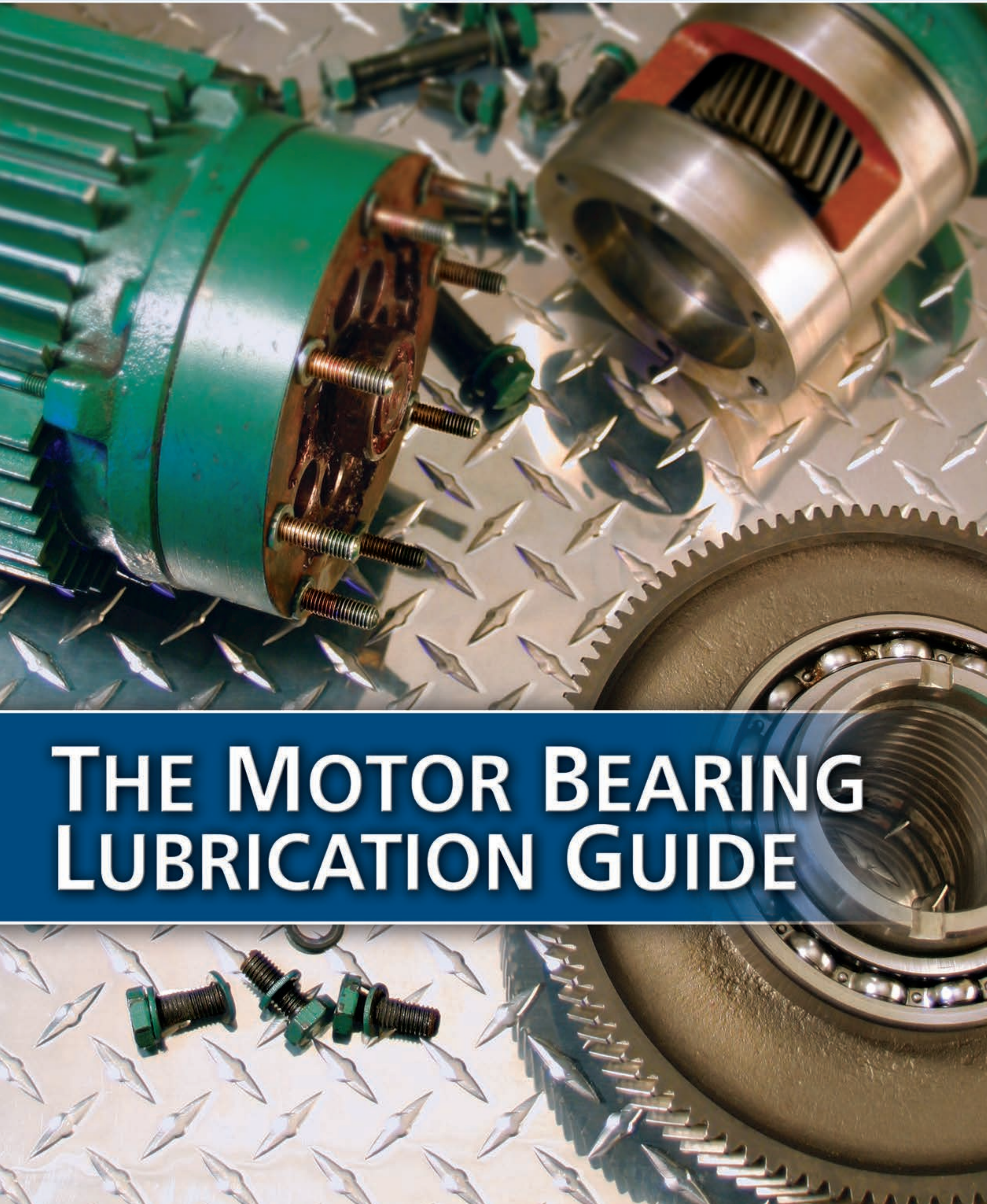
THE MOTOR BEARING LUBRICATION GUIDE



The Motor Bearing Lubrication Guide

First Edition

Published by Noria

Published 2008 by
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The Motor Bearing Lubrication Guide

Lubricating Electric Motors
Using the Hybrid Method

By Jeremy Wright, Noria Corporation

Determining when to lubricate bearings and how much lubrication to apply are two issues that face technicians responsible for maintaining bearings. Underlubrication can cause a bearing to wear out prematurely. On the other hand, applying too much lubricant can often lead to catastrophic results to the bearing (grease churning and overheating) or long-term damage to motor coils and windings.

The Regrease Interval

There are several methods for determining a regrease time cycle. Multiple calculators, tables and charts provide a good starting point. Most calculators have common factors such as load, operation time, bearing type, temperature, environment and speed. Pick a method you're comfortable with or use the average value calculated from several of the methods and use it throughout your plant to build a database of lubrication intervals.

Figure 1 illustrates how to use the new database in conjunction with the acoustic monitoring equipment. As time passes (following the trend line from left to right), you will see two possible outcomes. The trend line will cross the alarm threshold or the calculated regrease interval. When either of these two lines is crossed, it is time to relube. After several cycles, a pattern should emerge.

If the trend line never crosses the acoustic monitoring alarm threshold, then the calculated interval is set too short. Likewise, if the calculated interval is never reached, then the calculated interval is too long. Using this pattern or trend, the regrease interval can be adjusted. The interval will be optimized when the trend line crosses both limits at approximately the same moment in time.

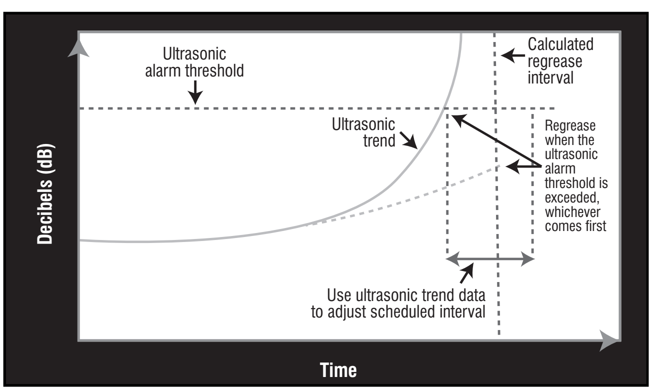

Figure 1. When to Regrease

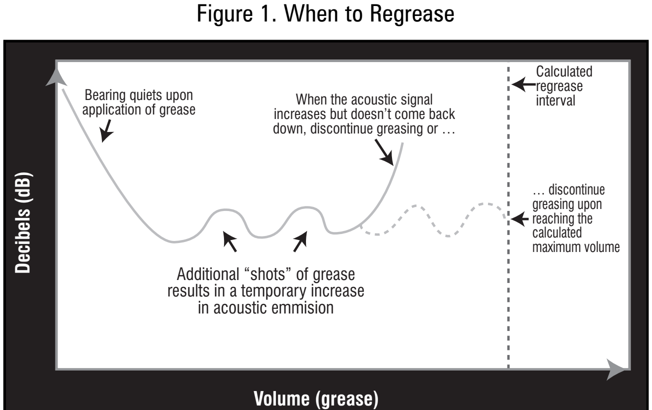

Figure 2. Regreasing a Bearing Using a Grease Gun

As with the interval, there are multiple calculators, tables and charts to determine the correct volume of grease to apply at the determined interval. A simple equation takes a logical approach to determining the volume of grease to be added. The formula is:

$$G = 0.114 \times D \times B$$

Where G = the amount of grease in ounces, D = the outside diameter in inches and B = the bearing width in inches.

Apply this formula to all the greased lube points in the plant and add them to the interval database.

Figure 2 illustrates the significance of this value in the hybrid approach. As the initial charge of grease is added to the lube point, there should be a drop in the acoustic emission. Adding each additional shot will temporarily increase the emission. This presents two possible outcomes. The first result is that grease continues to be added until the calculated regrease volume is reached.

In this instance, no more lubrication should be added to this lube point. If the acoustic signal does not come back down during the addition of grease, discontinue greasing. The database should track when a calculated volume is not reached. This could be a sign of an inherent problem in the bearing.

Abridged Procedure Steps for the Hybrid Method

1. Locate the grease fill ports at the top half of the bearing. Locate the grease relief port or plug at the bottom half of the bearing at either 180- or 120-degree offset.
2. Remove the drain plug and make sure the grease opening is free of solidified grease.
3. Attach the magnetic mounted transducer to the bearing housing at the prescribed location and tune the unit to 30 kilohertz (or according to original equipment manufacturer recommendations).
4. If the decibel (dB) reading is at or below baseline value, record the dB reading. Do not add grease. If the dB reading is 50 percent over the baseline value, the bearing may need lubricating. Record this initial dB reading along with sound quality and proceed to grease the bearing as below.
5. Wipe the grease fitting and make sure the end of the grease gun connector is free of contamination. Press the grease gun hose end connection onto the grease fitting. Gradually apply the grease while carefully observing the discharge port for old grease.
6. After each shot, listen to the sound of the bearing and watch the dB meter. If the bearing surface receives lubrication, there should be a noticeable drop in audible and dB sound levels upon application of the grease.
7. After the sound level has dropped, slowly add more grease and continue to monitor audible and dB levels. Discontinue greasing when either the audible or dB levels rise and remain high, or when the recommended volume of grease has been added.

8. Replace the dust cap on the zerk (or other) grease fitting. If no cap is available, then leave a thin covering of grease on the fitting.
9. Allow excess grease to exit the drain, then replace the drain plug.

Hybrid Method

For the hybrid method to be successful, there needs to be a direct communication between all parties involved, from the lube tech to the maintenance planner. The transfer of data can be handled in several ways. It could be through a wireless system that updates in real time via a handheld PDA the technician carries, or as simple as a face-to-face meeting after the lube/inspection route to discuss the nonconformist assets.

Either way, feedback is needed to make adjustments to intervals and volumes. The database that was created should be evolving and continually improving. The only way to accomplish this is through communication.

A New Perspective on Grease-lubricated Electric Motors

By John Underwood, DuPont Engineering Technology

Over the past few years, there has been a renewed interest in the industry regarding the proper lubrication methods for grease-lubricated electric motors.

This chapter reviews the results from laboratory testing of a grease-lubricated NEMA-frame, 3,600 rpm electric motor manufactured to IEEE 841 standards and equipped with open deep-groove ball bearings and grease relief valves on bearing housing outlets.

Results and conclusions from this work were confirmed in the field and will be the basis for modification of a DuPont lubrication engineering standard covering electric motor lubrication.

Background

DuPont lubrication standard "PL 43 – Lubrication of Electric Motors" provides detailed guidance on acceptable lubricants and lubrication methods for electric motors, both grease and oil-lubricated. This article focuses on grease-lubricated NEMA-frame motors between 10 and 200 horsepower typically used to drive process pumps, mixer gearboxes, cooling tower pumps and fans, and other nonprocess-critical general-purpose applications.

Motors can be equipped with either open-, single- or double-shielded deep-groove ball bearings depending upon the manufacturer's preferences. According to our motor lubrication standard, on motors equipped with shielded bearings, the shields are to be oriented toward the grease cavity in the end bells. All bearing housings are to be fitted with grease relief valves to prevent overlubrication and damage to the windings, as well as possible damage to shielded bearings should the bearing housings become full of grease. Use of a high-quality, polyurea-thickened, mineral base oil grease is recommended for general-purpose applications up to 3,600 rpm and ambient temperatures up to 40°C.

