SCHEDULED ROUTINE MOTOR CARE MAINTENANCE PROGRAM

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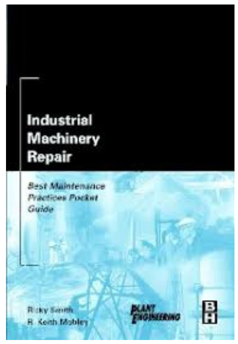

A specific maintenance plan that is carried out on a regular basis is a primary factor in preventing motor problems and failures. And, when problems do arise and system shutdown is inevitable, a logical, step-by-step method of troubleshooting can save time and money. At the very least, the motor manufacturer's maintenance schedule should be adhered to on all electric motors. The amount of additional maintenance attention required and the stocking of spare parts, or even spare motors, depend to a large degree on the importance, cost, and complexity of the motor. For example, a small, normally stocked, low-horsepower, low-cost standard motor that is not necessarily vital to the continuous operation of a system may not demand such a rigid maintenance schedule. Spare parts may be readily available and stocked. In some cases, it may be less costly to replace the entire motor rather than to proceed with intense repair.

On the other hand, a high-cost specialty motor on which an entire manufacturing process depends will demand more painstaking care and maintenance. Spares may not be readily available, or cost-effective.

Scheduled routine inspection and service will minimize motor problems. Frequency of routine service depends upon the application. It is usually sufficient to include motors in the maintenance schedule for a driven machine or general plant equipment. If a breakdown could cause health or safety problems, severe loss of production, damage to equipment, or other serious losses, a more frequent maintenance schedule should be adopted.

It is important to plan and document your maintenance program. This includes prepared forms for recording such data as the date of inspection, items inspected, service performed, and general motor condition. These records can help identify specific problems in an application and help avoid breakdowns and production losses. Routine inspection and service can usually be done without disconnecting or disassembling the motors. The inspection should consider each of the following categories. Warning: Internal parts of a motor may be at line potential even when it is not rotating. Before performing any maintenance that could result in contacting any internal part, be sure to disconnect all power from the motor.

- Motors using rectified power units disconnect all A-C line connections.
- Motors using rotating power units disconnect all D-C line and field connections.

GREASE-LUBRICATED ANTIFRICTION BEARINGS.

Lubricate bearings only when scheduled. *Do not* over-lubricate. Excessive grease creates heat due to churning and can damage bearings. Follow the manufacturer's recommendation for lubrication frequency and amounts.

Before lubricating, thoroughly clean the lubrication equipment and fittings. Dirt introduced into bearings during lubrication probably causes more bearing failure than lack of lubrication. Use only clean, fresh grease from clean containers, and handle so as to avoid contamination.

Over-greasing bearings can cause mechanical churning of the grease and will result in elevated bearing temperature, leaching of the oil from the grease, and shortened bearing life. Excessive lubricant can also find its way inside the motor where it collects dirt and causes insulation deterioration.

The frequency of routine greasing of ball and roller bearings increases with motor size and the application’s severity. The user for the specific conditions should establish actual schedules. Before scheduled greasing, both the inlet and drain plugs should be removed. Pump grease into the housing using a standard grease gun, suitable grease fitting, and light pressure.

Should bearings remain hot or noisy even after correction of bearing overloads, remove the motor from service. Wash the housing with a good solvent. Replace the bearings. Repack the bearings, assemble the motor, and fill the grease cavity.

Whenever motors are disassembled for service, check the bearing housing. Wipe away any old grease. If there are any signs of grease contamination or breakdown, clean and repack the bearing system as described in the preceding paragraph. Again, make certain that the inlet and outlet passages are clean and free of dirt or chips.

Oil-Lubricated Sleeve Bearings.

As a rule of thumb, fractional horsepower motors with a wick lubrication system should be oiled every 2000 hr of operation, or at least annually. Dirty, damp, or corrosive locations or heavy loading may require oiling at 3-month intervals or more often. Follow the manufacturer’s recommendations for quantity, frequency, and type of oil.

Many larger motors are equipped with oil reservoirs and usually a sight gage to check proper level. As long as the oil is clean and light in color, the only requirement is to fill the cavity to the proper level with the oil recommended by the manufacturer. Do not overfill the cavity.

