CHAPTER 4

ELECTRIC MOTORS

4-1. Maintenance of electric motors.

This information is intended to aid personnel concerned with the maintenance of electric motors. The data provided cover all DC and AC motors. The recommendations are general in nature and normally can be applied to the type of motors found on military installations. They are not intended to cover in detail the specialized applications occasionally encountered. For such cases, the manufacturer's instructions should be followed. Periodic inspection and regularly scheduled preventive maintenance checks and services will enhance continuous operation of the equipment without undue breakdowns. Frequency of these inspections often depends upon elements such as the criticality of the service, hours equipment is normally in service, and environment under which the equipment operates. In order to ensure an accurate data base from which an effective maintenance program can be initiated, a complete listing of machines in operation, the functions they perform and past history of operation and maintenance services must be maintained. Motor inspection and scheduled maintenance in the Air Force is performed by the work center responsible for the system (HVAC, sewer plant, water plant, etc.). Preventive maintenance will generally involve lubrication, cleaning and checking for sparking brushes, vibration, loose belts, high temperature, and unusual noises. Repair work on larger motors is normally limited to replacement or refinishing of bearings, commutators, collector rings, brushes, etc. Motor rewinding should not be attempted by the installation support groups (Directorate of Engineering and Housing, Public Works or Civil Engineer Shops) since it is more economical to contract such work to commercial shops that specialize in motor rewinding. With regard to the many thousands of fractional horsepower motors in operation throughout the military services, it may be more economical to replace a motor than to attempt to repair it. The local electrical supervisor must make this determination. Table 4-1 can be consulted to aid in the selection of proper replacement motors. Special consideration should also be given to high-efficiency motors since they save both energy and money throughout the life of the motor. The following safety precautions should be observed when working on electric motors:

a. Make sure the machine is de-energized, tagged and locked out before starting work (para 12–2).

b. Personal protective equipment such as goggles, gloves, aprons and respirators should be worn when working with hazardous substances (chap 11).

c. Great care should be exercised in selecting solvents to be used for a particular task.

d. Adequate ventilation must be provided to avoid fire, explosion, and health hazards where cleaning solvents are used.

e. A metal nozzle used for spraying flammable solvents should be bonded to the supply drum, and to the equipment being sprayed.

f. After tests have been made, discharge stored energy from windings by proper grounding before handling test leads.

4-2. Alternating current (AC) motors.

AC motors should, with reasonable care, give long continuous service. However, there is a tendency to neglect motor maintenance and, as a result, motor failures are frequent and repairs may become a continuous and costly process. It is therefore recommended that a preventive maintenance program be established to minimize emergency breakdowns. The program should be supported with an effective spare parts stock to speed up any unscheduled outages that may occur.

a. Squirrel-cage induction unit. This AC motor is the most prevalent in use at military installations (fig 4-l). The squirrel-cage motor is the most rugged and the least expensive of all types of induction motors. The squirrel-cage motor is nearly a constant speed machine. Typically its speed varies 0–5 percent from synchronous speed from no load to full load. The basic design of the rotor can be modified to provide a limited degree of external speed control.

b. Wound-rotor induction unit. This AC motor has connected to its collector rings the insulated phase windings on the rotor (fig 4-2). Through stationary brushes in contact with the collector rings, any desired value of external resistance may be added to the secondary (rotor) winding to give greater speed control of the motor. Also, use of external resistance allows the motor to deliver a high starting torque with a relatively small inrush current.

c. Synchronous unit. This type of AC motor (fig 4–3) has an insulated winding in both the rotor and the stator. A variable source of DC excitation is supplied to the rotor winding and an AC line source is supplied to the stator winding. A synchronous motor is a constant speed machine with similar

APPLICATION	TYPE	USUAL HP	SPEED 60 HERTZ	VOLTAGE RATING 60 HERTZ	TEMPERATURE RISE COIL WINDINGS	NORMAL ROTATIONAL (FACING END OPPOSITE DRIVE SHAFT)	OTHER DISTINCTIVE FEATURES
Refrigeration compressor, belt-driven	Single-Phase: a. Capacitor-start b. Repulsion-start Polyphase Induction: a. Squirrel-Cage, Constant speed.	1/6, 1/4, 1/3, 1/2, 3/4	1,725 rpm at full load	Capacitor-start, 1/4 hp and less-115V and 230V; 1/3 hp and more - 115/230V. Repulsion-Start, 115/230V. Polyphase, 208V, 230V, 440V, 460V.	Thermometer: 40° C. Resistance: 50° C.	Stock Motors, counter clockwise; adaptable for either direction.	Open or dripproof: sleeve bearings for horizontal mounting. Spring cap oiler on front end; extended oil cap oiler on back end.
Centrifugal ejector pumps, direct-driven	Single-Phase: a. Split phase. b. Capacitor-start c. Repulsion-start Polyphase induction: a. Squirrel-Cage, Constant speed.	1/4, 1/3, 1/2, 3/4, 1 1/3 and up	3,450 rpm at full load, polyphase - constant speed.	Split Phase 115V and 230V; Capacitor-start, 115/230V. Repulsion-Start, 115/230V. Polyphase, 208V, 230V, 440V, 460V.	Thermometer: 40° C. Resistance: 50° C.	Clockwise	Open Frame: Grease-lubricated ball bearings. Horizontal or verticaL mountings. Terminals located in front end shield or frame adjacent to front end shield.

Table 4-1. Motor application guide.