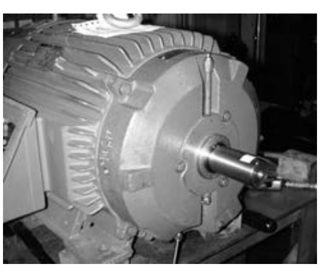

Figure 1. IEEE 841 Test Motor

Figure 2a. Inner Cap on Bearing Housing Fitted with Gits Cup

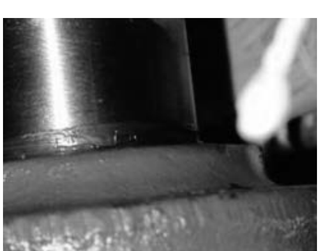

Figure 2b. Inner Cap on Bearing Housing Fitted with Alemite Grease Relief Valve

Figure 3. Grease on Labyrinth Seal Outer Diameter and on Inner Cap

While two methods of relubrication were permitted in the DuPont standard, Motor Stopped and Motor Running, the Motor Stopped method was clearly preferred assuming that this was the best method to prevent overlubrication and damage to the windings. However, in actual practice, the Motor Running method is the predominant method used at the plant level, because operational demands precluded shutting down a piece of equipment for routine relubrication, as this could upset the process and cause an unanticipated plant shutdown.

In the early 1990s, DuPont entered into a preferred supplier alliance with an internationally known manufacturer of high-quality electric motors to provide new and/or replacement motors manufactured to the IEEE 841 standard. These 841-compliant NEMA-frame horizontal motors are equipped with open ball bearings, grease relief valves and rotating labyrinth seals on both bearing housings. In addition, motors were equipped with a patented bearing housing design to provide positive lubrication of motor bearings for long, trouble-free lives.

Prior Testing

In August 2001, DuPont conducted tests at an authorized electric motor repair facility in the Mid-Atlantic area, which raised even more questions on the effectiveness of the Motor Running method in preventing/minimizing grease from entering the windings of an in-service motor.

In this impromptu test, an industry-leading polyurea grease was added to the bearing housing of a newly rebuilt electric motor. The motor, equipped with double-shielded deep-groove bearings was operating at normal speed and ambient shop temperature. Grease was added slowly from a hand-operated grease gun until grease exited the bearing housing 1/8-inch NPT relief port opening. Once grease was observed at the exit port, the motor was stopped, disassembled and inspected for the presence of excess grease.

Inspection showed a substantial amount of grease pushed through the outboard shield, the rotating bearing elements and the inboard shield, and entering the motor winding cavity. These findings were somewhat surprising as well as troubling, because this arrangement was thought to provide the best system to prevent overalubrication. Now, with our movement to the IEEE 841 standard design with its open bearing configuration, we became even more concerned about the feasibility of continuing to support the Motor Running lubrication method within our motor lubrication standard.

Even more concerning was that this test was conducted without any obstructions in the bearing housing outlet port, such as extension pipes and/or grease relief valves, which were permitted and even encouraged in the standard.

Also, the grease was absolutely fresh, whereas, long-life in-service motors could potentially have hardened or dried grease, possibly adding more restriction in the outlet path. Based on these factors, we felt additional testing on the new 841 design motor was warranted to determine the effectiveness of this design in preventing overlubrication and motor winding contamination.

Recent Testing

In April 2002, with the assistance of our alliance motor vendor, and other DuPont engineering and mechanical specialists, a comprehensive testing program was carried out at the vendor's Baytown, Texas repair facility.

Six test cases, two static and four dynamic, were developed to evaluate the following factors:

- Motor Stopped vs. Motor Running lubrication method
- Effectiveness of grease relief valves, Gits cup vs. Alemite pin design
- Effectiveness of positive lubrication system in reducing/preventing overlubrication and motor contamination
- Performance of industry-leading polyurea grease vs. a competitive low-noise polyurea – effects of physical/chemical properties on lubrication performance

A new IEEE 841 compliant motor (Frame 326T, 3,600 rpm) was supplied by the DuPont LaPorte THF area for the test. The motor was equipped with rotating labyrinth seals, open deep-groove ball bearings and grease relief valves on both motor bearing housings. A thermocouple was installed in contact with the output shaft bearing outer race to monitor bearing temperatures during the test.

Relief Valve Static Tests

The first series of static tests were conducted to evaluate the effectiveness of the two approved grease relief valves in controlling/minimizing grease entry into the motor in the Motor Stopped condition. The following test protocol was used:

- The motor end bell was removed and the motor bearings and grease cavity were packed 100 percent full of the test grease for all test conditions to increase the severity of the test.
- The end bell was carefully reassembled and then a predetermined amount of grease, based on the bearing dimensions, was slowly added to the bearing housing.
- The motor end bell was removed and the grease distribution was evaluated both qualitatively and quantitatively.

The test was repeated using the same test protocol, but the Gits cup was replaced by an Alemite 314700 grease relief valve, rated at 1 psig opening pressure, and the same predetermined grease volume was again added to the bearing housing. The following results were obtained:

- There was little difference in the performance of either relief valve in the cold static test: Gits cup (Figure 2a), Alemite fitting (Figure 2b). One valve discharged 16 grams of grease, the other 14 grams.
- A negligible amount of grease migrated past the inner cap down the motor shaft as can be seen in Figures 2a and 2b.
- Both valves are effective in preventing gross overlubrication in a Motor Stopped cold condition.
- The Gits cup was judged slightly better than the Alemite fitting due to a larger bore opening in the fitting. Even after the grease gun was removed from the supply zerk fitting, grease continued to purge from the Alemite relief fitting for several seconds, which indicated residual pressure buildup in the bearing housing.

Based on the results of these static tests, the remainder of the dynamic tests were conducted with the Gits cup directly connected to the bearing housing outlet.

Dynamic Tests

Test Condition 3 – Motor Stopped Cold Start – Industry-leading Polyurea

In this test condition, the motor, which was at ambient conditions and bearing housing 100 percent grease full, was started on the test bench and allowed to run at its no-load speed of 3,600 rpm. The drive end bearing temperature was recorded at one-minute intervals until the temperature plateaued and started to drop, indicating that the bearing housing had purged all the excess grease and reached an equilibrium condition.

The motor was stopped and quickly opened, and all internal parts evaluated for grease migration.

A considerable amount of grease migrated past the inner cap and flung off the rotating shaft onto the motor windings. A considerable amount of grease was also found in the drive end bell. No grease exited the grease relief valve during the test.

Another interesting observation during this test was the fact that grease pushed through the drive end labyrinth seal and small bits of grease were thrown against the inner cap retainer bolt heads and onto the working surfaces around the motor (Figure 3).

From a practical perspective, this test condition simulated relubrication in the Motor Stopped condition and the grease relief valve did not function at all in this condition.

The drive end bearing operating temperature results are plotted in Figure 4.

The bearing temperature increased rapidly from a 70°F ambient to 120°F within the first minute of operation, then climbed steadily, reaching a maximum temperature of 176°F approximately 90 minutes into the test. The temperature then dropped slowly to a steady-state operating temperature of 152°F, approximately two and a half hours into the test.

The following interim conclusions were drawn from Test Condition 3:

1. The long temperature stabilization time indicted that the nominal 30-minute wait time in the lubrication standard may be inadequate for this relubrication method.
2. Due to temperature differences across the bearing housing and grease shearing in the ball path zone, undisturbed grease in the end bell at the exit port acts as a plug, preventing excess grease from exiting the bearing housing, whether or not a grease relief valve is present.
3. Operating at or near full housing conditions will force grease into the windings after a Motor Stopped lubrication event.

Test Condition 4 - Motor Running Normal – Industry-leading Polyurea

In the next test, 15 shots (3/4 ounce) of grease were added slowly to the stabilized, normal-operating motor using a standard hand-operated grease gun.

Again the outer race temperature was monitored and the motor components were inspected for excess grease after the test.

As observed in the previous test, grease migrated through the gap between the inner cap and the motor shaft and either dripped or was flung off the shaft into the motor winding and end bell.

However there was much less grease inside the motor, because unlike the previous test, the grease relief valve functioned as designed. However, after collecting and weighing all the excess grease from inside the motor and that which was expelled from the Gits cup, approximately one-third of the grease exited the relief valve and two-thirds leaked inside the motor.

Grease also continued to be purged out of the rotating labyrinth seal.

The consistency of the grease was found to be soft and drippy, suggesting loss of structural stability of the soap structure. It was not determined if this loss of stability was temporary or permanent.

The drive end bearing temperature is shown in Figure 5.

Again, the temperature increased rapidly over 20°F in the first minute of operation and then slowly increased over the next 40 minutes to approximately 175°F as seen in the previous Test Condition 3. However, the equalization time for this lubrication method is much closer to the generally accepted 30 minutes purge time contained in the standard and generally accepted within the industry.

The most important finding from this test was the fact that the grease relief valve system did function as designed and partially relieved the pressure in the bearing housing. This reduced the level of contamination in the motor cavity.

A plausible explanation for this result is that in the normal running condition, the grease within the bearing housing is much softer and more pliable, thus offering less resistance to flow of excess grease within the bearing system. It now appears that the Motor Running lubrication method reduces/minimizes the amount of grease that purges into the motor internals, especially under full housing conditions and should be the preferred method of lubrication for grease-lubricated motors.

Conclusions and Recommendations

1. Neither the Reliance positive lubrication system (PLS) with open bearings nor potentially other motors equipped with shielded bearings can prevent the ingression of grease into the motor windings.
2. Grease relief valves are most effective in preventing gross overlubrication in the Motor Stopped ambient temperature condition, but may not function during an ambient temperature restart, resulting in even more grease entering the motor internals.
3. Grease relief valves can reduce the amount of grease that enters the motor internals when relubrication is performed while the motor is running at steady-state operating temperature conditions.
4. Grease relief valves should be thought of as “excess lubricant indicators”. If grease is observed exiting the port, bearing housings are full. Reduce the lubricant amount or increase the lubrication interval.
5. The Motor Running method should be the preferred lubrication procedure for grease-lubricated electric motors requiring relubrication.
6. Adding a measured amount of grease at regular intervals should minimize the amount of grease getting into the windings without adverse affects on motor life.

The increase in temperature illustrated here may vary with different greases depending upon their chemical structure and physical properties as well as base oil viscosity.

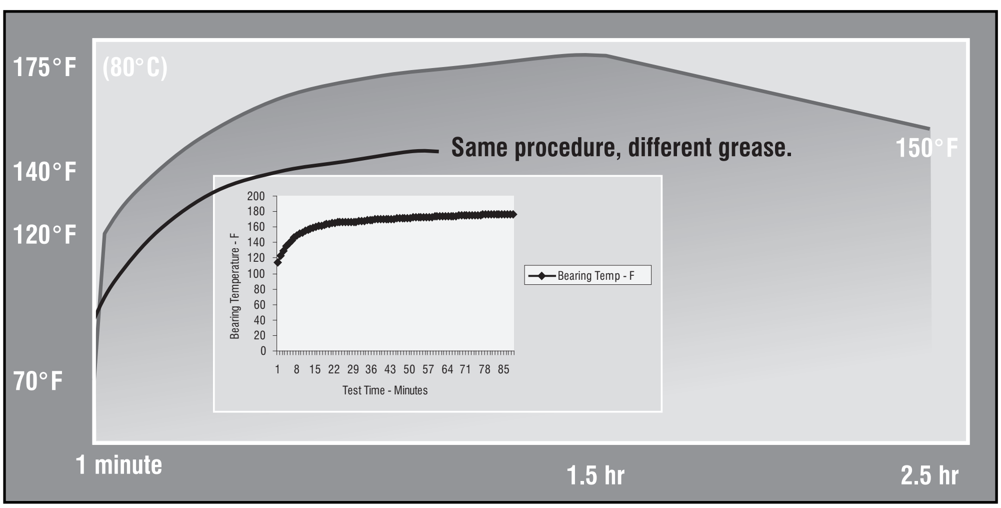

Figure 4. Overgreased, Stopped Motor Restart, No Grease Relief, Get Grease into Windings and out Labyrinth