If the oil is discolored, dirty, or contains water, remove the drain plug. Flush the bearing with clean solvent until it comes out clear. Coat the plug threads with a sealing compound, replace the plug, and fill the cavity to the proper level.

If the oil discolors frequently or becomes unusually dark, it is advisable to disassemble and inspect the bearing parts. Possible causes of dark oil are:

- Wiping or melting of Babbitt bearing face, caused by improper scrapping, dirt, heat, or vibration.
- Thrusting the shaft shoulder into the end face of the bearing, caused by improper alignment of the motor to driven equipment, improper internal motor axial clearances, and end float.
- Rubbing of oil rings on reservoir housing.
- Improper or insufficient sealing of bearing housing bolted surfaces. This can allow contaminated air to be drawn into the bearing reservoir.

When motors are disassembled, wash the housing with a solvent. Discard any used packing. Replace badly worn bearings. Coat the shaft and bearing surfaces with oil and reassemble. Be certain that new bearings are properly scraped and fitted.

HEAT, NOISE, AND VIBRATION.

Check the motor frame and bearings for excessive heat or vibration with suitable test equipment. Listen for abnormal noise. All indicate possible system failure. Identify and eliminate the source of heat, noise, or vibration. A continuous log comparing vibration levels should be used to predict problems and bearing life.

Heat.

Excessive heat is both a cause of motor failure and a sign of other motor problems. Primary damage caused by excess heat is the increase of the insulation’s aging rate. Heat in excess of the insulation’s rating will shorten winding life.

An approximate rule of thumb is that insulation life is reduced to half its normal life for each 10°C (50°F) increase above the designed temperature. Overheating results from a variety of different problems, grouped as follows:

- ***Improper application***. The motor may be too small or have the wrong starting torque characteristics for the load. This may be the result of poor selection or changes in the load requirements.

- ***Poor cooling***. Accumulated dirt or poor motor location may prevent the free flow of cooling air around the motor. This may also result from the motor drawing heated air from another source. Internal dirt or damage can prevent proper airflow through all sections of the motor. Dirt on the frame may prevent transfer of internal heat to the cooler ambient air.

  - Wipe, brush, vacuum, or blow accumulated dirt from the motor’s frame winding and air passages. Do not use high-pressure sprayers. Thick dirt insulating the frame’s outer surface and clogging passages reduces cooling airflow, causing motors to run hot. Heat reduces insulation life and eventually causes motor failure. On open machines, measure the temperature of air in and out using a thermocouple. The difference between these readings in the temperature indicates the rise of the air. Comparison of these readings for a constant or non-varying load after a sequence of periodic inspections is meaningful. Gradual increase over a period of time indicates a need for cleaning.

  - Feel for air being discharged from the cooling air ports. If the flow is weak or unsteady, internal air passages may be clogged. The motor should be removed from service and cleaned. Also, for fancooled enclosures, check for large A-C typically unidirectional fans installed in the reverse direction.

- ***Overloaded driven machine**.* Excess loads or jams in the driven machine force the motor to supply higher torque, draw more current, and overheat.

- ***Excessive friction**.* Misalignment, poor bearings, and other problems in the driven machine, power transmission system, or motor increase the torque required to drive the load, and raise the motor operating temperature.

- ***Electrical overloads**.* An electrical failure of a winding or connection in the motor can cause other windings or the entire motor to overheat.

- ***Incorrect line voltage**.* Excessive voltage can cause increased magnetic losses in the motor. Insufficient voltage will cause the motor to draw excessive current under load, thus increasing the resistance losses.

Other possible causes of low voltage at motor terminals include excessively long supply leads, insufficiently sized leads, poor electrical connections, and bad starter contacts.

Noise and Vibration.

Noise usually indicates motor problems but usually does not cause damage. It is usually accompanied by vibration, however, which can cause damage in several ways.

Vibration tends to shake windings loose and mechanically damages insulation by cracking, flaking, or abrading the material. Excessive vibration also causes embrittlement, or flaking, of lead wires from excessive movement and brush sparking at commutators. Finally, vibration can bring about bearing failure by causing bearings to Brinell (ball indentations in race), sleeve bearings to be pounded out of shape, or the housings to loosen in the shells.

Whenever noise or vibration occurs in an operating motor, the source should be quickly isolated and corrected. What may seem to be an obvious source of the noise or vibration may be a symptom of a hidden problem. Therefore, a thorough investigation is often required.

