Guide to Electric Motor Bearing Lubrication

The proper lubrication of electric motor bearings is essential to maintaining them in peak operating condition and, ultimately, in reducing unnecessary downtime. This bulletin, for Mobil™ customers, is intended to serve as a practical guide to the proper lubrication of electric motor bearings utilizing grease as a lubricant. It can help you to apply Mobil's™ years of lubrication experience with that of bearing and motor manufacturers from around the world to provide you with a guide to the proper lubrication of electric motor bearings.

Grease Lubrication

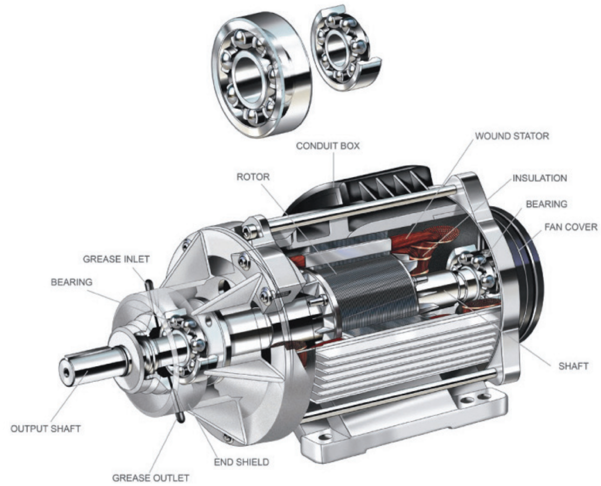
Grease is frequently used as an electric motor bearing lubricant because of its simplicity of application and unique characteristics. The primary functions of an electric motor bearing grease are to:

- Reduce friction and prevent wear
- Protect bearings against corrosion
- Act as a seal to prevent entry of contaminants

Grease is a semi-solid lubricant composed of a base oil, a thickener and additives. These components are combined in complex chemical reactions under controlled temperatures and pressures. The base oil used in greases may be mineral or synthetic. Mineral oils are adequate for most electric motor bearing applications. However, synthetic base oils may be required for extreme temperature applications or where longer regreasing intervals are desired.

The thickener primarily serves as a carrier for the oil and prevents it from leaking out of the application. Some common thickeners include metallic soaps that can be composed of calcium, lithium, sodium, aluminum or barium and complex metallic soaps such as lithium-complex. A thickener increasingly employed in electric motor bearing lubrication is polyurea. **Polyrex™ EM** utilizes a polyurea thickener.

As with many lubricating oils, additives are frequently used to impart special properties to the grease. Commonly used additives include, corrosion inhibitors, antiwear or extreme pressure agents, oxidation and corrosion inhibitors, pour point depressants, lubricity agents, and dyes or pigments.



Choosing the Right Electric Motor Grease

Important Grease Characteristics for Electric Motor Bearings

The following criteria may be used as typical indicators of a good electric motor grease:

- **Viscosity:** Oil viscosity should be appropriate for the load and speed of the application at operating temperature. This will help to insure maximum protection and component life. The typical mineral oil viscosity in an electric motor grease is in the range of 500 to 600 SUS at 37°C. Your electric motor builder may provide a specific recommendation.
- **Consistency:** A grease's consistency is one of its most visible characteristics. A grease's consistency or firmness is stated in terms of its NLGI (National Lubricating Grease Institute) grade, which ranges from 000 to 6. The consistency of a grease should be appropriate to the application, as it affects pumpability and ability to reach the areas to be lubricated. A NLGI 2 grade grease is the most commonly used in electric motor applications.
- **Oxidation Resistance:** Electric motor greases should have outstanding resistance to oxidation. This extends the life of bearings running at high speeds and high temperatures. ASTM D 3336 High Temperature Grease Life test results give a good indication when operating under extreme conditions. Choose a grease with a high ASTM D 3336 oxidation life.