APPLICATION	TYPE	USUAL HP	SPEED 60 HERTZ	VOLTAGE RATING 60 HERTZ	TEMPERATURE RISE COIL WINDINGS	NORMAL ROTATIONAL (FACING END OPPOSITE DRIVE SHAFT)	OTHER DISTINCTIVE FEATURES
Fans and blowers, shaft-mounted (propeller fans or centrifugal blowers with or without airflow; not for belted loads).	Single-phase: a. Split Phase. b. Permanent Split. Polyphase induction: a. Squirrel cage, constant speed.	Single-Phase 1/2 hp and up Polyphase, 1/8 hp and up	Two-speed near synchronous and near 2/3 synchronous speed; or adjustable varying speed down to 1/2 to synchronous speed. No variable speed on polyphase.	Split phase 115Vand 230V. Permanent, split capacitor, 115/230V. Polyphase 208V, 230V, 440V, 460V.	Thermometer: 55° C. Resistance:65° C.	Stock Motors, Counter-Clockwise; adaptable for either direction.	Totally enclosed: Horizontal motors, sleeve bearings and vertical motors, ball bearings
Fans and blowers, belt-drive, commonly used on hot air heating system, blowers, and attic fan ventilators.	Single-Speed: a. Split Phase. b. Capacitor-Start. c. Repulsion-start. Two-speed: a. Split Phase. b. Capacitor-Start	Single-Speed: a. Split Phase, 1/6, 1/4 and 1/3. b.Capacitor-Start, 1/3, 1/2 and 3/4. c.Repulsion-start, 1/3, 1/2 and 3/4. Two Speed: a. Split Phase. 1/6, and 1/4 at highest speed. b.Capacitor-start, 1/3, 1/2 and 3/4 at highest speed.	1725/1140 at full load.	115 and 230.	Thermometer: 40°C. Resistance:50°C.	Stock motors, counter-clockwise; adaptable for either direction	Open or dripproof: sleeve bearings for horizontal operation. Resilient mounting.

Table 4-1. Motor application guide--continued.

APPLICATION	TYPE	USUAL HP	SPEED 60 HERTZ	VOLTAGE RATING 60 HERTZ	TEMPERATURE RISE COIL WINDINGS	NORMAL ROTATIONAL (FACING END OPPOSITE DRIVE SHAFT)	OTHER DISTINCTIVE FEATURES
Motors for either domestic of industrial-type stokes.	Single-Phase: a. Capacitor-start b. Repulsion-start Polyphase: a. Squirrel-Cage, Constant speed.	Capacitor-start: a: 1/6 and 1/4, 115 and 230 volts. b. 1/3 and larger, 115/230 volts. Repulsion-start, 115/230 volts. Polyphase, 208/230, and 460 volts.	1,725 rpm at full load	See hp Column	Thermometer: Totally enclosed, 55° C. Open 40° C. Resistance: Totally enclosed, 64° C. Resistance, 50° C.	Stock Motors, counter clockwise; adaptable for either direction.	Open or totally enclosed: Latter type preferred 1/6, 1/4, 1/3 provided with resilient mounting; 1/2 and larger arranged for rigid mounting. Capacitor on top of motor. Terminals located in front end shield or on right hand side facing front.

Table 4-1. Motor application guide - continued.

APPLICATION	TYPE	USUAL HP	SPEED 60 HERTZ	VOLTAGE RATING 60 HERTZ	TEMPERATURE RISE COIL WINDINGS	NORMAL ROTATIONAL (FACING END OPPOSITE DRIVE SHAFT)	OTHER DISTINCTIVE FEATURES
Sump pumps and, basement or cellar drains.	Single-Phase: a. Split phase.	Usually 1/3.	1,725 rpm at full load.	Thermometer: 50° C. Resistance: 60° C.	Thermometer: Totally enclosed, 55° C. Open 40° C. Resistance: Totally enclosed, 64° C. Resistance, 50° C.	clockwise.	Dripproof: Two-ball bearing; or lower bearing sleeve-type; suitable for vertical mounting. Ball bearings should be replaced with care depending on mounting, in order to provide for adequate axial thrust capacity. Be aware of proper bearing application when installing new bearings.

Table 4–1. Motor application guide - continued.

APPLICATION	TYPE	USUAL HP	SPEED 60 HERTZ	VOLTAGE RATING 60 HERTZ	TEMPERATURE RISE COIL WINDINGS	NORMAL ROTATIONAL (FACING END OPPOSITE DRIVE SHAFT)	OTHER DISTINCTIVE FEATURES
Gasoline dispensing pumps.	single-phase: a. Capacitor-Start. b. Repulsion-Start. Polyphase, induction.	Usually 1/2.	1725 rpm at full load	Single phase, 115/230V polyphase, 220V, 230V.	Thermometer: 55° C. Resistance 65o C.	Clockwise.	Totally enclosed. explosion proof: sleeve bearings, usually. Nameplate on top of motor.
Oil Burners, mechanical draft.	Single-phase: a. Split phase	1/6, 1/3, 1/12	Same	115 V and 230 V.	Thermometer:55° C. Resistance 65o C.	Clockwise	Totally enclosed: nameplate marked "oil-burner motor."

Table 4-1. Motor application guide - continued.

APPLICATION	TYPE	USUAL HP	SPEED 60 HERTZ	VOLTAGE RATING 60 HERTZ	TEMPERATURE RISE COIL WINDINGS	NORMAL ROTATIONAL (FACING END OPPOSITE DRIVE SHAFT)	OTHER DISTINCTIVE FEATURES
Washing machines	Single-phase: a Split-phase.	1/3, usually	1725 rpm at full load	115V and 230V.	Thermometer: 50° C. Resistance 60° C.	Clockwise	Open or dripproof; depends on location: Horizontal: sleeve bearing. Usually provided with built-in connection box located on end opposite driven.
Centrifugal coolant pumps.	Single phase a. Split phase b. Capacitor Start. Polyphase: a. Squirrel cage, induction.	Capacitor-start: a. Up to 1/4, 115, 230 volts. b. 1/3 up to 3/4 115/230 volts.	Same	Split phase, 115V and 230V, Repulsion, 115V and 230V. Polyphase 208V, 220V, and 230V.	Thermometer: 55° C. Resistance 65° C.	Clockwise	Totally enclosed grease-lubricated ball bearings suitable for horizontal or vertical mounting.