Noise and vibration can be caused by a misaligned motor shaft or can be transmitted to the motor from the driven machine or power transmission system. They can also be the result of either electrical or mechanical unbalance in the motor.

After checking motor shaft alignment, disconnect the motor from the driven load. If the motor operates smoothly, with both power on and power off, check the source of noise or vibration in the driven equipment.

If the disconnected motor still vibrates, remove power from the motor. If the vibration stops, look for an electrical unbalance. If it continues as the motor coasts without power, look for a mechanical unbalance.

Electrical unbalance occurs when the magnetic attraction between stator and rotor is uneven around the periphery of the motor. This causes the shaft to deflect as it rotates, creating a mechanical unbalance. Electrical unbalance usually indicates an electrical failure, such as an open stator or rotor winding, an open bar or ring in squirrel-cage motors, or shorted field coils in synchronous motors. An uneven air gap, usually a result of badly worn sleeve bearings, also produces electrical unbalance.

The main causes of mechanical unbalance include a distorted mounting, bent shaft, poorly balanced rotor, loose parts on the rotor, or bad bearings. Noise can also come from the fan hitting the frame, fan shroud, or foreign objects inside the shroud. If the bearings are bad, as indicated by excessive bearing noise, determine why the bearings failed.

Corrosion.

Check for signs of corrosion, including corroded terminals and connections inside the conduit box. Severe corrosion may indicate internal deterioration and/or a need for external repainting. Schedule the removal of the motor from service for complete inspection and possible rebuilding.

BRUSHES AND COMMUTATORS (D-C MOTORS)

- Observe the brushes while the motor is running. The brushes should ride on the commutator smoothly with little or no sparking and no brush noise (chatter).

- Stop the motor. Be certain that:
  - The brushes move freely in the holder, and the spring tension is equal on each brush.
  - Each brush has a polished surface over its entire working face, indicating good seating.
  - The commutator is clean, smooth, and has a polished brown surface where the brushes ride. *Note:* Put each brush back into its original holder. Interchanging brushes decreases commutation ability.
  - There is no grooving of the commutator (small grooves around the circumference of the commutator). If grooving is present, schedule the motor for corrective action. This can lead to a serious problem.

- If there is any chance or indication that the brushes will not last until the next inspection date, replace them. Fit the face of new brushes to the radius of the commutator with sandpaper only; do not use emery abrasive. Final seating of the brushes to the commutator surface may be accomplished with the use of a fine commutator seating stone.

Generally, brushes should be replaced in full sets. However, some motors may have specific brushes that wear at significantly different rates. Selective replacement might be advisable where this pattern is established. Brushes that might wear at a more rapid rate include:

- The positive brush or brushes on some unidirectional motors.

- The brushes in the outer track or tracks, where the brushes on each stud are not in a straight line across the commutator. Purposely misaligning brushes is known as “stepping” or “staggering” brushes, and is used to improve the electrical characteristics of the motor. It also lengthens the life of all brushes except the last brushes to maintain contact with a given commutator bar. It is best to have all brushes in the motor be of the same grade of carbon from the same manufacturer and from the same manufacturing lot. Mixing brush manufacturers or carbon grades should be avoided.

- Clean any accumulated foreign material from the grooves between the commutator bars and from the brush holders and posts. Use only clean, dry compressed air.

- Brush sparking, chatter, excessive wear, or chipping and a dirty or rough commutator are indications that the motor requires prompt service.

Brush and Commutator Care.

Many factors are involved in brush and commutator problems. All generally involve brush sparking, usually accompanied by chatter and excessive wear or chipping. Sparking may result from poor commutator conditions, or it may cause them.

The degree of sparking should be determined by careful visual inspection. It is imperative that a remedy be determined as quickly as possible. Sparking usually feeds upon it and becomes worse with time until serious damage results.