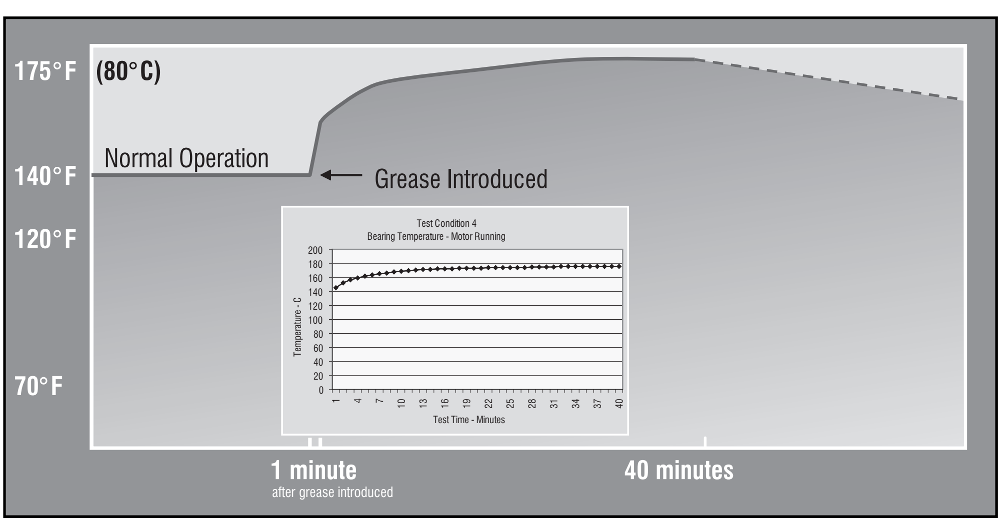

Figure 5. Normal Operation, Bearing Regreased,
Some Grease Relief, Some Grease into Windings and out Labyrinth

Proper Lubrication for Reducing Electric Motor Failures

By Jeremy Wright, Noria Corporation

Rolling element bearings used in electric motors are at risk for various modes of failure if an incorrect maintenance or lubrication strategy is implemented. These include incorrect lubricant selection, contamination, loss of lubricant and overgreasing. This article discusses several effective strategies to minimize the likelihood of these failure modes.

Most electric motors are designed with grease-lubricated, antifriction, rolling element bearings. Grease is the lifeblood of these bearings because it provides an oil film that prevents the harsh metal-to-metal contact between the rotating element and races. Bearing troubles account for 50 to 65 percent of all electric motor failures, and poor lubrication practices account for most of these bearing troubles. Proper maintenance procedures, planning and the use of the correct lubricant can increase productivity by reducing these bearing troubles and motor failures.

Failures

Get to know the failures. By knowing the failure modes, focus can be placed on reducing or even eliminating them.

Incorrect Lubricant – It is important to use the correct grease for specific applications. Regreasing with the wrong grease can lead to premature bearing failure. Most oil suppliers have grease that is specifically designed for electric motors, which is different from their multipurpose extreme purpose (EP) grease.

Grease Incompatibility – Greases are made with different thickeners, such as lithium, calcium or polyurea. Unfortunately, not all greases are compatible with each other, even those with the same thickener type. Therefore it is important to use the same grease or compatible substitute throughout the life of the bearing.

Motor Casing Full of Grease – If the grease cavity is overfilled, and high pressure from the grease gun is applied, the excess grease can find its way between the shaft and the inner bearing cap and press into the inside of the motor. This allows the grease to cover the end windings of the insulation system and can cause both winding insulation and bearing failures.

Lubricant Starvation – There are several possible causes of lubrication starvation. The first is insufficient grease being added during installation. The second is inappropriate, elongated relubrication intervals. The third involves the possibility that the oil has separated from the thickener base due to excessive heat.

Overpressurization of the Bearing Housing – Anytime there is an overpressurization of the bearing housing, stresses are placed on parts that were not designed to handle the pressure. Keep in mind that the standard manual grease gun can produce pressures up to 15,000 psi.

Overheating Due to Excess Grease –Too much volume will cause the rotating bearing elements to churn the grease, trying to push it out of the way. This results in parasitic energy losses and high operating temperatures, and increases the risk of oil separation and bearing failure.

Getting Started

To begin, a plan must first be in place. The following suggestions are the bare minimum that need to be discussed and implemented to get the program started.

1. Make an equipment list that includes all the assets needed in the program.
2. Verify the type of bearings and their seals that are installed in both the inboard and outboard ends of motors. This will determine if the bearings are regreasable. A policy should also be determined for the regreasing of shielded bearings, commonly found in motors. (Some experts recommend not greasing double-shielded bearings.)
3. Choose a grease type that will be adequate for the program. Remember that once a grease type and manufacturer are chosen, it's best to not deviate from this choice. If this grease is different from a grease previously used in the bearings, the previous grease will need to be cleaned out or flushed from the bearings and housings.
4. Make all necessary modifications to the electric motors. This includes adding fittings and making them accessible.
5. Establish a set of procedures for maintaining the motors.

Develop a PM System

There are many choices to make when deciding on a preventive maintenance (PM) system. In some plants it may be beneficial to use only a spreadsheet, while others have the need for complete dedicated systems. The end goal is the same. Each motor needs to be tracked as an asset, accomplished by noting the attention each motor receives. Some factors to include in the PM system are: date of installation,

horsepower, frame size, rpm, bearing type and environmental conditions. Setting up a system like this may take some time, but once completed it will be a great tool.

Determining Lube Type

When searching for a lube type and manufacturer or supplier, there are several things to consider. The following is a list of qualities of a good electric motor grease:

- Good channeling characteristics
- NLGI Grades 2 to 3
- Base oil viscosity of an ISO VG 100 to 150 or more specifically 90 to 120 cSt at 40°C
- High dropping point, 400°F minimum
- Low oil bleed characteristics, per D1742 or D6184
- Excellent resistance to high-temperature oxidation
- Good low-temperature torque characteristics
- Good antiwear performance (but not EP)

Polyurea grease is popular with many bearing and motor manufacturers. A significant proportion of equipment manufacturers also specify some type of polyurea grease in their electric-powered machinery. A polyurea-based grease is an excellent grease for electric motors; however, this thickener is incompatible with most other thickeners. Some manufacturers don't recommend mixing one brand of polyurea with another. Instruct the motor rebuild shop on what grease to use, and make sure the grease type is specified on new motor purchase orders.

Determine Regrease Time Cycle

There are several methods for determining a regrease time cycle. It is important to realize that no single method will provide a magical answer to a plant's problems. The multiple calculators, tables and charts available can provide a good starting point. They can be used to determine how to set the cycles. The real fine tuning, however, must be done by trial and error. The factors that most calculators have in common are load, operation time, bearing type, temperature, environment and speed. This is where the database that was built will be beneficial.

Grease Volume Control

Grease volume control has been a long-standing problem for industry, and simply following OEM recommendations may not be enough to solve this problem. There is a simple equation that takes a logical approach to determining the volume of grease to be added. The formula is:

$$G = 0.114 \times D \times B$$

Where G = the amount of grease in ounces, D = the bore diameter in inches and B = the bearing width in inches.

Once the volume is found, it must be converted into shots, or pumps of the grease gun. There is one way to obtain the value used to convert the number; for this the user will need the grease gun to be used and a postal scale. After finding the output per full stroke of the handle, label the gun so that it is now "calibrated". The average value is approximately 18 shots per ounce for most manual guns but grease gun output can vary by a factor of 10, so be sure to calibrate each gun.

The Use of Feedback Instruments

Feedback from the lubrication points is needed to verify that the proper frequency and volume has been chosen. Ultrasonic instrumentation might be the best tool available to dial in the optimum relubrication frequency. A conservative approach is to use a frequency generation method as a starting point, and continuously refine that value based on feedback from the ultrasonic equipment. Likewise with volume, ultrasonics can be used to hone in on the correct amount of grease by using the hybrid method.

Procedure

The intent of a good maintenance program is to extend the service life of a motor. In most cases, improper lubrication procedures can have a negative impact on the program. A basic set of procedures should include some variation of the following:

1. Ensure the grease gun contains the appropriate lubricant.
2. Clean the areas around the relief and fill fittings.
3. Remove the grease relief valve or drain plug.
4. Grease the bearing with a calculated amount of grease. Slowly add grease to minimize excessive pressure buildup in the grease cavity.
5. Watch for grease coming out the relief port. If excessive amounts of grease are pumped into the motor and the old, used grease is not being purged, stop and check for hardened grease blocking the relief passage.
6. If regreasing is performed with the motor out of service, run the motor until bearing temperature increases to operating temperature to allow for thermal expansion of the grease. Ensure the relief valve or drain plug is left out during this process.
7. Allow the motor to run at this temperature for a short time to expel any excess grease before installing the bottom grease relief valves.
8. After excessive grease has been purged, reinstall the drain plug and clean excessive grease from the relief port area.

More Lubrication Strategies for Electric Motor Bearings

By Heinz Bloch, Process Machinery Consulting

The proprietary in-house statistics of a number of petrochemical plants in the United States indicate that approximately 60 percent of all motor difficulties originate with bearing troubles. If a bearing defect is allowed to progress to the point of failure, far more costly motor rewinding and extensive downtime will often result. Improvements in bearing life should not be difficult to justify, especially if it can be readily established that most incidents of bearing distress are caused by lubrication deficiencies.

There is some disagreement among electric motor manufacturers as to the best bearing arrangement for horizontal-type, grease-lubricated, ball bearing motors. There is also disagreement on the best technique for replenishing the grease supply in the bearing cartridge. If the user of these motors wishes to follow the recommendations of all these manufacturers for their respective motors, he must stock or have available ball bearings in a given size with no shield, single-shield and double-shield. He should also train personnel in the relubrication techniques for each make of motor. The confusion thus created in the minds of maintenance personnel may indeed bring about a less-than-satisfactory method of maintaining expensive, important equipment.

This discussion will focus on grease lubrication methods for electric motor bearings. All too often, an industrial user will employ less-than-ideal lubrication strategies, or vulnerable bearing housing configurations. These are the issues addressed first.

How Grease-lubricated Bearings Function in Electric Motors

A shielded, grease-lubricated ball bearing (Figure 1) can be compared to a centrifugal pump having the ball-and-cage assembly as its impeller and having the annulus between the stationary shield and the rotating inner race as the eye of the pump. Shielded bearings are not sealed bearings. With the shielded bearing, grease may readily enter the bearing, but dirt is restricted by the close-fitting shields. Conversely, bearings of the sealed design will not permit entry of new grease, whereas with shielded bearings, grease will be drawn in by capillary action as the bearing cage assembly rotates. The grease will then be discharged by centrifugal force into the ball track of the outer race. If there is no shield on the back side of this bearing, the excess grease can escape into the inner bearing cap of the motor bearing housing.

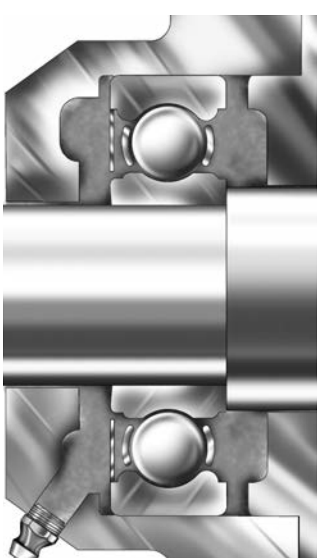

Figure 1. Shielded, Grease-lubricated Bearing

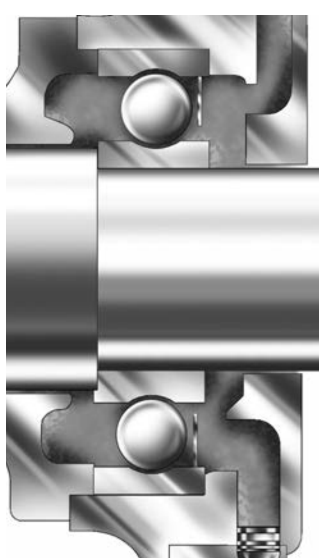

Figure 2. Single-shielded Motor Bearing with Shield Facing the Grease Cavity

Single-shielded Bearings

Many bearing users consider the regular single-shielded bearing with the shield facing the grease supply (Figure 2) to be the best arrangement. Experience indicates this simple arrangement will extend bearing life. This arrangement will also permit an extremely simple lubrication and relubrication technique. The shield serves as a baffle against agitation. The shield-to-inner-race annulus serves as a metering device to control grease flow. These features prevent premature ball bearing failures caused by contaminated grease and heat buildup due to excess grease. For other services where an open bearing is necessary, as in some flush-through arrangements, the shield can be removed in the field.