Table 4-1. Motor application guide - continued.

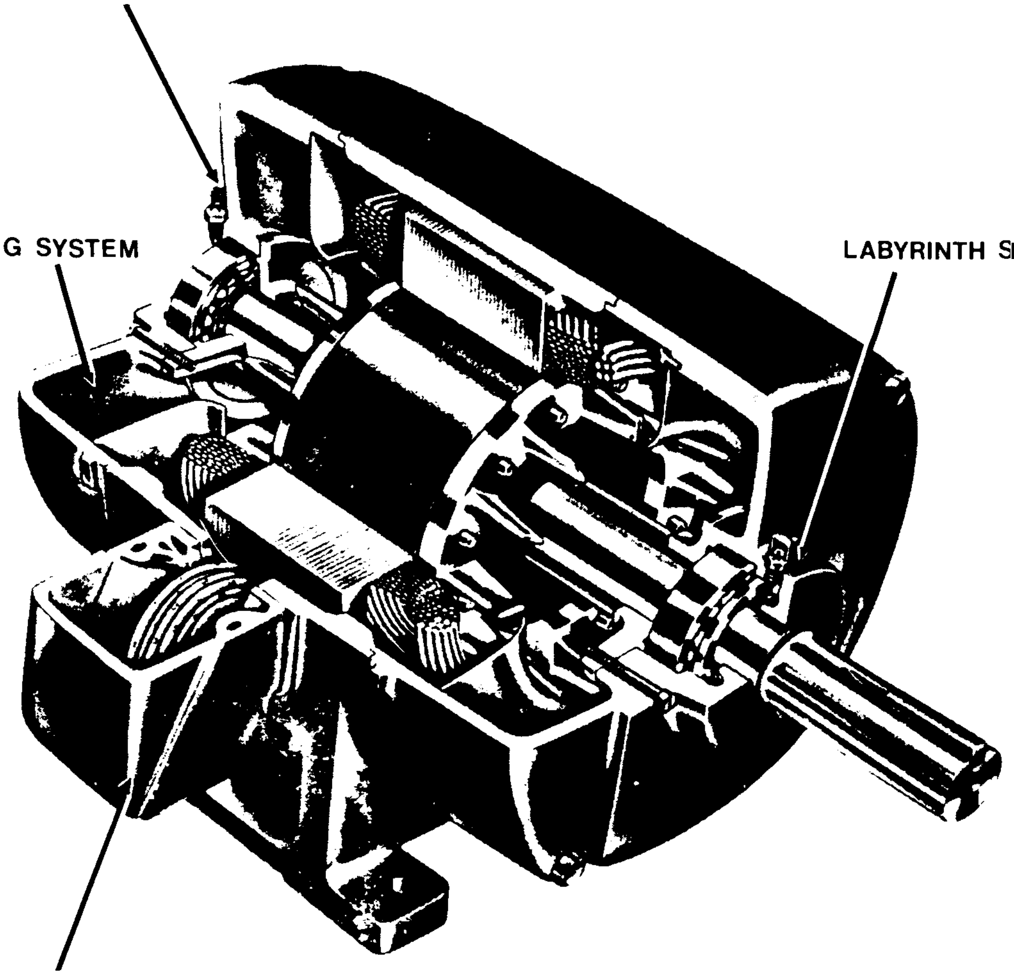


Figure 4–1. Cutaway view of squirrel-cage induction motor.

torque limitations. It may be used for power factor improvement since a synchronous motor operates at unity or a leading power factor (in addition to lagging power factor). They are also more efficient than some induction or DC motors having the same speed and power rating. But the higher cost, larger size per horsepower and lower starting torque are the disadvantages that limit synchronous unit application.

d. High-efficiency unit. This motor is specially designed to reduce electrical losses as much as 50 percent so that less electricity is used over the entire life of the motor. These motors also operate at higher power factor values which help avoid power factor penalties and reduce the cost of power factor correction. They can deliver longer service, are more reliable, and are more easily maintained than normal efficiency motors.

e. Components of AC machines. Maintenance operations on an AC motor will encompass maintenance on the following components.

(1) *Stator and rotor windings.* The primary parts of a typical motor are (fig 4–4): the frame and base that support the assembled motor; the stator which is the stationary part consisting of an iron core and insulated windings; and the rotor which is the rotating element. The term armature is often used in lieu of rotor, particularly with DC motors and for AC motors with commutators or collector rings and brushes. Most stator and rotor problems can be traced to winding failures. The life of a winding depends upon keeping it as near to its original condition as long as possible. Insulation failure causes immediate outage time. The following points should be carefully examined and corrective action taken during scheduled inspections to prevent operation failures.