Eliminating sparking requires a thorough review of the motor and operating conditions. Always recheck for sparking after correcting one problem to see that it solved the total problem. Also remember that after grinding the commutator and reseating the brushes, sparking will occur until the polished, brown film reforms on the commutator. In eliminating sparking, consider external conditions that affect commutation. Frequent motor overloads, vibration and high humidity cause sparking. Extremely low humidity allows brushes to wear through the needed polished, brown commutator surface film. Oil, paint, acid, and other chemical vapors in the atmosphere contaminate brushes and the commutator surface. Look for obvious brush and brush holder deficiencies:

- Make certain that the brushes are properly seated, move freely in the holders, and are not too short.
- The brush spring pressure must be equal on all brushes.
- Be certain that spring pressure is not too light or too high. Large motors with adjustable springs should be set at about 3 to 4 lb per sq in. of brush surface in contact with the commutators. If a choice has to be made between setting pressure higher or lower than recommended, choose the higher setting. Arcing due to low pressure is much more detrimental than the frictional increase of high pressure.
- Remove dust that can cause a short between brush holders and frame.
- Check lead connections to the brush holders. Loose connections cause overheating.

Look for any obvious commutator problems:

- Conditions other than a polished, brown surface under the brushes can indicate a problem. Severe sparking causes a rough, blackened surface. An oil film, paint spray, chemical contamination, and other abnormal conditions can cause a blackened or discolored surface and sparking. Streaking or grooving under only some brushes or flat and burned spots can result from a load mismatch. Grooved commutators should be scheduled for removal from service. A brassy appearance shows low film buildup on the surface and may result from low humidity, wrong brush grade, or prolonged light loading.

- High mica or high or low commutator bars make the brushes bounce, causing sparking.
- Carbon dust, copper slivers, or other conductive dust in the slots between commutator bars causes shorting and sometimes sparking between bars.

If correcting the obvious deficiencies does not eliminate sparking or noise, look at the less obvious possibilities:

- If the brushes were changed before the problem was apparent, check the grade of brushes. Weak brushes may chip. Soft brushes may allow a thick film to form. High-friction or high-abrasion brushes wear away the brown film, producing a brassy surface. If the problem appears only under one or more of the brushes, two different grades of brushes may have been installed. Generally, use only the brushes recommended by the motor manufacturer or a qualified brush expert.

- The brush holder may have been reset improperly. If the boxes are more than $\frac{1}{8}$ in. from the commutator, the brushes can chatter and chip. Setting the brush holder off neutral causes sparking. Normally, the brushes must be equally spaced around the commutator and must be parallel to the bars so all make contact with each bar at the same time.

- An eccentric commutator can cause sparking and may cause vibration. Normally, concentricity should be within .001 in. on high-speed, .002 in. on medium-speed, and .004 in. on slow-speed motors.

- Various electrical failures in the motor windings or connections manifest themselves in sparking and poor commutation. Look for shorts or opens in the armature circuit and for grounds, shorts, or opens in the field winding circuits. A weak inter-pole circuit or large air gap also generate brush sparking.

Brushes and Collector Rings (Synchronous Motors)

- Remove any black spots on the collector rings by rubbing lightly with fine sandpaper. These spots, if not removed, will cause pitting that requires regrinding the rings.

- Check for an imprint of the brush, signs of arcing, or uneven wear. Should any of these be present, remove the motor from service and repair.

- Check the collector ring brushes under the same circumstances as described previously under Brushes and Commutators. Note that these brushes will probably not wear as rapidly as D-C commutator brushes.

WINDINGS

Routine inspections generally do not involve opening the motor to inspect the windings, unless it is an expensive, high-horsepower motor. Therefore, long motor life requires selection of the proper enclosure to protect the windings from excessive dirt, abrasives, moisture, oil, and chemicals. Routine testing can identify deteriorating insulation and is particularly helpful in severe operating conditions or in an application that shows a history of winding failures. Such motors should be removed from service and repaired before unexpected failures stop production.

Insulation resistance of a winding will vary, depending upon the temperature, moisture in or on the winding, cleanliness, age, test voltage value, and duration of the test voltage. The best method of making these tests is IEEE 43, “Recommended Guide for Testing Insulation Resistance of Rotating Machinery,” published by the Institute of Electrical and Electronics Engineers, 345 East 47th Street, New York, NY 10017.

The standard value of insulation resistance is the least value that a winding should have after cleaning and drying. The ratio of insulation resistance obtained by a 10-min and 1-min voltage application is the polarization index (PI). This is used to determine when drying is complete or to determine winding conditions when no other information is available. The PI of A-C stator windings that are clean and dry are usually 1.5 or more for class “A” windings and 2.5 or more for class “B” windings.