Double-shielded Bearings

Some motor manufacturers subscribe to a different approach, favoring double-shielded bearings. These are usually arranged as shown in Figure 3. The housings serve as a lubricant reservoir and are filled with grease. By regulating the flow of grease into the bearing, the shields act to prevent excessive amounts from being forced into the bearing. A grease retainer labyrinth is designed to prevent grease from reaching the motor windings on the inner side of the bearing.

On motors with this bearing configuration and mounting arrangement, it is not necessary to pack the housing next to the bearing full of grease for proper bearing lubrication. However, packing with grease helps prevent dirt and moisture from entering. Over a long period, oil from this grease reservoir enters the bearing to revitalize the grease within the shields. Grease in the housing outside the stationary shields is not agitated or churned by the rotation of the bearing and consequently, is less subject to oxidation. Furthermore, if foreign matter is present, the fact that the grease in the chamber is not being churned reduces the probability of the debris contacting the rolling elements of the bearing.

On many motors with grease-lubricated double-shielded bearings, the bearing housings are not usually equipped with a drain plug. When grease is added and the housing becomes filled, some grease will be forced into the bearing, and any surplus grease will be squeezed out along the close clearance between the shaft and the outer cap. This happens because the resistance of this path is less than the resistance presented by the bearing shields, metering plate and the labyrinth seal.

Open Bearings

High-load and/or high-speed bearings are often supplied without shields to allow cooler operating temperature and longer life. One such bearing is illustrated in Figure 4. If grease inlet and outlet ports are located on the same side, this bearing is commonly referred to as "conventionally grease-lubricated." If grease inlet and outlet ports are located at opposite sides, it is referred to as cross-flow, or cross-lubrication.

Lifetime-lubricated, Sealed Bearings

Lubed-for-life bearings incorporate close-fitting seals in place of, or in addition to shields. These bearings are customarily found on low-horsepower motors or on appliances that operate intermittently. Although it has been claimed that sealed ball bearings in electric motors will survive as long as bearing operating temperatures remained below 150°C (302°F) and speed factors DN (mm bearing bore times revolutions per minute) did not exceed 300,000. Other studies showed that close-fitting seals can cause high frictional heat and that loose-fitting seals cannot effectively exclude atmospheric air and moisture which will cause grease deterioration. These facts preclude the use of lubed-for-life bearings in installations where expected life in the typical plant environment is more than three years. Moreover, some experts believe this is the reason bearing manufacturers advise against the use of sealed bearings larger than size 306 (30 mm shaft size) at speeds exceeding 3,600 rpm.

A 1989 guideline issued by a major bearing manufacturer gives a DN value of 108,000 as the economic, although not technically required, limit for lifetime-lubrication.

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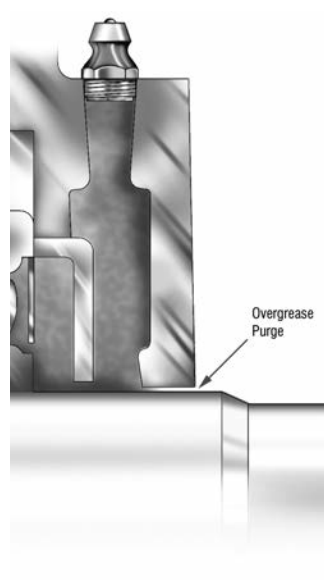


Figure 3. Double-shielded Bearing with Grease-metering Plate Facing Grease Reservoir

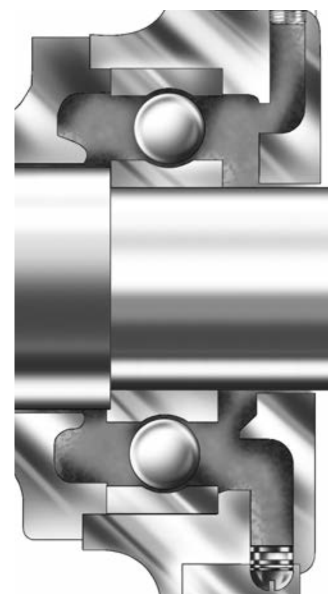


Figure 4. High-load and/or High-speed Bearings are Often Supplied without Shields

	Oil	Oil	Grease	Dry Lubricant
	Rolling bearing alone	Rolling bearing with gearing and other wearing parts	Rolling bearing alone	Rolling bearing alone
← Decreasing service life[2]	Circulation with filter, automatic oiler	Circulation with filter	Automatic feed	
	Oil-air spray			
	Oil-mist	Oil-air spray		
		Oil-mist		
	Circulation without filter[1]			
		Circulation without filter[1]		
	Sump (bath), regular renewal		Regular regreasing of cleaned bearing	
		Sump (bath), regular renewal[1] Rolling bearing		
	Sump (bath), occasional renewal		Regular grease replenishment	
		Sump (bath), occasional renewal Rolling bearing		Regular renewal
			Occasional renewal	
			Occasional replenishment	
			Lubrication for life	Lubrication for life

[1] By feed cones, bevel wheels, asymmetric rolling bearings. [2] Condition: Lubricant service life less than fatigue life. Ref: ISBN 0-471-26283-8

Table 1. Influence of Lubrication on Service Life (Source: FAG Bearing Corporation)

Improving Motor Bearing Reliability

By Jerry Honeycutt, Tennessee Valley Authority

Overgreasing rolling element bearings in motors has been an industry problem for several years. More motors have bearing failures due to overgreasing than from undergreasing. For the nuclear power generation industry in particular, the Nuclear Regulatory Commission (NRC) provided guidance and direction through the development of Information Notice 88-012, issued in July 1988, to address this problem. The method delivered mixed performance results for the amount of resources that companies have had to devote to motor relubrication, motivating some organizations to develop additional improvements.

One such improvement, developed through a coordinated effort between the Electric Power Research Institute (EPRI) and several utilities, has produced the "Electric Motor Predictive and Preventive Maintenance Guide," NP-7502, which provides guidance on how to regrease motors, when to add grease and how much grease to add. However, while NP-7502 is a useful guideline, it cannot be applied to resolve the issue of overgreasing motors that are already in service and already have an unknown quantity of grease in the bearing cavity. Consequently, even with NP-7502 guidance, overlubrication of greased bearings could still be a problem.

Current Status

All of TVA's nuclear sites use NP-7502 for regreasing guidelines. Practices used prior to the adoption of the new guideline resulted in overfilling several motors. Subsequent actions required by NP-7502 served to further pressurize grease cavities of the bearing housings, in some cases to the extent that bearing shields were pressed into the ball cage of the rolling elements, resulting in the failure of shields and bearings.

In cases where the bearing did not include the use of a shield, sufficient grease pressurization of the cavities occurred, causing grease to pass through the rolling elements and between the air gap between the inner bearing cap and the shaft into the windings. This led to windings and insulation becoming covered with grease, which led to motor failure or degraded operation.

An example of a bearing failure due to bearing shields being pushed into the raceway as a consequence of overgreasing is shown in Figure 1. This was a control rod drive (CRD) fan motor at Watts Bar Nuclear Plant. The bearing experienced a ball cage failure due to the bearing shield (Figure 2) being pushed down on the ball cage due to overpressurization of the grease cavity.

Approximately 90 percent of grease-lubricated motors within the power generation industry have the shield configuration shown in Figure 3. As illustrated, the grease enters and exits from the same side of the bearing cavity. This means that, using the existing relubrication standard, if the bearing grease cavity becomes overfilled with grease, or the existing grease in the cavity hardens in place, the elevated grease pressure generated by the addition of new grease will force the shield into the ball cage and rolling elements leading to premature bearing failure.

In the absence of shields, grease passes through the rolling elements of the bearing, fills up the inner bearing cap grease cavity and eventually is forced through the air gap of the inner bearing cap and the shaft. The grease then becomes deposited on the motors and windings. This can lead to a premature winding failure. TVA Nuclear has experienced both of these types of failures.

Present Method of Relubrication in TVA

The normal sequence to regrease a motor is as follows:

1. If possible, the bearing should be at a stable, normal operating temperature, making the grease less viscous.
2. Remove the drain plug and any hardened grease.
3. Clean the grease (zerk) fitting before attaching the grease gun.
4. Use the regreasing guidance provided by EPRI NP-7502 for the grease fill quantity and regreasing frequency.
5. After regreasing is complete, leave the drain plug out and operate the motor under normal bearing operating temperatures for at least one hour. This allows the grease to thermally expand and vent out the port, relieving any excess pressure in the cavity.
6. After thermal expansion is complete, clean the excess grease and reinstall the drain plug.

This sequence requires several hours with operational support to grease and operate each motor. With the large number of motors within TVA that require lubrication, there is considerable cost associated with

Figure 1

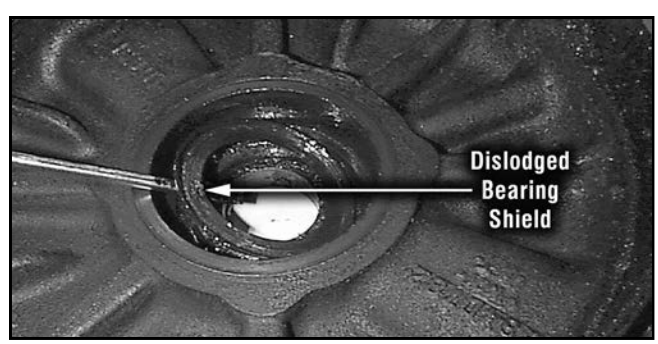


Figure 2. End bell with bearing shield that has become dislodged from the bearing.

motor lubrication. Additionally, even when the sequence is followed precisely, a bearing cavity may still become overfilled throughout the life of the bearing. This is further complicated if the existing quantity of grease in the grease cavity for a motor is unknown.

Proposed Change to Eliminate Overpressurization

To eliminate overgreasing and to reduce maintenance and operational support time to perform regreasing, existing relief ports and hydraulic fill fittings are replaced with relief valves and a pressure-controlled grease-fill fitting. The new method incorporates the new fittings as follows:

1. Install a pressure-sensitive (20 psi differential) grease-fill fitting that will not allow the cavity to be pressurized beyond 20 psi. This should minimize excessive pressure buildup on the bearing shield while the motor is being regreased.
2. Install a grease-relief valve-fitting to take the place of the grease drain plug. The grease-relief valve will open between 1 and 5 psi and will minimize risk of over-pressurization of the grease cavity from re-lubrication and thermal expansion of the grease (while running the motor).
3. Follow the regreasing guidance of EPRI NP 7502, "Electric Motor Predictive and Preventive Maintenance Guide," Appendix B. This information may be obtained from EPRI - Nuclear Maintenance Applications Center in Charlotte, North Carolina. Contact project manager Wayne Johnson at 704-547-6100.
4. For motors with housings around a cooling fan on one end bell, install an extension tube (NPT pipe nipple) at the drain plug. The extension tube should be long enough to clear the housing. The grease-relief valve should be installed at the end of the pipe tube.