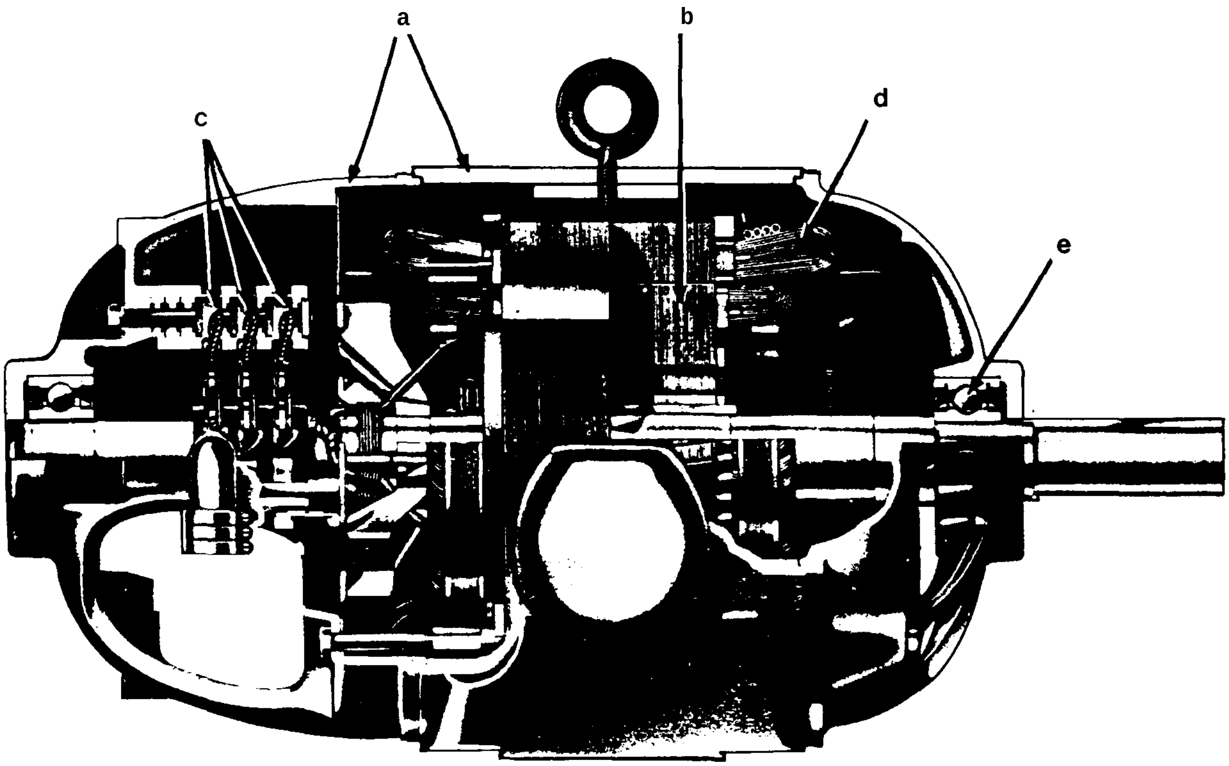


Figure 4-2. Cutaway View of Wound-Rotor Induction Motor: a) Housing, b) Roto Assembly, c) Slip Ring Brushes, d) Stator Windings, 3) Ball Bearings.

(a) Cleaning motor windings. Dust and dirt are almost always present in windings that have been in operation under average conditions. Dust combined with high humidity becomes highly conductive. It may break down the winding insulation and short circuit the motor windings. Frequent cleaning and drying may be necessary. Removing dry dirt with a clean, dry cloth is usually satisfactory if the apparatus is small and the surfaces to be cleaned accessible. Do not use any material that will leave lint, for lint will adhere to the insulation and collect even more dirt. For removal of loose dust, dirt and particles, vacuum cleaning is preferred rather than blowing out with compressed air since there is less possibility of damage to the insulation and less chances of conductive or abrasive particles getting into areas that may cause damage during motor operation. Where dirt cannot be vacuumed, compressed air blowing may be used. However, care should be taken that the dirt is not blown out of one machine into another. Air pressure should not be greater than 30 psi. The air should be dry and directed in such a manner as to avoid further closing ventilation ducts and recesses in insulation. Goggles or face shield should be worn when using compressed air to clean motors. Accumulated dirt containing oil or grease requires cleaning with a solvent. The solvent should be as recommended by the manufacturer. A rag, barely moistened (not wet) with a nonflammable solvent, may be used for wiping. Avoid liquid solvent spraying which can carry conductive contaminants into critical areas and contribute to short circuits and grounds. Apparatus which has been clogged with mud from dust storms, floods or other unusual conditions, will require a thorough water washing. Usually, a hose at pressures not exceeding 25 psi is used. After cleaning, the surface moisture should be removed immediately to keep the amount of water soaked up by the insulation to a minimum. Silicone-treated windings require special treatment, thus the manufacturer should be contacted for advice.

(b) Drying motor windings. If after cleaning, storing or shipping, tests indicate that the winding insulation resistance is below a safe level (para 4-5), then the motor should be dried before being placed in operation. Two general drying methods commonly used are external or internal heat. External heat is preferred since it is the safer application. When forced air is used (fig 4-5), it may be heated electrically or by steam. This method is usually inefficient and costly unless built into the original installation. Electrical space heaters or infrared lamps may be used. They should be distributed so as not to overheat the insulation. Coil insulation may be dried by circulating current through the