Keeping windings dry will improve the performance of the insulation. If the motor has been exposed to dampness, it should be thoroughly dried, by either the D-C method or the external heat method. Regardless of the method used, the winding should not be heated over 90°C (194°F) measured by resistance or 75°C (167°F) measured by thermometer.

The D-C method is done with the motor stationary. A low-voltage, high-current, D-C power source is used to dry out armature windings. The armature terminals may be connected either in series or multiple.

The external heat method uses an oven, preferably one with circulating air, at a temperature not exceeding 85°C (185°F). This would be continued until the insulation resistance becomes practically constant.

Whenever a motor is opened for repair, winding care should be as follows:

- Accumulated dirt prevents proper cooling and may absorb moisture and other contaminants that may damage insulation. Vacuum the dirt from the windings and other internal air passages. Do not use high-pressure air, as this can damage windings by driving the dirt into the insulation.

- If a motor repair facility is available, windings can be cleaned by steam or by washing in proper detergent solvents. Again, care must be taken to prevent forcing contamination deeper into any existing breaks or cracks in the insulation. Windings cleaned by this method should be dried in a forced draft oven for at least 8 hr at 121°C (250°F). Re-varnishing with a polyester or epoxy varnish can be done after the windings are thoroughly cleaned and dried. These varnishes should be baked for 6 to 8 hr at about 148 to 157°C (300 to 315°F).

- Abrasive dust drawn through the motor can abrade coil noses, removing insulation. If such abrasion is found, the winding should be re-varnished or replaced.

- Moisture reduces the dielectric strength of insulation that results in shorts. If the inside of the motor is damp, dry the motor per information found below under Cleaning and Drying Windings.

- Wash any oil and grease from inside the motor. Use care with solvents that can attack the insulation.

- If the insulation appears brittle, overheated, or cracked, the motor should be re-varnished or, with severe conditions, rewound.

- Loose coils and leads can move with changing magnetic fields or vibration, causing the insulation to wear, cracks, or fray. Re-varnishing and retying leads may correct minor problems. If the loose coil situation is severe, the motor must be rewound.

- Check the lead-to-coil connections for signs of overheating or corrosion. These connections are often exposed on large motors, but taped on small motors. Repair as needed.

- Check wound rotor windings as described for stator windings. Because rotor windings must withstand centrifugal forces, tightness is even more important. In addition, check for loose pole pieces or other loose parts that create unbalance problems.

- The cast rotor bars and ring ends of squirrel-cage motors rarely need attention. However, if they are open or broken, they create an electrical unbalance that increases with the number of bars broken. An open end-ring causes severe vibration and noise.

Problems due to open circuits (bars) or high-resistance points between the rotor and end rings are identified by reduced torques, higher slip under load, increased heat, and noise. These open bars associated with rotors are rarely visible, but can be checked by applying 10 to 25 percent single-phase voltage to the stator with an ammeter in one line, slowly rotating the shaft by hand, and observing the ammeter for significant current changes. A significant current change with rotor position indicates a defect in the winding cage. A pulsing sound related to slip under load is usually the first observation and indicates that the rotor should be replaced.

Rotor construction typical of many large induction and many high-resistance motors consists of a fabricated cage with bars brazed to the end rings. A cracked rotor bar or brazed cage with bar extensions between the iron core and end ring can usually be seen. Generally localized heating, causing discoloration, will reflect brazed joint problems. A competent repair shop should replace cracked bars.

Should cracked rotor bars on die-cast rotors be visible where bars and end rings meet, replace the rotor. Only qualified competent personnel should do replacing or brazing broken bars on squirrel-cage rotors.

TESTING WINDINGS.

Routine field-testing of windings can identify deteriorating insulation, permitting scheduled repair or replacement of the motor before its failure disrupts operations. This is good practice especially for applications with severe operating conditions or a history of winding failures and for expensive high-horsepower motors and locations that can cause health and safety problems or high economic loss.

The easiest field test that prevents the most failures is the ground-insulation, or megger test. It applies D-C voltage, usually 500, 1000, or 2500 volts, to the motor and measures the resistance of the insulation.