For nuclear operations, the change in fill and drain plug fittings has been discussed with the environmental qualification (EQ) representatives to ensure acceptability for use in EQ motor applications.

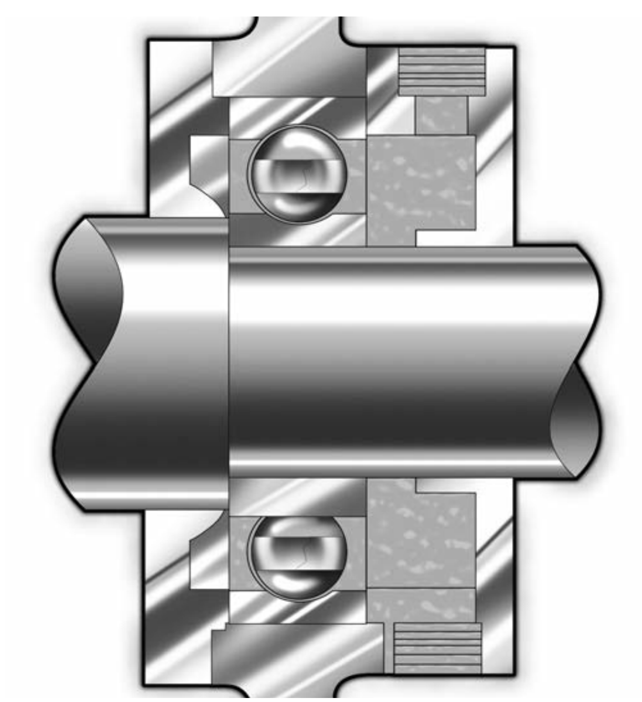


Figure 3. Motor Bearing

There were no EQ or seismic concerns raised for the use of these fittings on EQ motors.

Hydraulic Shut-off Grease Fittings

These fittings are intended to prevent overlubrication and overpressurization of bearing shields. The design provides for pressure-specific shut-off (for example, 20 psi). At the given shut-off pressure, the grease flow will stop. When pressure falls below the maximum, the grease flow can resume. The typical design includes a 60-degree angle and a 1/8-inch PTF male pipe thread. They are available from various manufacturers in various quantities. McMaster Carr provides this unit in packages of 10 for approximately $0.35 each.

Pressure-relief Vent Fittings

These fittings are intended to work as pressure-relief valves. Any time the pressure rises above the designed limit (for example, 1 to 5 psi), the unit will open, venting pressure. After pressure is relieved, the fitting will close to form a seal. McMaster Carr provides this unit in 3 sizes, 0.125, 0.25, and 0.50-inch OD with NPT threads, in packages of 10 for up to $0.70 for the 0.50-inch fittings.

Benefits

The cumulative savings between operation reliability, reduction in manpower requirements for operations and maintenance, and the reduced radiation dose exposure in the nuclear environment will be significant. Improvements in reliability realized from the enhancement include: reduction of motor bearing failures from cavity overpressurization and subsequent collapse of the grease shield, improved flushing of contaminants and debris from the housing, and improved lubricant quality through reduced churning.

Additional improvements in utilizing manpower include:

1. Reduced motor bearing failure
2. Reduced damage to windings and insulation
3. Improved contaminant flush
4. Reduced lubricant degradation due to churning
5. Reduced risk of radiation exposure.

In conclusion, because the addition of the fittings does not change the motor design or its operational characteristics, the motor's original design is maintained and documentation for new procedures development will be minimal.

Grease Guns - Learning the Basics

By Stan Morgan, Advanced Glassfiber Yarns

Four shots every 28 days. It couldn't get any simpler than that, right? At least I thought so at first.

Two years ago, when I was asked to manage our facility's machinery lubrication program, I had limited experience with lubrication. My manager suggested I refocus the program on the basics; which I agreed was a reasonable starting point. Several preceding engineers had established our facility's excellent program; plus I had good technical resources reporting to me from whom I could learn. I must admit that at first, I thought of lubrication as a menial task, as many do. My attitude quickly changed as I realized the importance of lubrication in a manufacturing facility.

Advanced Glassfiber Yarns is a 59-year old textile mill in Huntingdon, Pennsylvania, which produces a variety of fiberglass yarns and continuos fiberglass mat. Our equipment varies in size and age, but much of it is specialized state-of-the-art equipment. The nature of our process exposes a large amount of the equipment to a wet, abrasive (glass) environment. We also have a wide range of equipment operating speeds within our facility. We have slow moving conveyor rolls running at less than 50 rpm, and high-speed spindles that run at more than 6000 rpm. We also have equipment that resides outdoors (exposed to Pennsylvania winters), and some equipment subjected to temperatures greater than 350°F (177°C).

A large portion of the program in our facility involves the application of grease. Although we have some automated lubrication systems, because of the nature of our process, most of our grease applications are performed manually with grease guns. A lubrication database was developed by one of the preceding engineers who calculated the amount of grease required for each piece of equipment and the equivalent number of pumps (shots) of a grease gun required to achieve this amount. Although it seems basic, the grease gun is a good place to start to learn lubrication practices.

The grease gun is an effective tool for moving grease to a point of application, though it is often taken for granted. The most common styles of grease guns include the lever, pistol-grip, hand grip, air-powered and battery-powered. The lever style is the most economic and widely used of all the grease guns.

Courtesy Alemite Corporation

Lubrication technicians need to know the output per stroke of the grease gun in order to know how much grease is added each time a piece of equipment is lubricated. Grease guns vary in the amount of grease pumped per stroke, from one to three grams of grease or higher. The actual output can vary depending on the age of the grease gun. One of the technicians informed me that although our lubrication database stated the number of strokes required to relubricate each piece of equipment, there were many different brands and models of grease guns in use throughout our facility. Maintenance personnel in each process department purchased various grease guns over the years, without designating one particular model or type as a company standard. Individuals simply ordered whatever was available and looked good at the time.

We performed an audit of our facility to determine exactly how many and what types of grease guns were in use. We found that we had 33 grease guns that ranged from 0.56 to 3.10 grams per pump. The audit revealed that we had a uniformity problem that needed to be addressed, and we wanted to do so correctly.

The first step was to contact a local vendor and arrange an in-house training session on grease guns. This allowed us to ask questions and learn as much as possible before formulating a corrective action plan. There are many companies selling high-quality, dependable industrial grease guns. Two of the largest are Lincoln and Alemite.

Some factors to consider when establishing standard grease guns for your facility include:

1. How are you going to load the grease gun - suction fill, cartridge or bulk?
2. What are your common lubrication quantities? You do not want a high-volume grease gun for areas requiring only a few grams of grease for lubrication tasks.
3. Where is the lubrication task being performed? Some lubrication points are easier to reach with a pistol or hand-grip grease gun than a lever and vice versa. This will also help determine where rigid extension and flexible extensions are needed.

Another factor to consider is the type of grease fittings used in the facility. Most fittings have a ball check in the head of the fitting, which prevents dirt from getting to the bearing. The spherical contour of the fitting head provides a ball-and-socket joint between the fitting and the hydraulic coupler of the grease gun. The most common fitting is the hydraulic fitting, available in standard and metric sizes.

Hydraulic fittings are available in threaded, thread-forming, rivet and drive styles. They are available in different angled configurations and a wide variety of extension lengths to allow you to position the fitting for easy access with a grease gun on different types of equipment. Other common types of fittings include button head, flush (where protruding fittings cannot be used), pin, pressure relief and vent. There are also hydraulic shut-off fittings that shut-off at specified pressures to prevent overlubrication and blowing out bearing seals. Each application needs to be examined to determine the correct fitting and which style of grease gun and coupler is needed.

Grease gun fittings and accessories can enhance a lubrication program in several ways. Caps help keep contaminants out of the fitting and the bearings. Paint markers or colored labels (such as dots) can be used to identify the proper grease to use on a fitting. It is important to ensure that the proper grease is used on the equipment in your facility.

To prevent the accidental lubrication of bearings with an incompatible grease, we are considering using button head fittings on lubrication points in our facility that require a polyurea grease to eliminate the possibility of adding the wrong product. We are also examining standard hydraulic fittings on lubrication points that require lithium grease. Again, do not overlook the basics and the chance for improving the tribology program at your facility.

After careful consideration, we selected a lever-style grease gun for most of our manual grease lubrication tasks. We also found it necessary to use a hand-grip style grease gun on certain equipment in one area of our facility. Because of the location of the hydraulic fittings, it is necessary to hold a flexible extension on the fitting with one hand while pumping the grease gun with the other hand. The lever-style grease gun disperses 1.28 grams of grease per pump while the hand-grip style disperses 0.86 grams per pump.

The next step was to replace the old grease guns with the new grease guns. To make sure the old grease guns were completely removed from service, we gave them to craft personnel to take home for personal use. This made a number of employees happy and helped to gain acceptance for the distribution of the new grease guns. Buying all new grease guns also allowed us to mark the new grease guns with colored labels, identifying what grease to use with each gun.

Strategic Work Systems (www.swspitcrew.com) offers a shrink-tube sleeve made of polyolefin to fit over a cartridge grease gun after affixing labels. The sleeve is attached by using a heat gun to shrink the tube, which is resistant to chemicals and oils and provides an easy-to-grip surface. Remember that it is important to identify the type of grease to be used in each grease gun.

A basic step that is often overlooked is training the lubrication technician on the proper use of the grease gun. A high-pressure grease gun delivers pressure up to 15,000 psi. Most bearing seals will rarely handle more than 500 psi. A grease gun in the hands of an untrained technician can compromise the bearing's seal and lead to early failure. The compromised seal invites dirt or other foreign materials as well as overlubrication due to little or no back pressure.

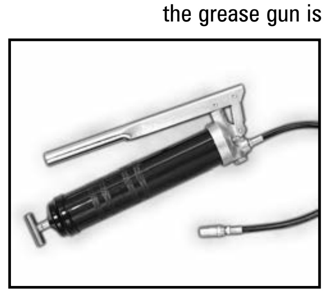
Safety training can also be a factor when using a needle-point applicator to disperse grease to certain types of fittings. If the needle slips off the grease point and punctures the hand or finger, grease can be forced into the skin. This can cause the punctured area to become swollen, stiff, and even gangrenous, which could lead to amputation. This is why grease gun injuries require immediate medical treatment. Remember to use caution when using needle-point applicators on grease guns.

Some common tips for using a grease gun:

1. Calculate the proper amount of grease needed for relubrication of bearings, based upon the calibrated delivery volume of the selected grease gun.
2. Use a vent plug on the relief port of the bearing to help flush old grease to reduce the risk of too much pressure on the bearing.
3. Use extreme caution when loading grease into the grease gun to ensure that contaminants are not introduced. If using a cartridge, be careful when removing the metal lid that no metal slivers are introduced into the grease.
4. Make sure the grease gun is clearly marked to identify the grease with which it should be charged. Do not use any type of grease other than that which is identified.
5. Always make sure the dispensing nozzle of the grease gun is clean before using. Pump a small amount of grease out of the dispensing nozzle, then wipe off with a clean rag or lint-free cloth before attaching to the grease fitting.
6. Clean the grease fitting of all dirt before attaching the grease gun. Inspect and replace damaged fittings. Also clean the grease fitting after applying grease. It is helpful to use grease-fitting caps to keep them clean, but still wipe fittings clean before applying grease.
7. Ensure the proper grease is used at every grease point. Applying the wrong grease can cause an incompatibility problem which can quickly cause bearing failure. Lubrication points should be clearly identified with which grease is to be used. This can be done with colored labels, adhesive dots or paint markers.
8. Grease guns should be stored unpressurized in a clean, cool, dry area and in a horizontal position to help keep the oil from bleeding out of the grease. Grease gun clamps make storage easy and organized. Also cover the coupler to keep it free from dirt and contaminants.
9. Calibrate grease guns regularly to ensure the proper delivery volume.
10. Use caution and safety when working around moving equipment and when using a grease gun.

