right amount
- At the right time

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**Table A: Ball and Roller Bearing Lubricant (Oil and Greases)**

<table>
<thead>
<tr>
<th>Shaft Diameter</th>
<th>Operating Temperatures</th>
<th>Lubricant Recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>°C</td>
<td>°F</td>
</tr>
<tr>
<td>up to 2.54 cm (1&quot;)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.54 cm to 5.08 cm (1&quot; to 2&quot;)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.08 cm to 7.62 cm (2&quot; to 3&quot;)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.62 cm to 10.16 cm (3&quot; to 4&quot;)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over 10.16 cm (4&quot;)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Up to 1000 rpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 rpm to 3000 rpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000 rpm to 10,000 rpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over 10,000 rpm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPLICATIONS: A BRIEF TOUR

BESIDES SLIDING SURFACES, the most common applications for lubricants are:

- Gears, both open and closed
- Bearings
- Chains

Gears are devices used to transfer rotary motion from one place to another. Gears are used to:

- Transmit power
- Change speed
- Reverse direction of rotation
- Change direction of transmitted power

Because Chesterton® does not at this time manufacture gear lubricants, we will not go into depth in this area except open gear applications.

OPEN GEARS

Many gears are contained in an enclosure called a gearbox. A gearbox is used to prevent contamination from coming in contact with the gears. It is also used to hold lubricant around the assembly. In some cases, it is not economical, practical or even possible to enclose some gear assemblies (Figure 8). Open gears are still found in many instances in industrial settings. They are routinely exposed to dust, moisture, or other unfavorable operating conditions. Because there is no enclosure to contain lubricant, these gears are working under conditions of boundary lubrication at best. As such, special consideration must be made in the selection of a gear lubricant. The most important factors in the lubrication of open gears are:

- Length of lubrication interval
- Operating environment (dust and moisture)
- Lubricant loss due to slings off

Lubrication of open gears is best accomplished by placement of a reservoir that permits the gear to dip into it. The next most preferable method of lubrication is the employment of drip oilers, followed by hand lubrication via brush, oil can, or sprayer. In any case, the main properties to have in an open gear lubricant should be:

- Excellent adhesion/tack
- Extreme pressure capabilities
- High viscosity index
- Excellent water washout resistance

Because open gears are subject to a wide range of operating temperatures, a high viscosity index material will give the best performance.

If an open gear lubricant is to maintain a lubricating film under conditions of intermittent application, a tenacious film is required. Tacky films remain on the contact surfaces and resist squeeze out during tooth mesh. Open gears suffer more exposure to the elements and because of this, excellent water washout resistance is required. Finally, good extreme pressure characteristics are a prerequisite for any gear lubricant.

It is important to realize that no lubricant will extend the life of gears that are improperly aligned or adjusted. Worn-out gears will not run any longer or quieter by oiling them. The damage has already been done and the best thing to do is to is to replace worn parts and lubricate properly. Always inspect moving parts and gears for wear BEFORE beginning a lubrication program.

Figure 8
Open Spur Reduction Gears
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