- **Anti-Wear:** Unless a motor is mounted so there is a thrust load on the bearings, it is generally advisable to use a grease without extreme pressure (EP) additives. EP additives can shorten the life of the grease and should not be recommended where they are not needed. On the other hand, bearings designed to handle heavy thrust loads may require a grease with an EP additive.
- **Dropping Point:** The dropping point gives an indication of the temperature at which the grease will melt or the oil will separate from the thickener. Due to the high temperatures that can be reached in an electric motor bearing, a grease with a high dropping point is frequently desirable. Lithium complex greases and polyurea-thickened greases both have dropping points of approximately 260°C or higher.
- **Shear Stability:** ASTM D 217 Cone Penetration of Lubricating Grease test measures the consistency of the grease after it has been worked 100,000 strokes. An electric motor bearing grease should soften no more than 1 to 1.5 NLGI grades in this test. An electric motor bearing grease that softens more than that may leak out of the bearing with age.

Grease Compatibility

With some exceptions, greases with different types of thickeners should be considered incompatible with each other. We recommend running grease compatibility tests if mixing different greases is unavoidable. Generally, incompatible greases will soften or become fluid. This can result in lack of lubrication and can lead to premature bearing failure. However, stiffening may occur and can also lead to a lack of lubrication. Always purge as much of the old grease as possible, and then regrease more frequently to purge all the old grease out of the bearing.

Adding Grease to Electric Motor Bearings

Re-greasing Intervals

Electric motors utilizing double shielded or double sealed bearings, which are typically of the lubricated-for-life design, usually do not require regreasing. On the other hand, all others, those being open or single shielded or sealed bearings, should be re-lubricated periodically to replace grease that has deteriorated, leaked away, or become contaminated. Generally, operating conditions will dictate the relubrication interval required.

All greases deteriorate at some rate, even under moderate operating conditions. The principal causes are oxidation, excessive oil bleeding, and mechanical working. At high temperatures, oil evaporation may also be a factor. Oxidation eventually increases the oil viscosity and hardens the soap. Some oil bleeding is desirable, but too much reduces the ability of the grease to maintain an effective lubrication film. Mechanical working, or shearing, may change grease properties such as consistency, making the grease less suited to the application. Excessive oil evaporation may harden the grease. Deterioration often ends in hard, dry, deposits that can neither lubricate bearings nor protect them against contaminants.

Operating and other factors that influence relubrication frequency include: temperature, continuity of service, quantity of grease in housing, size and speed of bearing, vibration, exposure to contaminants, effectiveness of seals, and the grease's suitability for the particular service.

1. High grease temperatures increase the oxidation rate, doubling it for every 18°F (10°C) rise above 120°F (49°C). High temperature also tends to increase the rate of bleeding and evaporation of the oil. Additionally, grease tends to soften as temperatures increase and may become fluid enough to leak out of housings. Other things being equal, operating at high temperatures will require more frequent relubrication, or the use of a high temperature grease.
2. Continuity of service means hours of service per day or other time unit. A grease continuously subjected to deteriorating factors will need replacement more often than the grease in a bearing used only occasionally.
3. A large quantity of grease in a properly designed housing will last longer than a small quantity in a proportionally smaller housing. The small quantity will be reworked more often than an equal portion of the large quantity and will not benefit from reserve capacity (including more oil and additives). Under moderate conditions, however, a small quantity of grease in a factory lubricated sealed or shielded bearing may last a long time, perhaps several years.
4. The Dn value of a bearing (bore diameter in mm x speed in rpm) is proportional to the linear speed of the rolling elements and may be used as a guide to determine relubrication frequency. In bearings operating in the Dn range of 150,000 to 200,000 or more, grease in the path of the elements is severely worked and heated. Such bearings require more frequent relubrication even with correctly selected grease that does not slump excessively. Some bearing manufacturers use Ndm (speed in rpm x pitch diameter of the bearing) instead of Dn. This method produces somewhat higher reference values, but considers the effect of rolling element size and the bearing's cross section dimensions.

