A PROVEN ELECTRIC MOTOR REGREASING PROGRAM

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One of the most asked questions of grease lubricated motors is, what is the correct interval to regrease the bearings? This is usually followed by two questions: 1) how much grease should be added? and 2) what is the correct method for grease addition?

Unfortunately, there are many different answers that are given for these questions, depending on who or which company you ask. This leaves it up to the individual over the motor regreasing program to choose a method that he or she thinks will work for their company motor applications.

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

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

To address motor regreasing issues, a motor relubrication practice was developed by the Electric Power Research Institute (EPRI) in 1992 (NP-7502) and is widely used by the nuclear power industry today. The program was designed to minimize over greasing motor bearings in-between required bearing replacements. The EPRI recommended relubrication program, associated retrofits, and details are discussed in this write-up.

BACKGROUND

The problem of over greasing 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 motors which included a regreasing guide for electric motors based on size and bearing type. This program has helped utilities save money by reducing labor cost for regreasing and reducing bearing failures due to over greasing.

Since motors are essentially designed the same for nuclear as they are for the commercial industry, the regreasing program identified in the EPRI guide is considered to be applicable outside the nuclear industry.

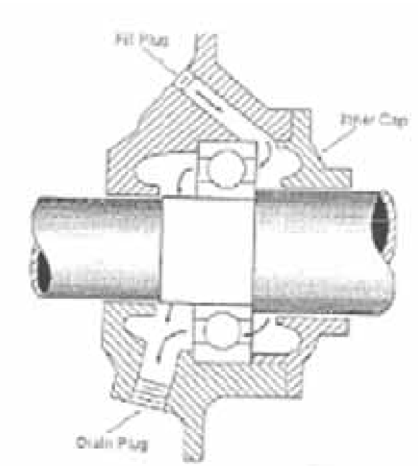

Figure 1. Flow-through design - used only with open face bearings.

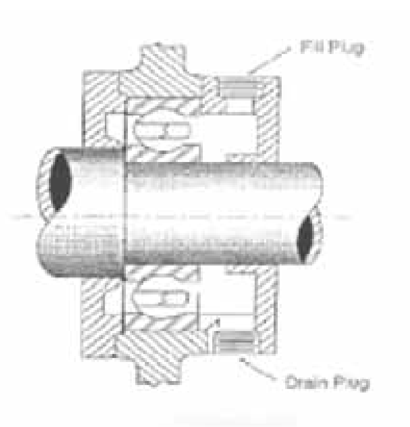

Figure 2. Same-side fill and drain - used with open, single-shielded and double-shielded bearings.

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) rather than a flow-through design (Figure 1). For both designs the drain plug is the only external path for the grease to exit the grease cavity.

NOTE: Figure 2 shows a single shielded bearing installed. The shield is placed toward the rotor to act as a second line of defense from filling the inside of the motor with grease during regreasing activities.

FOUR BASIC BEARING TYPES USED IN GREASE LUBRICATED MOTORS

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 grease in a grease cavity for lubrication. This bearing is considered fully regreasable when used with either of the bearing housing designs listed above.

Figure 3. Open Face Bearing.

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. There is a small air gap between the shield and the inner race which will allow grease transfer to the inner bearing cap.

It can be regreased and typically has the same regreasing intervals as an open face bearing. This bearing can only be

Figure 4. Single-Shielded Bearing.

used with a same side housing design as shown in Figure 2.

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 or not this type of bearing can be regreased. Regreasing double shielded bearings has been successful and this paper provides guidance for those who choose to place double shielded bearings in a regreasing program.

Figure 5. Double-Shielded Bearing

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 and is totally dependent on the lubrication packed from the bearing manufacturer for the life of the bearing.

If this type of bearing is installed in housings with grease fittings, it is highly recommended the fittings be removed and plugs installed.

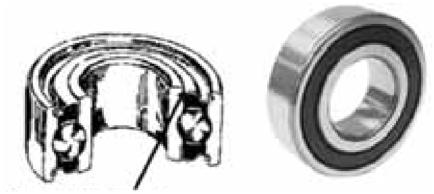

Figure 6. Sealed Bearing

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 poly-urea. 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. This requires grease specification when a double-shielded bearing is ordered so it will be compatible with the grease that will be added during regreasing activities.

The bearing, the grease cavity around the bearing, and the grease used during regreasing has to be compatible.

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.

Over pressurization of the bearing shields – When grease is added to a grease cavity, grease volume and cavity pressure increases. Damage can occur to the shield on a single or double-shielded bearing during regreasing if the grease is added too fast or if the grease cavity is full with no escape path for the excess grease.