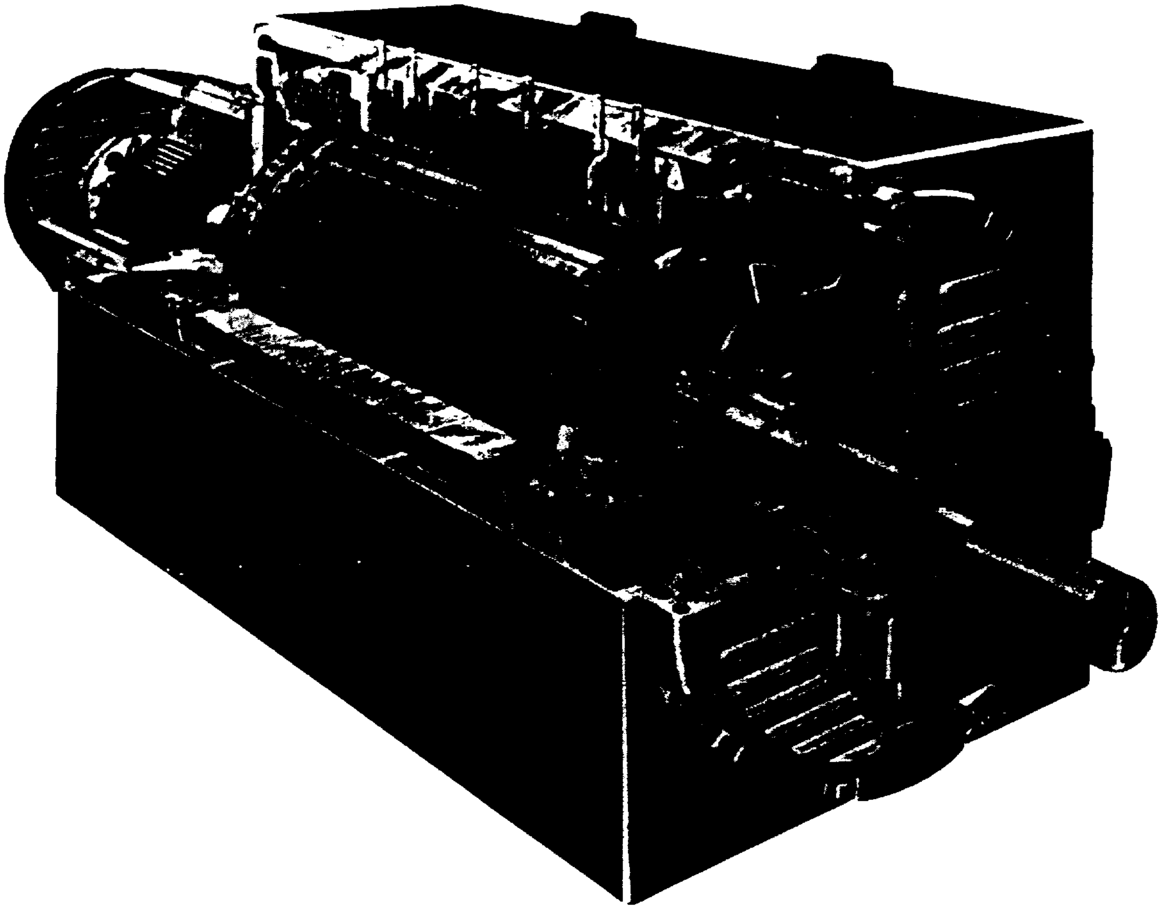


Figure 4-3. Cutaway view of synchronous motor.

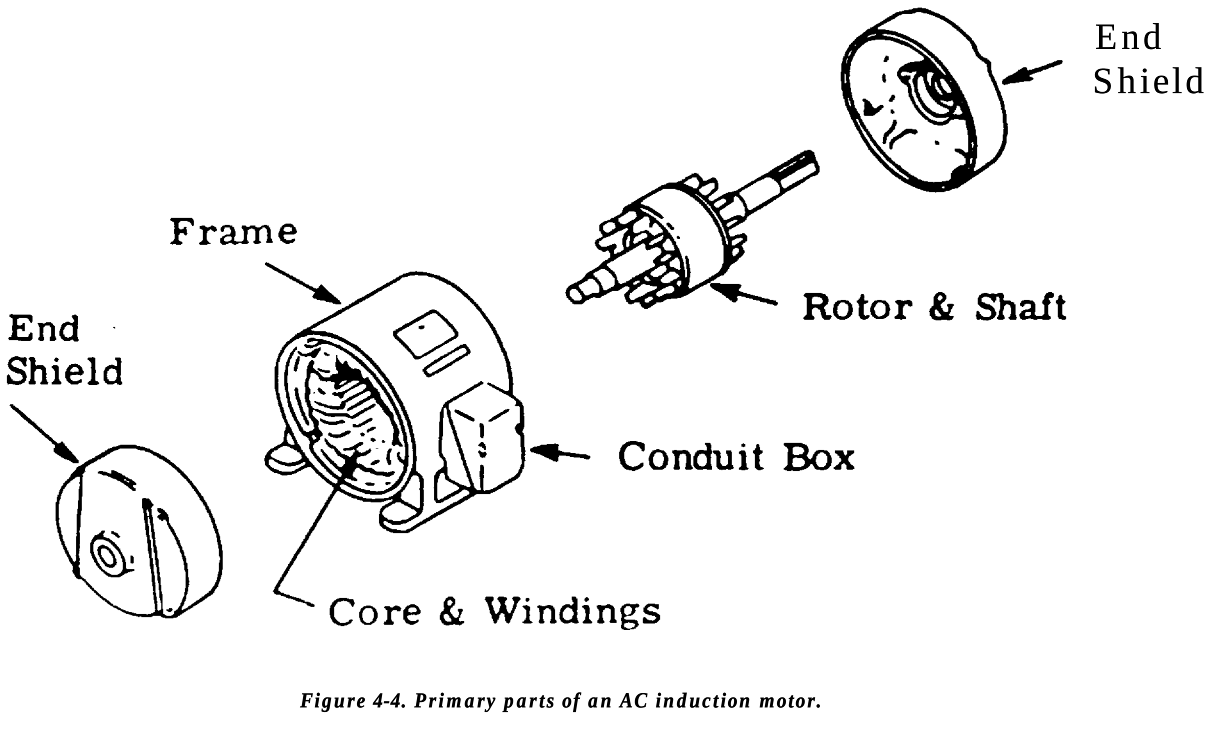


Figure 4-4. Primary parts of an AC induction motor.