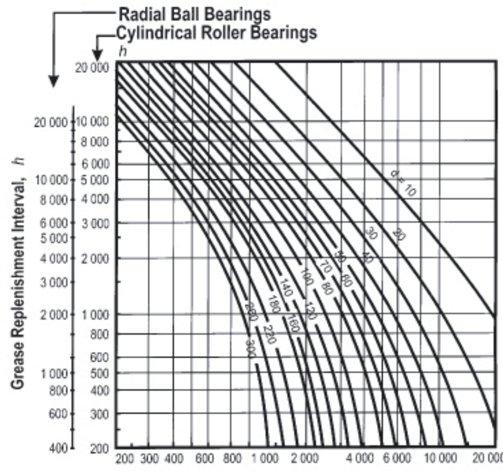
5. Vibration causes grease to feed more freely into the rolling elements' path, where it is worked and heated excessively. This reduces grease life, especially in high speed bearings. Churning and shearing in bearings "mills down" some greases, which become fluid enough to leak excessively. Either factor means more frequent relubrication.
6. More frequent relubrication usually will be required if the grease is marginal in any major characteristic — oxidation, bleeding, pumpability, antiwear and antirust properties, or mechanical stability.

It is not a simple matter to decide when and how often to relubricate. Generally, the decision reflects experience and the machine builder's and grease supplier's recommendations. Relubrication intervals for most rolling element bearings range from two weeks to two years although for many it is once a year during scheduled maintenance shutdowns. At the lower extreme, bearings running at or near their speed limits may require relubrication as often as every six to eight hours.

It is important to regrease on an appropriate schedule so that the old grease remains soft enough for purging. Bearing or equipment manufacturers recommend relubrication intervals based on operating conditions and type of grease. Typically, light to medium duty electric motors, that run continuously, will require at least annual relubrication. Reduce the relubrication interval by half for every 10°C above the nominally recommended temperatures. Two commonly used methods for determining the correct relubrication frequency follow.

1. The first utilizes the following equation:
   Frequency (hours) = {[14,000,000/(shaft rpm)(Bearing ID)1/2 mm] — [(4)(Bearing ID) mm]}{F bearing type}{F temperature}{F contamination} where,
   F bearing type = 1.0 for spherical or thrust bearing, 5.0 for cylindrical bearing, 10.0 for ball bearing
   F temperature = 1.0 for under 160°F, divide by two for every 20°F above 160°F
   F contamination = 0.1 to 1.0 depending on the level of contamination—motor bearings normally 1.0

   * Formula above taken from the Practical Handbook of Machinery Lubrication Second Edition plus added factors for temperature and contamination from field experience.
2. The second method utilizes the following graph for determining relubrication frequencies:



Courtesy of NSK Corporation

Determining the Correct Amount of Grease

Determining the correct amount of grease for an electric motor bearing is one of the most important steps in initial greasing and in regreasing of the bearings. An insufficient amount of grease could lead to bearing failure due to lack of lubrication. On the other hand, over-lubrication can also lead to bearing failure and cause problems due to migration of the lubricant in to the windings. One of the two methods following is frequently used for determining the quantity of grease to be added to a bearing:

1. 1/2 to 2/3 of the free space in the bearing — when operating speed is less than 50% of the limiting speed of the bearing. 1/3 to 1/2 of the free space — when the speed is more than 50% of the limiting speed of the bearing.
2. Another method of determining the appropriate quantity of grease to fill the bearing is determined by the following equation. This is a simple method of calculating the amount of grease needed for a standard application. Quantity of grease (g) = Outer bearing diameter (mm) X bearing width (mm) X 0.005, or Quantity (oz) = 0.114 X (bearing OD) in X (bearing width) in.

It is common practice to pack the bearings as well as the bearing housing with grease. In addition to holding the bearing in place, the bearing housing also acts as a grease reservoir. The following may be used as a guide to filling the housing with grease.

- 30% to 50% fill — Typically used. For very high speeds the lower limit should be used in order to reduce churning and overheating of the grease. Overpacked bearings tend to overheat, and to overheat even more at higher speeds.

3. ▪ 50% to 75% fill — For slow speeds, or in the absence of other methods of regreasing, fill the housing 50% to 75% with grease. After the housings are packed and the motor started, the rolling elements will push the excess grease from between the races into the housing, leaving only the thin lubricant film needed to minimize friction and wear.
4. Full pack — A particularly dirty environment may call for the housing to be completely filled, but the bearing itself will only contain enough grease for lubrication. The pressure relief method will also produce a full pack.