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 (see Figures 7 and 8).

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 (see Figure 9).

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 grease volume will cause the rolling elements to churn the grease, resulting in parasitic energy losses and high operating temperatures, which in turn increase risk of bearing failure.

Contamination of grease – Greases are the same as oils when it comes to contamination (water, dirt, fiber, gasket sealant, etc). The more contaminants that are in the grease, the shorter the grease life and the greater the reduction of its lubrication properties.

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

Figure 7. Over-greasing Failure

Figure 8. Shield was pressurized by excessive grease which caused a cage failure.

NOTE: This is a double shielded bearing and grease was pushed through

Figure 9. Over-greasing caused the inside of the motors to fill with grease.

to the inside of the motor. Indication that grease can flow through a double shielded bearing design.

HARDWARE TO LIMIT OVERGREASING AND OVERPRESSURIZATION OF BEARING CAVITIES

One thing that happens with grease addition 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 10 and 11. The use of these fittings can minimize overpressurization and eliminate the need to remove the drain plug for purging excess grease and pressure release during the regreasing activity.

The pressure cut-off-fill-plug does not allow additional grease to be added to a grease cavity when the pressure exceeds 20 psi.

The plunger drain plug opens the center plunger on 1 to 5 psi (depending on which plug is purchased) to purge excess grease and pressure.

The fittings shown in Figures 10 and 11 are commercially available from Alemite and have been successfully used in the nuclear power industry.

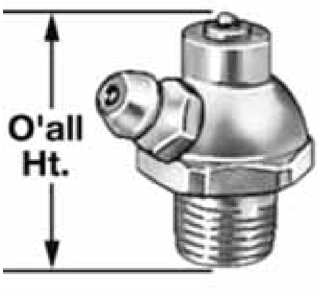

Figure 10

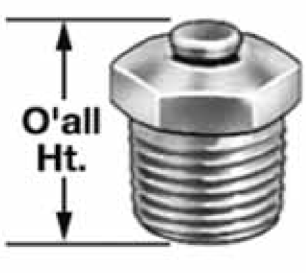

Figure 11

GREASE DEGRADATION

Grease degradation is a gradual process. Most degrading influences are more prominent 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. It can also be caused by extended times of inactivity of the motor which will allow the oil to bleed out of the base material of the grease.

• 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. Misalignment can also cause high bearing loads.

• Oil separation from grease base material – This occurs on motors that remain idle for long periods of time during operation 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 the grease will degrade typically from the excessive churning of the grease.

• Bearing size – The larger the bearing, the more grease degradation can occur due to the extra demand on the lubrication system by the larger bearing. 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. This is due to the temperature at which the bearings (and grease) will run, which is the temperature rise of the bearing plus the ambient temperature.

REGREASING PROGRAM

From the previous discussions, it is easy to see that several factors (listed below) 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. Determine the bearing housing grease chamber design (flow through or same side)

3. Verify the initial grease fill of the grease cavity to ensure available space for future regreasing and that the grease in the grease cavity is touching the bearing.

4. Identify the grease type (GP, EP, lithium, polyurea gel, synthetic, etc.) and the manufacturer if possible.

5. Make grease fittings accessible, both fill and drain fittings (this may require extension tubes on some motor designs).

6. Establish cleanliness around the fill and drain fittings.

7. Establish an owner of the program. If there is not an owner then a successful program is doubtful.

NOTE: If you do not have a program owner for motors that includes the regreasing activities, then you do not have a program.

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 there is no program that will eliminate over greasing already filled grease cavities, 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.

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. Leave the drain plug out for the duration of the regreasing process. If the plunger type drain plugs are used, this step can be eliminated.

4. Grease the bearing with the proper amount of grease. The grease should be added slowly to minimize excessive pressure buildup in the grease cavity.

5. The motor should be operated at least an hour if already running to purge excess grease. If the motor is idle, run the motor until bearing temperature stabilization occurs, to allow excess grease to be purged from the grease cavity. Ensure the drain plug is left out during this run unless the plunger type is used.

6. After excessive grease has been purged, reinstall the drain plug and clean purged grease from the drain area.

NOTE: It is not uncommon for no grease to be purged if the grease cavity is only partially filled. The grease volume and the internal pressure of the grease cavity are the two driving forces that purge the grease from the grease cavity. If the grease cavity is only partially filled, then the addition of new grease during regreasing will only fill up the empty space in the grease cavity.

If the upgraded fittings have been installed, then removal of the drain plug is not required.