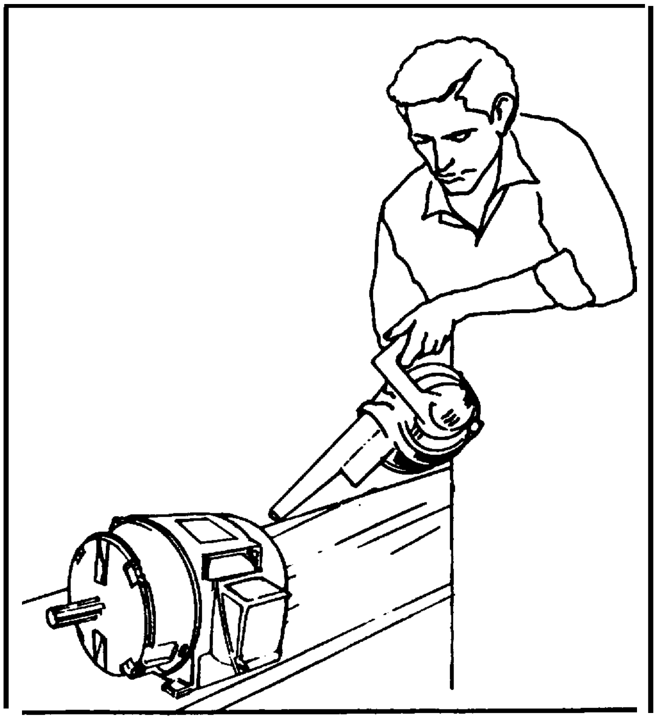


Figure 4-5 Cleaning and drying motors in place.

winding. However, there is some hazard since the heat generated in the inner parts is not readily dissipated. This method should be followed only under competent supervision. For synchronous motors, the "short circuit method" is sometimes used. This method is achieved by shorting the armature windings, driving the rotor and applying sufficient field excitation to give somewhat less than full load armature current. Once the drying process has been completed, insulation testing of the motor winding is recommended to determine whether the insulation has been properly reconditioned. If a motor must continue to operate in a damp environment, then special enclosures are necessary to limit the effects of a moist atmosphere.

(c) Inspecting motor windings. Check winding tightness in the slots or on the pole pieces. One condition which hastens winding failure is movement of the coils due to vibration during operation. Check insulation surfaces for cracks, crazing, flaking, powdering, or other evidence of need to renew insulation. Usually under these conditions, when the winding is still tight in the slots, a coat or two of air-drying varnish may restore the insulation to a safe value. Check the winding mechanical supports for insulation quality and tightness, the binding ring on the stator windings, and the glass or wire-wound bands on rotating windings. Examine squirrel-cage rotors for excessive heating or discolored rotor bars which may indicate open circuits or high resistance points between the end rings and rotor bars. The symptoms of such conditions are slowing down under load and reduced starting torque. Repairs to cast aluminum rotors with open bars are not feasible and such rotors have to be replaced. Copper bar rotors can usually be repaired by rebrazing the joints.

(2) *Bearings.* The bearings are the most critical mechanical part of a motor. To assure maximum life, bearings should be subjected to careful inspection at scheduled intervals. The frequency of inspection is best determined by a study of the particular motor operating conditions. Bearings are subject to metal fatigue and will eventually wear out even though they are correctly applied, installed and maintained. Fatigue failures are characterized by flaking of the race surfaces along the ball or roller. Fatigue is a gradual process, which is dependent upon load and speed and usually is made apparent in its early stages by an increase in the operating temperature, vibration or noise level of the bearing. Bearing failures not attributed to fatigue failure are usually classified as premature. The majority of these premature failures are caused by the following: incorrect bearing type; misalignment of the motor or load; misalignment or improperly installed bearing; rusting during storage; preloading or improper end-play adjustment; excessive thrust or radial force; axial indentations; improper lubrication and entrance of contaminants into bearing. Follow manufacturer's instructions and use lubricants as specified. When using greases, store in clean containers, handle with clean paddles or use a grease gun and keep containers covered. Do not overfill bearing housings. Overfilling contributes to heat build-up, damaged seals, leaks and collecting of dirt. Overheating is particularly true of bearings running at high speeds. Machines that are normally idle for long periods should be exercised on a scheduled basis. Exercising will keep the oil circulated, reduce condensation within the housing and lessen the chances of flat spots developing on the bearing races, balls or rollers. Inspect seals and vents regularly. Periodic maintenance services of bearings involves keeping a bearing dry, covered, clean and lubricated as well as checking operating temperature. A clean bearing is particularly critical because dirt means damage. It is therefore important to remember the following when cleaning bearings (fig 4-6):

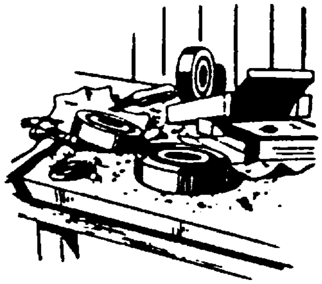
(a) Work with clean tools in clean surroundings. Do not use wooden mallets, dirty, chipped or brittle tools, or work on rough or dirty bench tops.

(b) Remove all dirt from the housing before exposing the bearings and take care to prevent loose dirt from getting into the housing.

KEEP BEARINGS CLEAN

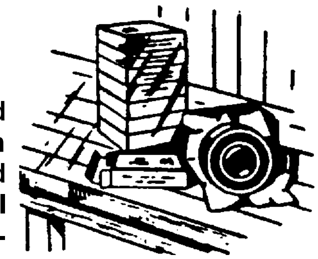
WRONG

New bearings should not be opened and exposed to dirt before they are ready to use.