One full pack method begins with the bearing filled with grease and the housing 75% full, leaving just enough space to receive the excess grease pushed out by the rolling elements. If the housing were actually packed full, the grease between the rolling elements could not escape and would be severely worked. The resulting friction could become so great that very high bearing temperatures would quickly develop. (Fig.1).

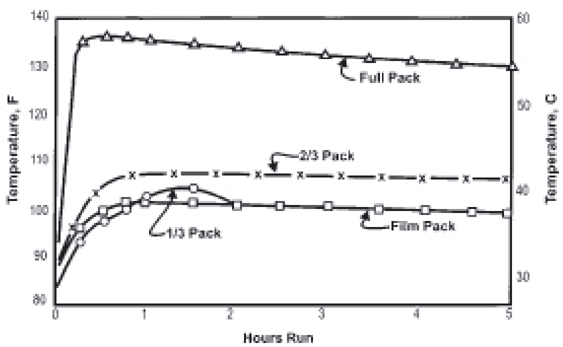


Fig. 1 — Temperature rise in grease lubricated bearing.

High temperatures would accelerate grease deterioration, possibly leading to bearing failure due to lack of lubrication. Furthermore, expansion of the grease could force it into the motor winding, resulting in damage to the motor, or cause seals to rupture. Such failure may be avoided by running the motor with the drain plug removed until excess grease is purged. This is the pressure relief method.

It is important to estimate the amount of grease dispensed by each shot from the grease gun. Bearing manufacturers frequently recommend the amount of grease to apply to a bearing by weight or volume. In practice, the amount of grease applied to a bearing is often determined by the number of shots from the grease gun. Therefore, it is important to know the amount of grease supplied from each shot of the grease gun. The grease-gun manufacturer can usually provide the volume per shot. However, the grease gun can be calibrated by counting the number of shots to dispense a known amount of grease. The weight from one shot can be determined using any laboratory scale, preferably in grams and/or ounces. Then the number of shots necessary to achieve the required amount by weight can be counted. Note that the volume or weight per shot may change slightly with a change in consistency.

The housings of many grease-lubricated bearings permit re-lubrication with a low-pressure grease gun. Fig. 2 shows an open type bearing with a supplemental grease reservoir on one side. This design has restricted purging since relubrication displaces and forces out of the drain only the grease in the outer housing. The drain passage should be short with a large diameter. Fig. 3 shows free-purging designs.

New grease forced into one side of the housing passes through the rolling elements to the drain on the other side. Again, the drain passage should be as short as possible and of large diameter Single shielded bearings, Fig. 4, allow a compact arrangement as required in electric motors and can be relubricated as shown.

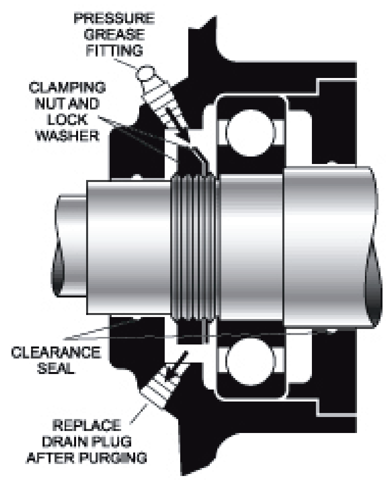


Fig. 2 — Bearing housing for relubrication.

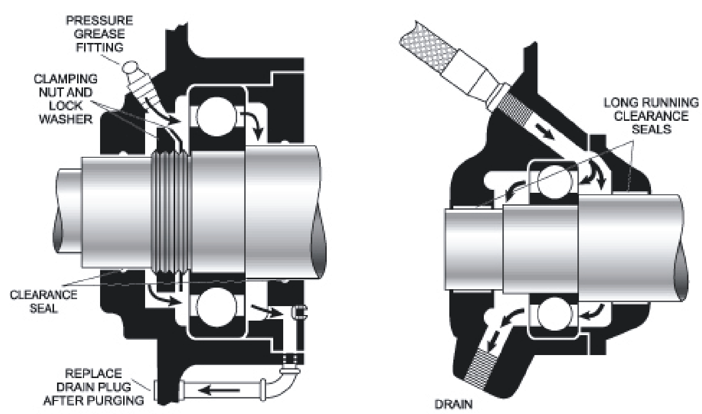


Fig. 3 — Free-purging housing designs. The design on the right, sometimes referred to as a transverse greasing design, may be preferable to that shown at left because the drain passage is shorter and larger.