The plunger type drain plug will allow excessive pressure and grease to be purged while the motor is running. This saves maintenance time and minimizes over pressurization.

HOW OFTEN SHOULD BEARINGS BE REGREASED?

The program presented in this article and listed in EPRI NP-7502 Report is based on the following information about the motor design and operation:

1. Continuous operation

2. Intermittent operation

3. Standby or lay-up

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 (relates to bearing size)

7. Load configuration – side-loaded versus direct-loaded

8. Ambient temperature - less than 140°F and greater than 140°F

Table 1 on the following page 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 but using the intermittent motors operation time, not calendar days, to calculate the adjusted regreasing interval.

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 listed in Table 1 and halve the amount added shown on the grease fill chart (Figure 12).

Table 1. Regreasing Intervals for open face and single shielded bearings.

RPM			HP		Load Configuration		Ambient Temp. (°F)		Operation		Regreasing Interval Months
1,200	1,800	3,600(a)	>100(a)	<100	Belt(a)	Direct	>140(a)	<140	Cont.(a)	Stby/Lay-up	
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)	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.

It is important to note that this regreasing program was designed to minimize overgreasing of bearings in-between bearing replacement. When a bearing is replaced, the bearing should be packed with grease and the grease cavity should be filled with grease to around 50 percent, 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 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 or grease transfer 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 lubricate starvation issue and possible bearing failure. Once the grease cavity becomes full, any excess grease must purge through the designated drain opening or it will be pushed into the motor. Unfortunately, due to frequent inaccessibility to the drain plug after motor installation, this often does not happen and the grease cavity becomes full after several regreasing activities.

Regardless of the reason for the grease cavity becoming full, overgreasing can lead to bearing shield deformation, cage failure, overheated bearing or filling the inside of the motor with excess grease.

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). The shaft diameter is the diameter of the shaft at the bearing.

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

Note: 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.

SUMMARY

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. The program described in this paper 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 successfully implemented this program for motor relubrication since the EPRI report was published in 1992.

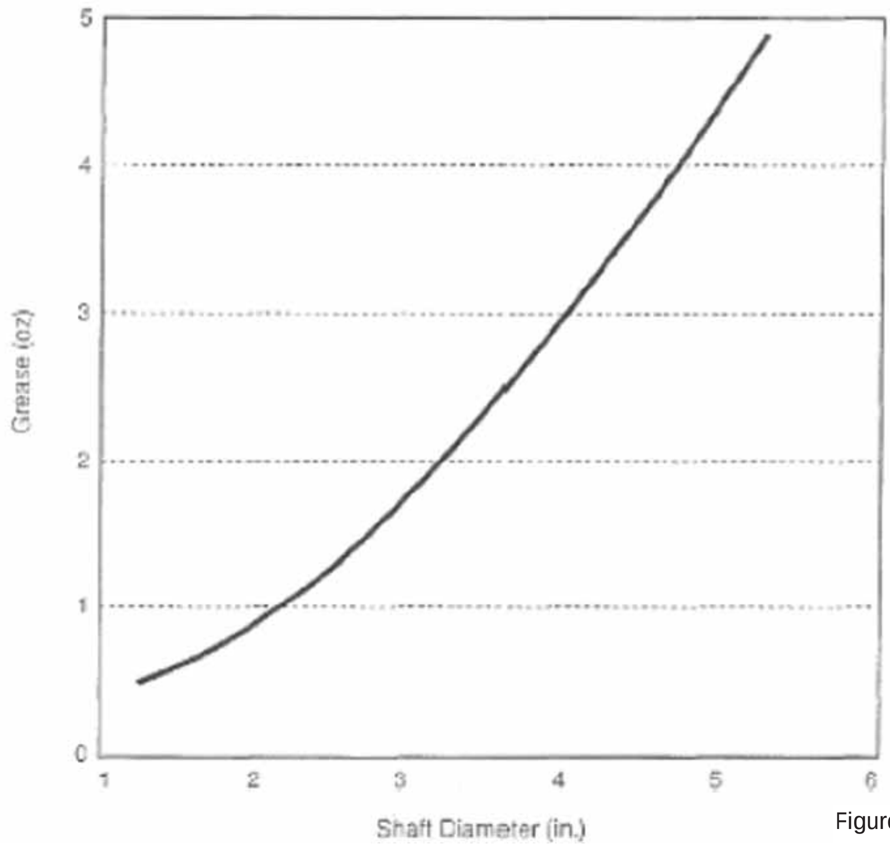

Figure 11