RIGHT

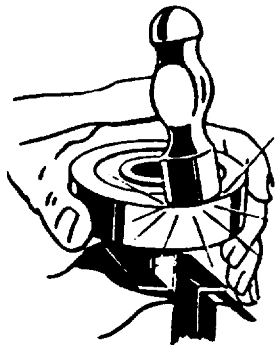
Bearing is opened on a clean bench and is not removed from package until ready to be installed.



INSTALL BEARING PROPERLY

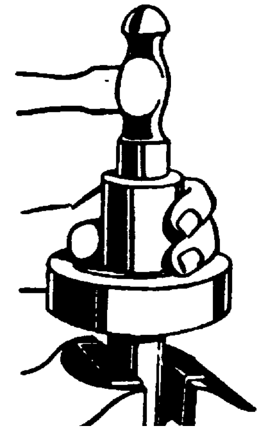
WRONG

Bearing should not be forced on shaft by means of the outer rings. It should not be forced on a badly worn shaft, or a shaft that is too large.



RIGHT

Bearing is proper size for the shaft and is being tapped into place by means of a metal tube that fits against the inner ring.



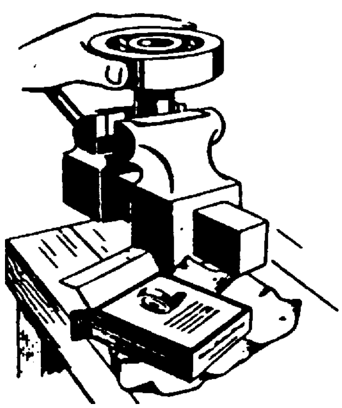
DO NOT TRY TO CLEAN NEW BEARINGS

WRONG

This new bearing does not have to be cleaned. The slushing oil on packed bearings should not be removed.

RIGHT

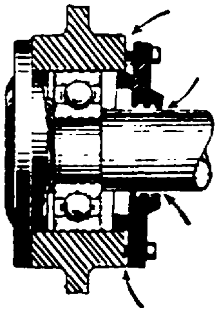
New bearing is removed from container and immediately installed. Packed bearings are already cleaner than you can make them.

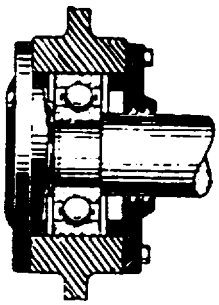


PROTECT OPERATING BEARINGS FROM DIRT

WRONG

Loose bearing covers permit dirt to get into bearing, causing excessive wear and heating.





RIGHT

Protective covers are tight to prevent dirt getting into bearing.

Figure 4-6. Bearing installation precautions.

(c) Handle bearings with clean, dry hands in conjunction with a clean, lint-free rag. This will limit the chance of corrosion due to perspiration.

(d) Handle a reusable bearing as carefully as a new one.

(e) Use approved solvents and oils for flushing and cleaning. Apply fire-preventive precautions if the solvent or oil is flammable.

(f) Lay bearings out on clean paper. Keep bearings wrapped in oil-proof paper when not in use.

(g) Protect disassembled bearings from dirt and moisture.

(h) Do not spin uncleaned bearings. Rotate them slowly while washing. A bearing should not be judged good until inspected after cleaning.

(i) Do not spin any bearing with compressed air

(j) Soak bearings thoroughly in plenty of solvent. Then rinse them in a separate clean container of clean solvent. Once cleaned, inspect the bearing surfaces for nicks or scratches;. broken or cracked rings, separators, balls, or rollers; and discolored, overheated bearings. If the bearing is to be reused in a short time, dip it in rust preventive, wrap in grease-proof paper and store. For longer storage, coat all bearing surfaces with a light protective grease, wrap in grease-proof paper and store.

(k) Clean the inside of the housing before replacing bearings.

(l) Keep bearings in their original carton until ready for use if they are new. Do not wash the oil or grease out of a new bearing. Do not disassemble new bearings.

(m) Install bearings properly after cleaning.

(3) *Ball and roller bearings.* External inspection of ball and roller bearings (fig 4-7) at the time of greasing will determine whether the bearings are operating quietly and without undue heating. Equipped with a grease chamber, they can be very easily overgreased. Overgreasing may be prevented by opening the grease relief plug (fig 4-8) after greasing has been completed and running the motor. When excess grease has drained through the relief plug, secure the plug.

Since ball bearings are often sealed, they require little maintenance but it is very important that the grease be kept clean. This also applies to sealed housings (with the exception of permanently sealed bearings) which should be cleaned and regreased every 2 years or as recommended by the manufacturer. The bearing housings may be opened to check the condition of the bearings and lubricant. If the lubricant must be changed, the bearing and housing parts should be thoroughly cleaned and new lubricant added. Special instructions regarding the type or quantity of lubricant recommended by the manufacturer should be followed. In all cases, standard lubricating practices should be followed.

(4) *Sleeve bearings.* Sleeve bearings (fig 4-9) are most often used in fractional horsepower motors. For older types of sleeve bearings, the oil should be drained, the bearing flushed, and new oil added at least every year. Newer sealed type sleeve bearings require very little attention since the oil level is frequently the only check needed for years of service.