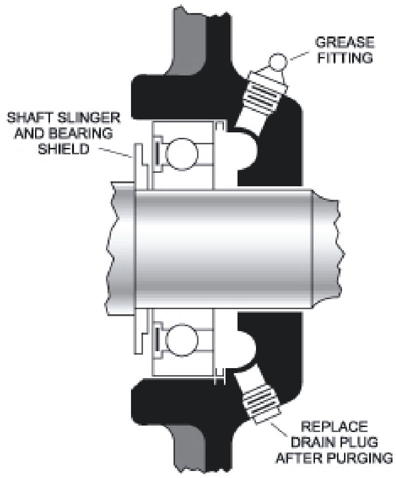


Fig. 4 — Lubrication – single-shielded bearing.

The pressure relief method is commonly used to relubricate bearings.

1. Remove the drain plug and clean old grease from the drain opening.
2. Clear the pressure fitting and grease gun nozzle to prevent introducing contaminants or abrasives into the bearing.
3. Using a hand operated grease gun, pump grease into the fitting until new grease appears at the drain opening. The motor should remain running and warm to allow for better dispersion of the grease.
4. After adding the new grease run the motor until the excess grease is expelled through the open drain plug. Clean the grease outlet of excess grease and replace the drain plug.

Note — When adding grease without the motor running, introduce only half the volume. Run the motor for 5-10 minutes at full speed, and add the final half. This purges the old grease from the bearing and prevents over packing and seal rupture.

The pressure relief method may be used for the initial filling of open type bearings. However, it is better to pack the bearings by hand or with a bearing packer before assembling them in the housings. If the bearings are not pre-packed, then after assembly apply grease with a gun until certain that it is uniformly distributed throughout the bearing and has not short circuited from inlet to drain. Start the motor and complete the pressure relief procedure.

Double shielded and double sealed bearings (Fig. 5), shields and seals on both sides, are generally of the lubricated-for-life design. Sealed-for-life bearings come prepacked with the correct amount of grease from the factory and do not require initial lubrication or in-service lubrication. Therefore, the bearing housing is typically not configured for grease re-lubrication.

To avoid unintended lubrication, remove any grease fittings and plug holes in motors containing lubricated-for-life bearings. Additionally, change maintenance records to indicate that the motor needs no further lubrication.

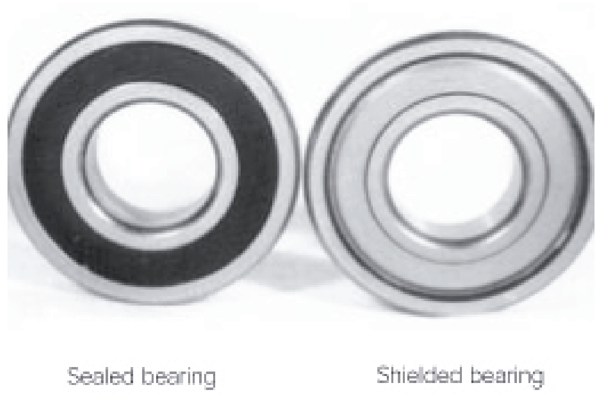


Fig. 5 — Double shielded and double sealed bearings.

Electric Motor Storage

Damage to electric motor bearings can occur even while a motor is in storage. The two main failure modes of bearings in storage, static corrosion and false brinelling are described below.