NEMA standards require a minimum resistance to ground at 40°C (104°F) ambient of 1 megohm per kilovolt of rating plus 1 megohm. Medium-sized motors in good condition will generally have megohmmeter readings in excess of 50 megohms. Low readings may indicate a seriously reduced insulation condition caused by contamination from moisture, oil, or conductive dirt or by deterioration from age or excessive heat.

One megger reading for a motor is not adequate. A curve of several readings recording resistance, with the motor cold and hot and the date, indicates the rate of deterioration. This curve provides the information needed to decide if the motor could safely remain in service until the next scheduled inspection.

The megger test indicates ground insulation condition. It does not, however, measure turn-to-turn insulation condition and may not pick up localized weaknesses. Moreover, operating voltage peaks may stress the insulation more severely than megger voltage. For example, the D-C output of a 500-volt megger is below the normal 625-volt peak of each half cycle imposed on an A-C motor when operating on a 460-volt system. Experience and conditions may indicate the need for additional routine testing. A test used to prove existence of a safety margin above operating voltage is the A-C high-potential ground test. This test should never be applied until a sufficiently high megger reading has been obtained.

For motors in service, it is advisable to test at 65 percent of the above value. This is a destructive test, and although this test does detect poor insulation condition, the high voltage can arc to ground, burning insulation and frame. It can also actually cause failure during the test. Repetitions of the test should be kept to a minimum.

D-C high potential (HI-POT) rather than A-C high-potential tests are becoming popular because the test equipment is smaller and the low test current is less dangerous to personnel and does not create as a great a degree of damage as A-C. *Caution: High-potential testing, whether D-C or A-C, is destructive testing, and is not generally recommended as a maintenance-type test.*

Polarization index is another method of measuring the ground resistance of the insulation. Normally, all three phases are measured together at one time. The test consists of applying 500 volts D-C and measuring the ground resistance of the insulation for a time period of 10 min. The quotient of the 10-min resistance reading divided by the 1-min reading must give an index number of 2.0 or greater to be acceptable (IEEE 43).

The surge test is a method for evaluating turn-to-turn insulation within the coils. This is a nondestructive test, which indicates shorts between turns and dissymmetry such as incorrect number of turns in a given coil. The test is done by comparing the unknown coil or winding to one of known quality. Comparison is made by viewing a decaying sine wave trace of a voltage applied to each coil on a dual beam scope.

CLEANING AND DRYING WINDINGS.

There are basically two ways to clean electric motor windings. For in-plant maintenance it is generally recommended to physically remove dirt and contamination by wiping, brushing, and very carefully blowing with compressed air. A light cleaning with compressed air and ground-up corncobs is sometimes very effective. The danger, particularly with compressed air, is that of forcing conductive contaminants into cracks or breaks in the insulation and possibly making the problem worse than it was. For this reason, air should only be used as a final touch-up after the majority of dirt has been physically removed.

The second method involves removal of dirt and grease by liquid solution. In the field, this would most likely involve the use of an electrical non-tracking solvent; follow the manufacturer’s direction for use of such solutions. A most effective method of applying solvents is with a suction-type atomizing spray nozzle. The light air pressure with the atomized solvent does an effective cleaning job. The hazards, however, are that of forcing and flushing conductive contaminants deeper into the winding. Also, some insulation materials, particularly adhesive tapes, may be attacked or softened by solvents. In the repair shop, steam cleaning and flushing, degreasing tanks, and rinsing troughs are common. Slowly rotating a D-C armature in a warm detergent solution can be a very effective method for removing carbon dust from deep down in the winding. A low-pressure stream of water or a water detergent solution best cleans motors that have been subjected to immersion because of floods. This will remove encrusted mud and debris. In all liquid pressure cleaning, avoid aiming the stream directly at the winding, but rather wash the dirt away by aiming at an angle to the winding surface. This should minimize the chances of forcing dirt into the winding.

In any washing or cleaning involving water, it is necessary to dry out the winding. It is recommended to dry the winding in a forced draft oven for at least 8 hr at about 121°C (250°F).

MOTOR TESTING.

Dynamometer load testing will identify performance problems including loss of torque and winding or bearing temperature problems. Load testing is particularly recommended for rebuilt D-C motors, where the test can verify the neutral setting, the inter-coil strength, and the relative polarities of the various windings, in addition to the load-carrying capability of the motor.