Manual grease guns have their place in industry. They have a few disadvantages, the chief of which is poor control that can lead to over- and underlubrication. Grease guns also present a higher risk of inducing contaminants. However, they do have advantages, such as low cost, ease of use once the technician is properly trained, and allowing the technician to inspect the equipment during lubrication tasks. Just remember not to overlook the basics, no matter how simple it may seem.

Always make sure the dispensing nozzle of the grease gun is clean before using.



Lever-style Grease Gun

Air-powered Grease Gun

Step-by-Step Grease Selection

By Jarrod Potteiger, Noria Corporation

How do you know if you're using the right grease? You might be using a high-quality grease. You may have put a lot of effort and money into selecting the best quality grease in the pursuit of lubrication excellence. But don't confuse the quality of the lubricant with the quality of the specification. Considering this lubricating oil analogy, the best quality turbine oil would most likely not make a good engine oil.

Most users are aware of the importance of selecting the right lubricant for a given application. When it comes to selecting lubricating oils for manufactured equipment, it's easy to determine which products meet the original equipment manufacturer (OEM) requirements. OEM specifications for a lubricating oil normally include viscosity at operating or ambient temperature, additive requirements, base oil type and even special considerations for different environmental conditions. Grease specifications, on the other hand, often lack the detail necessary to make a proper selection, leaving it up to the lubrication engineer to create the specification.

A common OEM grease specification might be to use an NLGI (National Lubrication Grease Institute) No. 2 lithium grease of good quality. Using this information alone, one could select the right consistency and thickener type. A similar specification for an oil-lubricated application would be to use a "good quality lubricating oil." What?!

Due to the lack of specificity in most grease recommendations, it is important to learn how to properly select greases for each application in the plant. Proper grease specification requires all of the components of oil selection and more. Other special considerations for grease selection include thickener type and concentration, consistency, dropping point and operating temperature range, worked stability, oxidation stability, wear resistance, etc. Understanding the need and the methods for appropriate grease selection will go a long way toward improving lubrication programs and the reliability of lubricated machinery. Let's walk through the grease selection process step by step, starting with the most important property.

Base Oil Viscosity

The most important property of any lubricant is viscosity. A common mistake when selecting a grease is to confuse the grease consistency with the base oil viscosity. Because the majority of grease-lubricated applications are element bearings, one should consider viscosity selection for those applications. While most would not use an EP 220 gear oil for an oil-lubricated electric motor bearing, many people will use a grease containing that same oil for an identical grease-lubricated bearing. There are several common methods for determining minimum and optimum viscosity requirements for element bearings, most of which use speed factors, commonly denoted as DN or NDm. Speed factors account for the surface speed of the bearing elements and are determined by the following formulas:

DN = (rpm) * (bearing bore) and

NDm = rpm * ((bearing bore + outside diameter) / 2)

The NDm value uses pitch diameter rather than bore diameter because not all bearings of a given bore have the same element diameter, and thus have different surface speeds. Knowing the speed factor value and likely operating temperature, the minimum viscosity requirement can be read directly from charts like Figure 1.

Figure 1 assumes the base oils' viscosity index. To be more precise, one would need to use a chart that identifies the viscosity at operating temperature, then determine the viscosity grade from a viscosity/temperature chart for a given lubricant.

Additives and Base Oil Type

Once the appropriate viscosity has been determined, it's time to consider additives. The additive and base oil types are other components of grease that should be selected in a fashion similar to that used for oil-lubricated applications. For instance, a lightly loaded high-speed element bearing does not require extreme pressure (EP) additives or tackifying agents, while a heavily loaded open gear set does. Most performance-enhancing additives found in lubricating oils

Operating Temperature	DN (Speed Factor)	NLGI No.*
-30 to 100°F	0 - 75,000	1
	75,00 - 150,000	2
	150,000 - 300,000	2
0 to 150°F	0 - 75,000	2
	75,00 - 150,000	2
	150,000 - 300,000	3
100 to 275°F	0 - 75,000	2
	75,00 - 150,000	3
	150,000 - 300,000	3

*Depends on other factors as well, including bearing type, thickener type, base oil viscosity and base oil type

Table 1

are also used in grease formulation and should be chosen according to the demands of the application. Figure 2 shows some common additive requirements by application.

Most greases are formulated using API Group I and II mineral oil base stocks, which are appropriate for most applications. However, there are applications that might benefit from the use of a synthetic base oil. Such applications include high or low operating temperatures, a wide ambient temperature range, or any application where extended relubrication intervals are desired.

Grease Consistency and Thickener Type

Now for that extra step: The consistency of grease is controlled by the thickener concentration, thickener type and the viscosity of the base oil. Even though base oil viscosity affects consistency, it is important to note that a grease can have a high consistency and a low base oil viscosity or vice versa. The NLGI has established a scale to indicate grease consistency which ranges from grades 000 (semifluid) to 6 (block grease). The most common NLGI grade is two and is recommended for most applications.

For bearings, speed factor and operating temperature can be used to determine the best consistency or NLGI grade for a given application. It may seem counterintuitive, but higher speed factors require higher consistency greases. Table 1 provides a general guide to selecting NLGI grade based on speed factor and operating temperature.

Numerous types of grease thickeners are currently in use, each with its own pros and cons. The most common types are simple lithium soaps, lithium complex and polyurea. Simple lithium soaps are often used in low-cost general-purpose greases and perform relatively well in most performance categories at moderate temperatures. Complex greases such as lithium complex provide improved performance particularly at higher operating temperatures. A common upper operating temperature limit for a simple lithium grease might be 250°F, while that for a lithium complex grease might be 350°F. Another thickener type that is becoming more popular is polyurea. Like lithium complex, polyurea has good high-temperature performance as well as high oxidation stability and bleed resistance. Thickener type should be selected based on performance requirements as well as compatibility when considering changing product types.

Performance Properties

Once the appropriate base oil viscosity, additive requirements and consistency have been determined, the remaining criteria to consider are the performance properties. This is where the grease quality factors in. Grease performance properties include many of the same properties used for lubricating oils, as well as others exclusive to grease. Properties exclusive to grease include dropping point, mechanical stability, water washout, bleed characteristics and pumpability. The most important performance properties are determined by the application. If an application operates continuously at room temperature, properties like dropping and upper operating temperature limits are not as important. If an application operates under heavy loads at low speeds, load carrying tests such as four-ball EP or Timken OK load should be considered. It is important to remember that greases, like oils, have a careful balance of properties. A product may excel in one category and perform poorly in another. For this reason, it is important to weigh each property’s significance relative to the intended applications to select the best overall fit.

Sometimes while trying to consolidate lubricants, it is easy to overconsolidate. Over time, this can lead to inaccurate lube specifications. A generic oil spec, including performance properties, should be configured for each lubricated point in the plant. Armed with this generic specification, it is easy to select the right product no matter what brand is preferred. It is also important to review these specifications on a periodic basis to guard against specification creep. While improving a lubrication program can be a tough job, lubricant specification is relatively easy. Armed with a little bit of knowledge and a few widely available tools, it is possible to rest easier knowing that the right grease is being used.

Additive	Journal Bearings	Ball Bearings	Thrust Bearings	Roller Bearings	Needle Bearings
Antioxidants	●	●	●	●	●
Antifoam Agents	●	●	●	●	●
Antiwear/EP		●	●	●	●
Rust Inhibitors	●	●	●	●	◒
Extreme Pressure			◒	◒	
Demulsibility	●	●	●	●	◒
VI Improvers	◒	◒	◒	◒	●
Corrosion Inhibitors	●	●	●	●	●

● Required ◒ Depends on application

Figure 2

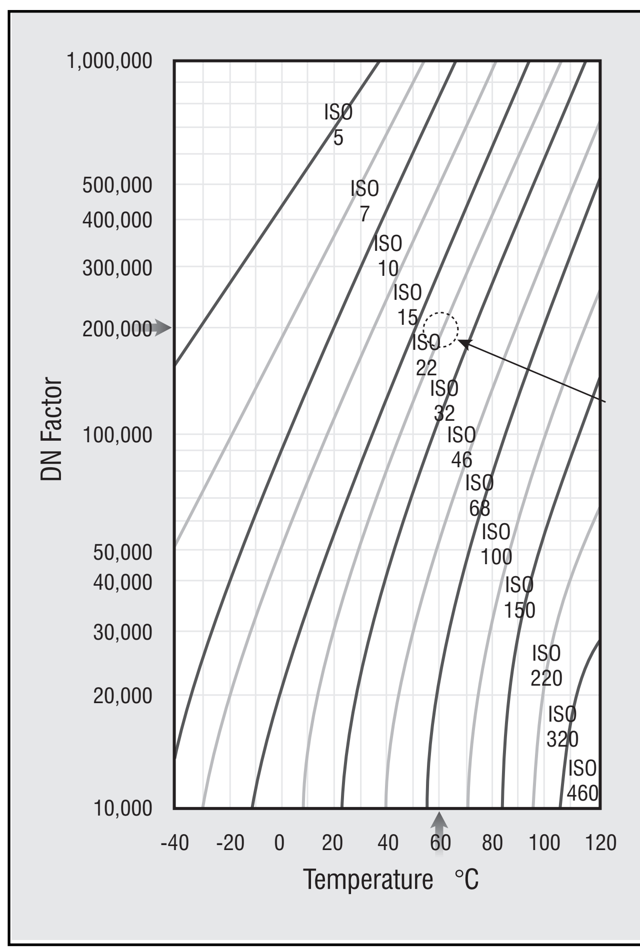


Figure 3. (Courtesy of ExxonMobil)

How to Design an Electric Motor Regreasing Program

By Jerry S. Honeycutt, Tennessee Valley Authority and Wayne Johnson, Electric Power Research Institute

Rolling element bearings used in electric motors have many failure causes such as incorrect bearing selection, improper bearing fits, poor handling during installation, improper installation techniques, excessive thrust loads, loss of lubricant, contamination and overgreasing.

Grease volume control has been a long-standing problem for industry, and simply following OEM recommendations may not be enough to solve this problem.

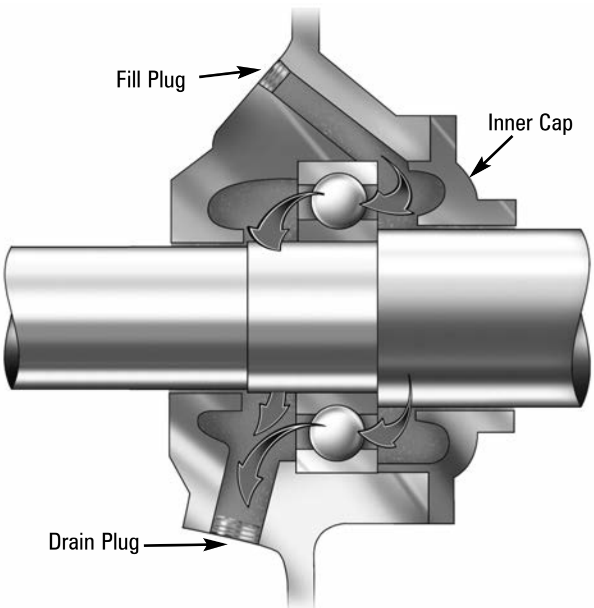


Figure 1. Flow-through design - used only with open face bearings.