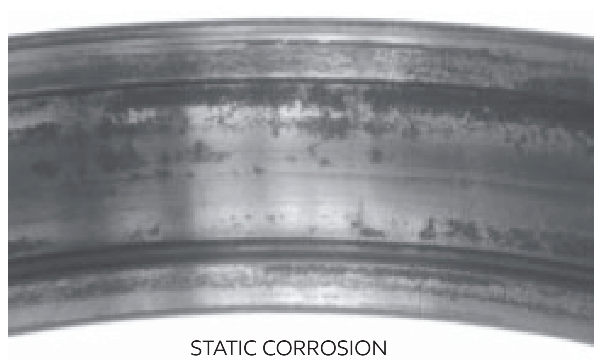


Fig. 6 — Static corrosion. Courtesy of NSK Corporation

Fig. 6 shows a bearing suffering from severe corrosive pitting. Corrosion can occur for two main reasons. First, the grease may not possess adequate rust and corrosion inhibitors to protect the metal surfaces. Second, the vibration in the motor could force out the grease from between the rollers and raceways in the load zone. Left unprotected, corrosion or rust can form on the metal surfaces.

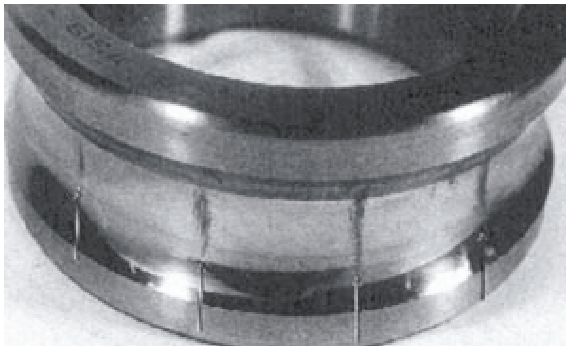


Fig. 7 — False Brinelling. Courtesy of NSK Corporation

False Brinelling

Fig. 7 illustrates a false brinelling failure mode. Vibration of the bearing in a static position causes the rolling elements to vibrate against the raceway in one place. Over time, the vibration can remove small bits of metal surfaces. This vibration induced metal removal can continue until the wear becomes very severe. This type of wear will appear as wear marks that line up with the spacing of the rolling elements. To prevent these and other types of damage, the following procedures should be followed:

- Fully grease motors going into storage. Tag the stored motor with the date of last lubrication and the lubricant name.
- Store motors in a clean, dry, vibration-free area.
- Store the motor on a surface that can absorb vibration such as wood, etc.
- Rotate idle motor shafts periodically to redistribute fresh grease and maintain a corrosion-preventive film on bearing surfaces.
- Align equipment and motor shafts carefully to obtain longest bearing life.
- Where the risk of contamination is high, grease cartridges are preferred since these are well sealed against contamination.

Condition Monitoring to Enhance Electric Motor Bearing Reliability

Lubrication and bearing problems often produce sonic and ultrasonic sound as well as heat. By using standard vibration analysis, ultrasonic sound (vibration analysis), and heat detection, electric motor bearing reliability can be optimized. Although this paper has supplied recommendations for the amount and frequency of re-lubrication, operating conditions of specific motors may dictate altered lubrication recommendations. By auditing electric motor operation, relubrication practices can be optimized and unsatisfactory conditions determined. Early detection of poor lubrication or bearing condition will allow appropriate action to be taken before extensive or unexpected equipment damage occurs.

Ultrasonic Detection for Bearing Lubrication

Ultrasonic vibration reading made with a passive contact ultrasonic listening device, should always be taken at the same location, in the same axis, and using the same acquisition parameters in order to develop good trending data. Choose a position and orientation that allows vibration to travel through the fewest number of interfaces possible. As high frequency energy travels from the bearing, the energy dissipates quickly as it moves through more and different surfaces. To gain the best data, take readings as close as possible to and in the same direction as the bearing load. Most bearing impacts will fall in the 4 kHz range, while lubrication and minor impacting problems will appear at 30 kHz (see Fig. 8). These are the frequency ranges that need to be examined when analyzing bearings.