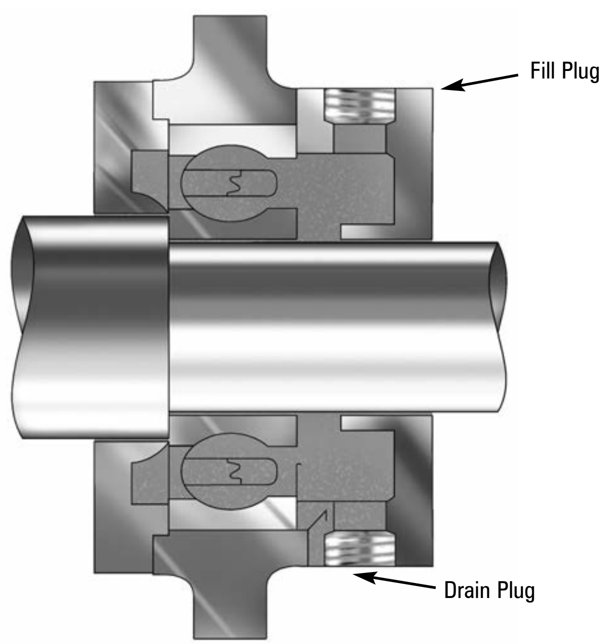


Figure 2. Same-side fill and drain – used with open, single-shielded, and double-shielded bearings.

A motor relubrication practice was developed by the Electric Power Research Institute (EPRI) in 1992 and is widely used by the nuclear power industry today. The program was designed to minimize overgreasing motor bearings in-between required bearing replacements. The relubrication program, associated retrofits and details are discussed in this article.

Background

The problem of overgreasing electric motors was first identified in the nuclear power industry in 1988. Several motor and/or bearing failures occurred at various nuclear power plants due to excessive grease addition. In 1992, EPRI's Nuclear Maintenance Application Center developed an electric motor predictive and preventive maintenance guide. This guide, outlined a complete maintenance program for various electric motors based on size and bearing type. Part of this maintenance program offered guidance on regreasing motor bearings. This program has helped utilities save money by reducing labor cost for regreasing and reducing bearing failures due to overgreasing.

Bearing Housing Designs

There are two basic bearing housing designs used in most motors with regreasable rolling element bearings.

More motors are manufactured with a same-side design (Figure 2) than a flow-through design (Figure 1). Figure 2 shows the drain plug is the only external path for the grease to exit the grease cavity.

Four Basic Bearing Types

1. **Open Face Bearing** – This bearing consists of the inner and outer race, the balls and the ball cage. It does not retain grease within shields and requires a grease cavity around it for lubrication.
2. **Single-shielded Bearing** – This bearing has a metallic shield on one side only, and is usually installed with the shield facing the motor winding. It can be regreased and typically has the same regreasing intervals as an open face bearing.
3. **Double-shielded Bearing** – This type has a metallic shield on both sides of the bearing and is designed to retain grease between the shields. There is a small air gap between the shields and the inner race which allows a certain amount of oil transfer over a long period of time between the grease in the grease cavity and the grease between the shields. There is some debate whether this type of bearing can be regreased. Regreasing double-shielded bearings has been successful and this article provides guidance for those who choose to place double-shielded bearings in a regreasing program.
4. **Sealed Bearings** – These bearings are designed similar to a double-shielded bearing with one exception. The inner race slides against the seals resulting in the absence of an air gap between the seals and the inner race. This type of bearing cannot be regreased.

Grease-related Bearing Failures

There are several types of grease-related bearing failures:

Lubricant starvation – Occurs when the grease cavity is not packed with the proper amount of grease during bearing installation, when the bearing is not regreased at the appropriate interval with the proper amount or when the oil is removed from the base of the grease by bearing overheating.

Grease incompatibility – Greases are made with different base compounds such as lithium or polyurea. Not all greases are compatible with each other; therefore it is important to use the same grease or compatible substitute throughout the life of the bearing.

Wrong grease – It is important to use the correct grease for the correct application. Some bearing designs and applications need only general purpose (GP) grease while others need extreme pressure grease (EP). Selecting or regreasing with the wrong grease can lead to premature bearing failure.

Overpressurization of the bearing shields – When grease is added to a grease cavity, grease volume and cavity pressure increase. Damage can occur to the shield on a single- or double-shielded bearing during regreasing if the grease is added too fast. When the motor is placed into service, the grease will thermally expand. If the grease cavity is full, thermal expansion can create damaging pressure on the bearing shields. In either case, the shields can be dislodged from the bearing or the outside shield can be pushed against the bearing cage by grease pressure, which can lead to a bearing failure (Figures 6 and 7).

Inside of motor full of grease – If the grease cavity is full and regreasing continues, the excess grease can find its way between the inner bearing cap and the shaft and flow to the inside of the motor. This allows the grease to cover the end windings of the insulation system and can cause both winding insulation and bearing failures (Figure 8).

Overheating due to excess grease – The balls of a bearing act as tiny viscosity pumps which roll on a small amount of oil film between the balls and the race. Too much volume will cause the elements to churn the grease, resulting in parasitic energy losses and high operating temperatures, which in turn increase risk of bearing failure.

Hardware to Limit Overgreasing and Overpressurization of Bearing Cavities

One thing that happens with adding grease to motors is that there is a limited path for excess grease to exit a bearing cavity. Two examples of hardware that can assist in limiting overgreasing and overpressurization of a bearing cavity are shown in Figures 9 and 10. The use of these fittings can eliminate the need to remove the drain plug for excess grease and pressure release during the regreasing activity.

The fittings shown in Figures 9 and 10 are commercially available from Alemite and have been used successfully in the nuclear power industry.

Grease Degradation

Grease degradation is a gradual process. Most grease degrading influences are more present only while the motor is running; however degradation can occur while a motor is idle. Grease degradation can be caused by any of the following conditions:

- Grease hardening – This usually results from absorption of dirt, moisture or oxidation over a long period of time.
- Chemical breakdown – Typically caused by excessive heat. Overgreasing can cause overheating.
- High bearing loads – Side-loaded motors can load a bearing system more than a direct coupled motor.
- Oil separation from grease base material – This occurs on motors that remain idle for long periods of time, when the grease is churned excessively, and over time due to the designed normal bleed rate.
- Rotational speed of the bearing – The higher the speed, the more grease will degrade.
- Bearing size – The larger the bearing, the more grease degradation can occur. The size of the bearing can usually be equated to the horsepower of the motor.
- Environment – Bearings operating in ambient temperature above 140°F can cause more rapid degradation of the grease.

Regreasing Program

Clearly, several factors must be considered to develop a sound regreasing program for all of the motors in a plant.

1. Verify the type of bearings installed in both the inboard and outboard ends. This will determine if the bearings are regreasable.
2. Verify the initial grease fill of the grease cavity to ensure available space for future regreasing.
3. Identify the grease type (GP, EP, synthetic, etc.) and the manufacturer if possible.
4. Make grease fittings accessible, both fill and drain fittings.
5. Establish cleanliness around the fill and drain fittings.
6. Identify an owner of the program. If there is no owner, then a successful program is unlikely.

Regreasing Techniques

How Should the Grease Be Added?

Because the bearing balls act as tiny viscosity pumps, and the grease is less viscous when hot, a bearing should be regreased while the motor is running. If this is not practical, then perform regreasing immediately after the motor is removed from service while the grease is still hot. Although no program eliminates overgreasing an already filled grease cavity, the steps listed below will help minimize overgreasing-related failures.

The following steps should be performed in the sequence listed:

1. Ensure the grease gun contains the appropriate lubricant for the bearings to be regreased.

Figure 3. Open Face Bearing

Figure 4. Double-shielded Bearing

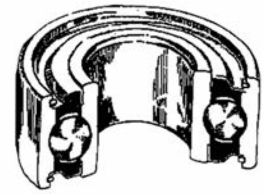


Figure 5. Sealed Bearing

2. Clean the areas around the fill and drain fittings.
3. Remove the drain fitting and if possible, run a spiral bottle brush into the grease cavity and remove a small amount of grease to form an exit path. If the plunger-type drain plugs are used, this step can be eliminated.
4. Grease the bearing with the proper amount of grease. Add grease slowly to minimize excessive pressure buildup in the grease cavity.
5. If regreasing is performed with the motor out of service, operate the motor until bearing temperature stabilizes to allow thermal expansion of the grease. Ensure the drain plug is left out during this run unless the plunger-type is used.

Figure 6. Overgreasing Failure

Figure 7. Shield was pressurized by excessive grease which caused a cage failure.

Figure 8. Overgreasing caused inside of motor to fill with grease.

4. Open face, single-shielded or double-shielded bearing (inboard and outboard). Different types can be used for the inboard and outboard bearings. Note: Sealed bearings cannot be regreased.
5. RPM of the motor
6. Horsepower of the motor
7. Load configuration – side-loaded verses direct-loaded
8. Ambient temperature - less than 140°F and greater than 140°F

Table 1 was designed for a relatively clean nuclear plant environment. A dirty or contaminated environment may require adjustments to the recommended intervals.

For intermittent duty cycle motors, the greasing intervals should be the same time frame as continuous duty cycle motors measured by their operation time, not calendar days.

For example, if an intermittent duty cycle motor runs 50 percent of the time and meets the same characteristics in the table as a continuous duty cycle motor that has a 24 - to 36-month regreasing interval, then the intermittent duty cycle motor's regreasing interval will be 48 to 72 months.

Because there is still some debate whether or not a double-shielded bearing can be regreased, the double-shielded bearing column was not included on the table in the EPRI report. However, for double-shielded bearings, it is recommended to double the frequency in the table and halve the amount added shown on the grease fill chart.

It is worth noting that this regreasing program was designed to minimize overgreasing of bearings in between bearing replacement. When a bearing is replaced, not only should the bearing be packed (open and single-shielded bearings), but the grease cavity is filled with grease to around 50 percent fill, leaving additional space for regreasing. The grease should be added to the grease cavity in such a way as to provide grease around 360 degrees of the cavity. It should also be added in such a way as to allow the grease to come in contact with the bearing. If the grease is packed only in the bottom of the grease cavity, no contact will occur between the grease and the bearing.

For bearing configurations that have their open side toward the bearing cavity, no grease contact would allow the bearing to sling out the grease packed around the balls and cause a lubricant starvation issue and possible bearing failure. Once the grease cavity fills, any excess grease must vent through the designated vent port, or will be pushed into the motor. Unfortunately, due to frequent inaccessibility to the vent port after motor installation, this often does not happen. Overgreasing can lead to bearing shield deformation, cage failure, overheated bearing or filling the inside of the motor with excess grease.

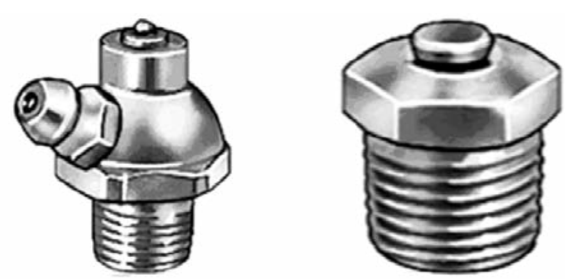


Figure 9. The pressure cut-off-fill-plug does not allow additional grease to be added to a grease cavity when the pressure exceeds 20 psi. (Left) Figure 10. The plunger drain plug opens the center plunger on 1 to 5 psi to purge excess grease and pressure. (Right)

How Much Grease Should be Added?

This is another area in which different manufacturers give differing recommendations. However, to provide guidance on the amount of grease to be added for different size motors, a grease weight versus shaft diameter curve was determined to provide the most useful information (Figure 11).

For ease of plant implementation, the number of ounces of grease should be converted into strokes for each different type grease gun used, or a calibrated grease meter can be attached to the output of a grease gun.

For motors in standby or lay-up mode and double-shielded bearings, the ounces of grease identified by the above curve for any given motor should be divided by two and that value should be used for the amount added.

The development of a regreasing program that will work for all motors requires ownership by someone familiar with motor designs, operating conditions, history of bearing replacements and type of grease used. Once the program is developed, it can be implemented by simply following procedures. This program has proven to be effective in providing adequate lubrication during the bearing life. It has also minimized bearing failures from overgreasing. Many of the nuclear power plants in the U.S. have implemented this program for motor relubrication since the EPRI report was published in 1992.

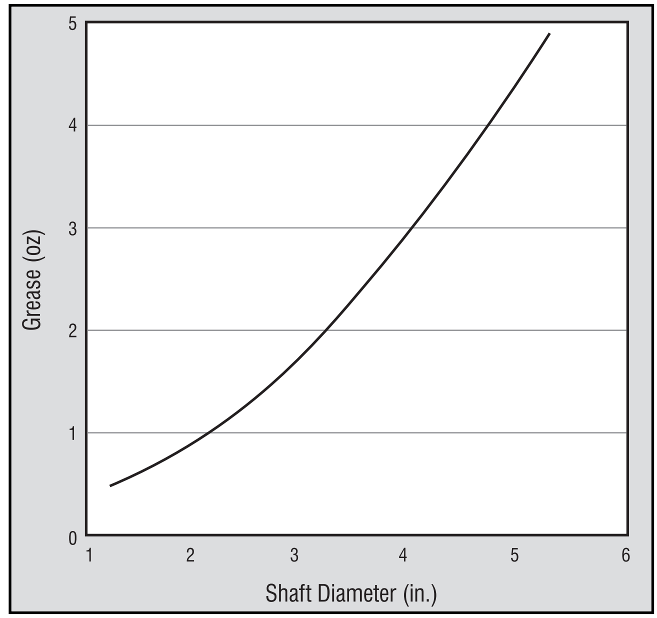


Figure 11. Grease Fill Curve

RPM			HP		Load Configuration		Ambient Temperature (°F)		Operation		Regreasing Interval Months
1200	1800	3600[a]	>100[a]	<100	Belt[a]	Direct	>140[a]	<140	Cont.[a]	Stby/Lay-up	
X			X			X	X		X		12-18[e]
X			X		X			X	X		12-18[e]
X			X		X		X		X		6-9[f]
	X			X		X		X	X	(b)	36-54[c]
	X			X		X	X		X	For all	24-36[d]
	X			X	X			X	X	standby	24-36[d]
	X			X	X		X		X	or lay-up	12-18[e]
	X		X			X		X	X	motors	24-36[d]
	X		X			X	X		X		12-18[e]
	X		X		X			X	X		12-18[e]
	X		X		X		X		X		6-9[f]
		X		X		X		X	X	(b)	24-36[d]
		X		X		X	X		X	For all	12-18[e]
		X		X	X			X	X	standby	12-18[e]
		X		X	X		X		X	or lay-up	6-9[f]
		X	X			X		X	X	motors	12-18[e]
		X	X			X	X		X		6-9[f]
		X	X		X			X	X		6-9[f]
		X	X		X		X		X		6-9[f]

(a) Motors with these design characteristics have less time between greasing intervals. The number of characteristics designated by (a) for which each motor is marked with an X (1, 2, 3, 4, or 5), was used for determining the greasing interval.
(b) The greasing intervals for motors in the standby or lay-up mode should be 1.5 times that of motors operating continuously.
(c) Once per 3 operating cycles, not to exceed 58 months.
(d) Once per 2 operating cycles, not to exceed 40 months.
(e) Once per operating cycle, not to exceed 22 months.
(f) Twice per operating cycle, not to exceed 11 months.
Note: Nuclear plant operating cycles are based on an 18-month cycle.

Table 1. Regreasing Intervals for Open Face and Single-shielded Bearings

Predicting Electric Motor Bearing Failures, Case Studies

By John Phelps of SPM Instrument, Inc.

Introduction

Typically there are two options of maintenance concerning electric motor bearings. One is to relubricate them and the other is to change them.

Monitoring electric motor bearing condition is paramount to insure reliability. Electric motors are an asset that must be managed and prolonging their life will insure more contribution to the bottom line profit. Preventing collateral damage caused by electric motor bearing failure is true cost avoidance.

There are several ways to monitor and measure bearing condition: ultrasonics, temperature, vibration analysis, and Shock Pulse just to mention a few.

Because lubrication is the first line of defense for prolonging bearing life it is imperative that the lubrication film thickness between the rolling elements and the raceways be measured and monitored.

Lubrication film thickness in rolling element bearings

What Really Matters!

Lubrication, the vital element between any moving parts and an absolute requirement in rolling element bearings.

There has always been much discussion and debate regarding the questions of how much, how often and what kinds of lubricants should be used in rolling element bearings and to many it still remains a mystery.

The following chart (Figure 1) indicates the many parameters related to the lubrication film thickness and film quality in a rolling element bearing.

Even "Sealed for Life" bearings will lose their lubrication film thickness. Knowing how much lubricant is left in a sealed bearing can make the difference between productive uptime and unscheduled downtime.

Knowing if lubricant is getting into the bearing will allow maintenance to maximize bearing life by optimizing oil film thickness and unscheduled downtime can be prevented.

Differentiating between bearing surface damage and lubrication film thickness as a bearing fault is a measurable function. Knowing the difference is valuable knowledge.

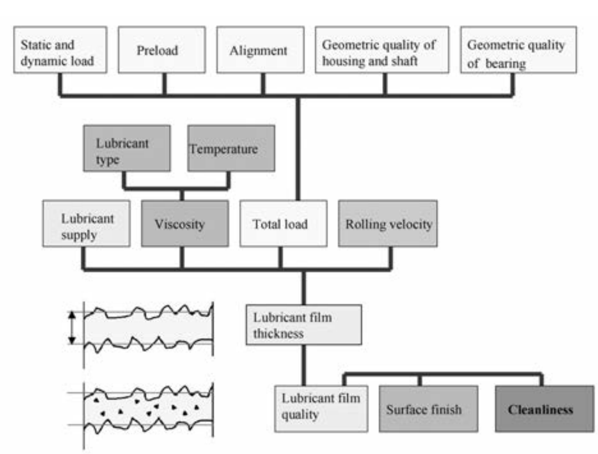


Figure 1.

Case #1

Maxim Corp.

Scrubber for cleaning contaminated water before dispersing into the waste water system.

Four small 3/4 hp motors with integral "C" face mounted impeller pumps plumbed with PVC piping. All four motors are running at the same time. (Figure 2) After demonstrating how to monitor bearing condition and measure lubrication film thickness at this printed circuit manufacturing plant we were asked to look at a small water scrubber. The screaming sound of a bad bearing could be heard but they could not pinpoint which bearing was making the noise. Was it the drive end or opposite drive end of which motor?

After a quick check the bearing was identified and its condition was determined.

This was a 6204.2RS sealed bearing (a sealed for life bearing). Cost about $9.00.

We left the plant with the promise to provide a quotation for a portable data logger instrument.

During the night the bearing froze up and tripped the motor so only three motors were now running. They lost 1/4th of the capacity of the system to clean water.

The next day (before the repair could be made) the Bay Area EPA inspector showed up. Water was still being dumped into the waste water system. Because of the lessened capacity (1/4th) when the water was tested it did not meet the cleaned requirements. The fine was $32,000.00.

The sad part is that they knew which bearing was bad. They also knew how bad it was. If PdM/CM was a part of their normal operating procedures this downtime and fine would never have happened.

Case #2

Electric Motor Shop ~ Laprino Foods

A 700 hp ABB electric motor for driving a fan for dehydrating milk.

ABB Motors have long recommended the use of Shock Pulse to measure their motor bearings. Many ABB motors are equipped at the factory with SPM adapters for quick-connect measurements.

A new ABB motor was installed at Laprino Foods and failed within the warranty period. The bearing froze up and twisted the shaft. There was no lubrication in the bearing.

After careful review the records showed that the maintenance personnel in the plant had indeed greased the bearing according to the recommended schedule.

The seal cap was removed from the end-bell of the drive end exposing the bearing for inspection. It was found that a machining error was made during manufacture and the grease pathway from the grease zerk to the bearing lubrication notch did not line up.

Grease could not get into the bearing. Even though the lubrication schedule was being adhered to, the bearing was not being measured so no one could tell if lubricant was actually getting into the bearing.

Production was interrupted so a new motor was taken from the Electric Motor Shop's inventory to replace the damaged motor. Before installing the new motor a test run was performed. While the motor was running a measurement was taken while lubricant (grease) was applied to the zerk. Without disassembling the motor or causing an intrusive action it was determined that the grease pathway was in the correct place and lubricant was truly getting into the bearing. The bearing's true condition was determined and the lubricant film thickness was measured and recorded.

ABB honored the warranty. The damaged motor was repaired and stored for a spare and the new motor is still running today.

An on-line monitoring system (MG-4) continues to monitor these ABB electric motor bearings.

Case #3

Evanite Fiber Corporation

125 hp motor and belt-drive on an exhaust fan for a spun glass process used to make high-density filters.

This example was not necessarily on the motor but on the fan shaft. One of the most common bearing installation faults that affects lubrication film thickness is the installation and set up of the tapered bore, doublerow spherical roller bearing using a split tapered adapter in a mounted unit, i.e. Pillow Block Bearing. While this is not an electric motor bearing it is in very close proximity to every drive motor.

The tapered adapter is used as a wedge device to hold the inter race of the bearing on to the shaft. All bearing manufacturers have recommended clearances for applying this type of bearing. This type of bearing in a pillow block housing is very common on larger fan applications and is a very popular style for many other applications.

If the tapered sleeve (adapter) is drawn up to far by over-tightening the spanner nut (a very common practice) the internal clearance of the bearing will be removed thus reducing the lubrication film thickness.

Even though these bearings are running with no apparent fault or vibration alarm the reliability of the machine has been put into jeopardy because the operator cannot see the film thickness problem.

Lubrication film thickness can be measured to determine the true condition of the bearing during start up without setting a baseline and treading. Differentiating bearing surface damage faults and lubrication film thickness faults is powerful knowledge.

Case #4

Superior Lumber Company

25 hp motor driving an edger in a sawmill. Standard foot mounted motors that are mounted in the vertical position must have special consideration related to lubrication.

The normally mounted bearing in a horizontal motor is supporting load/overhung load in the radical direction. If the motor is mounted in the vertical position the bearing will see more thrust loads and the lubrication will run out through the opening of an open or shielded bearing. A sealed bearing will hold the lubricant reservoir in the lower half of the bearing because the bearing is lying on its side in this application.

This position will also force all of the balls of a ball bearing to one side of the raceway thus placing them all in a more loaded situation both radial and thrust directions. Load affects the lubrication film thickness.

Normally a motor mounted in this position will need lubricating more often than what is recommended.

Summary

The ability to measure the lubrication film thickness is paramount. Better asset management and machine reliability can be obtained by measuring the film thickness as soon as the machine is turned on. This will prolong bearing and machine life.

Lubrication film thickness in rolling element bearings is critical. It can be measured to detect and troubleshoot for proper lubrication amounts (over/under), the right kind of lubricant for the right job, to detect installation faults and even to pinpoint the lack of film thickness if there is a compatibility and/or contamination problem.

Knowing the film thickness of lubrication in rolling element bearings, even a sealed bearing, is information worth measuring. Lubricant should only be applied to rolling element bearings because of demand requirements. Measuring the bearing film thickness before you lubricate will insure that there is truly a lubrication requirement. Automatic lubrication supply systems can provide the optimum amount of lubrication at just the right time when signaled by an on-line measuring system. Knowing the lubrication film thickness in rolling element bearings is instrumental in best asset management practices.

Knowing what really matters in rolling element bearings to insure machine reliability is knowing the lubrication film thickness.