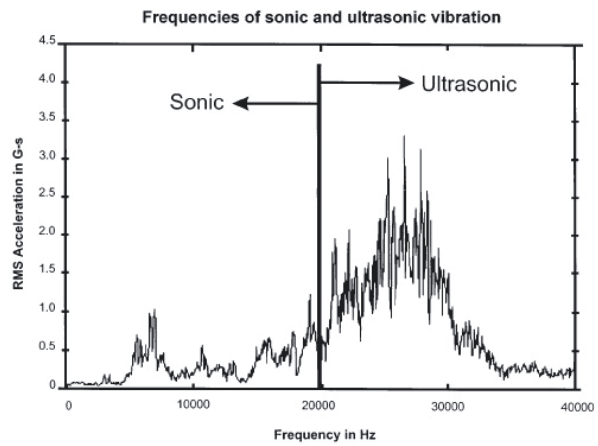


Fig. 8 — Normally, poor lubrication appears first in the ultrasonic range (over 20,000 hertz). Courtesy of Computational Systems Inc.

Under Lubrication: In rolling element bearings, sound is created by friction induced stress waves from the interaction of the rolling elements and raceway and the rolling elements and cage. As lubrication starvation occurs, the lubrication film thickness will decrease resulting in a greater coefficient of friction. The increased friction coefficient creates more heat and sound. At 30 kHz, under lubricated bearings will sound much like white noise and has little periodicity commonly heard in bearings with mechanical faults. Temperature is not generally a good indicator of under lubrication unless lubricant is absent altogether.

As a general rule, the optimum or baseline ultrasonic amplitude at 30 kHz should be 10 dB or less. Normal lubrication amplitudes should be 10 to 20 dB. Testing has shown that the critical level before permanent damage occurs is around 30 dB. These are general estimates that vary depending on the type of bearing and the application.

More accurate levels can be estimated through testing and trending. If the amplitude exceeds 30 dB (or if there is a significant increase in crackling/rushing noise for devices without dB readouts), grease should be applied until the noise goes under 30 dB or until it subsides.

Temperature Analysis for Bearing and Lubricant Condition

Sound analysis has proven ineffective for determining conditions of over lubrication. The best method for determining over lubrication is achieved by monitoring temperature increases.

Although temperature analysis can prove useful for determining the extent of over lubrication, there are other causes of temperature change, including:

- Poor motor ventilation (plugged motor end bell, missing or broken fan, plugged fan inlet, etc.)
- Excessive or abnormal loading on the device the motor drives
- Broken motor rotor bar
- Single phasing on a three phase induction motor
- Loose bearing fit on the motor shaft
- Failing bearing
- Poor coupling condition
- Poor shaft alignment between the motor and the driven unit
- Poor motor mounting (excessive soft foot)

Before applying more grease to a hot running bearing, investigate all possible reasons for increased temperatures.

Fig. 9 Shows the standard vibration frequency spectrum of a bearing that is operating in a poorly lubricated condition. The contact between rollers and raceway can excite some of the high resonant frequencies of other bearing components. Ultrasonic readings can help to detect poor lubrication long before this damage occurs. This type of analysis can also aid in determining if the motor bearing is re-lubricated with the correct amount of grease and at the correct frequency. Normally, poor lubrication appears in the range of 800 to 2000 hertz with 80 to 120 hertz peaks appearing.

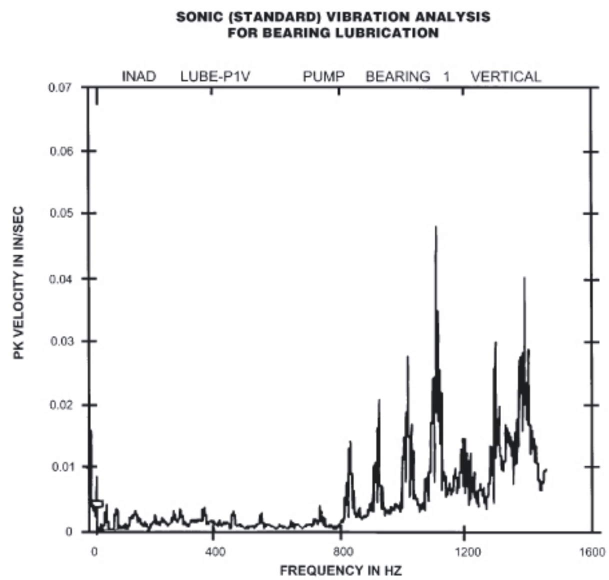


Fig. 9 — Courtesy of Computational Systems Inc.