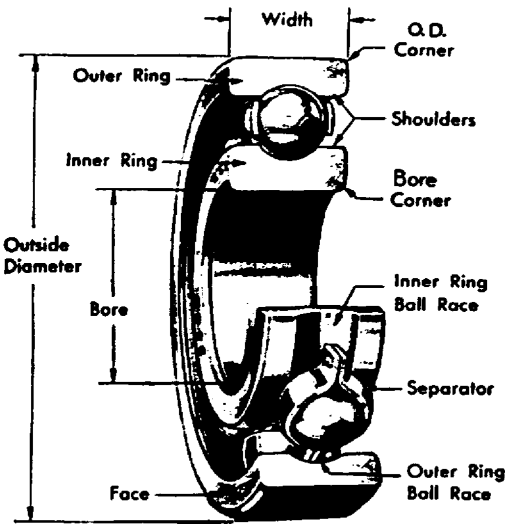
(5) *Insulation.* Failure of insulation is another major factor in motor breakdowns. Few types of insulation failures can be readily repaired. Insulation internal to the motor should be visually checked and defects further investigated. Heat is one of the principal causes of insulation failure in a motor. Make sure that the motor has adequate ventilation and that air openings are not obstructed. Also make sure that the motor is not overloaded which increases operating temperatures. Most motors are equipped with thermal overload devices applied directly to the motor winding which measure increases in temperature. At a predetermined temperature, the overload device will trip and disconnect the motor from the circuit. When an overload device has tripped, the operator should determine the cause of overheating, correct it if possible, and reset the overload before restarting the motor (para 5-4e). An indication of the condition of the insulation can be determined by performing an insulation resistance test (para 4-5).

4-3. Direct current (DC) motors.

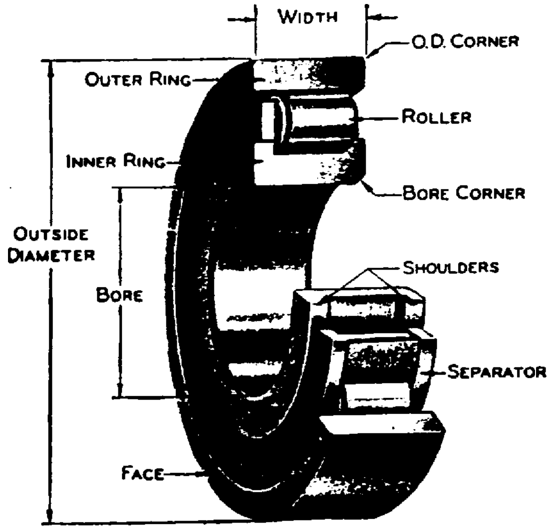
On military installations, DC motors (fig 4-10) are used only if AC voltage is not available or where there is a wide range of speed control desired. The reason for using a DC motor is often solely to achieve speed control. DC motor speed can be varied intentionally by varying the field current on shunt wound motors or by varying the input voltage to either series or shunt motors. DC motors are classified into different types based on the connection of the various windings. Shunt and series are considered the two basic types of motors, as all others are derivatives of the two.

a. Shunt motors. The most widely used type of DC motor is the shunt wound motor. As the name implies, these machines have the armature and field circuits connected in parallel (shunt) to a constant source of voltage (fig 4-11a). While the term “shunt” is still used, relatively few motors are now applied in this way. Shunt motors as now applied have their field circuits excited by a source of power that is separate from the armature source of voltage. The field excitation voltage level is usually the

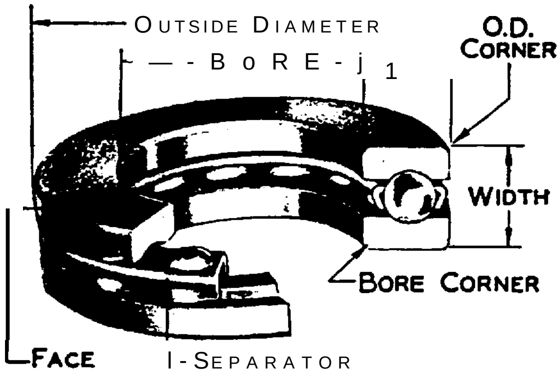
Ball Bearing



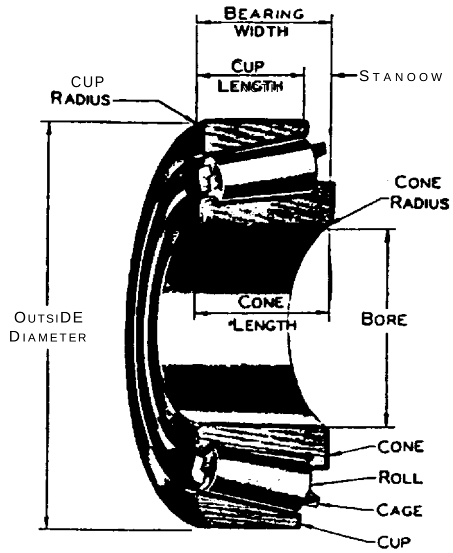
Straight Roller Bearing



Ball Thrust Bearing



Tapered Roller Bearing



Needle Roller Bearing

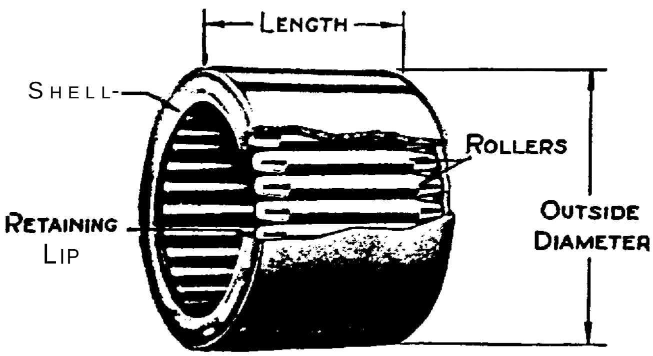


Figure 4-7. Construction of ball and roller bearings,

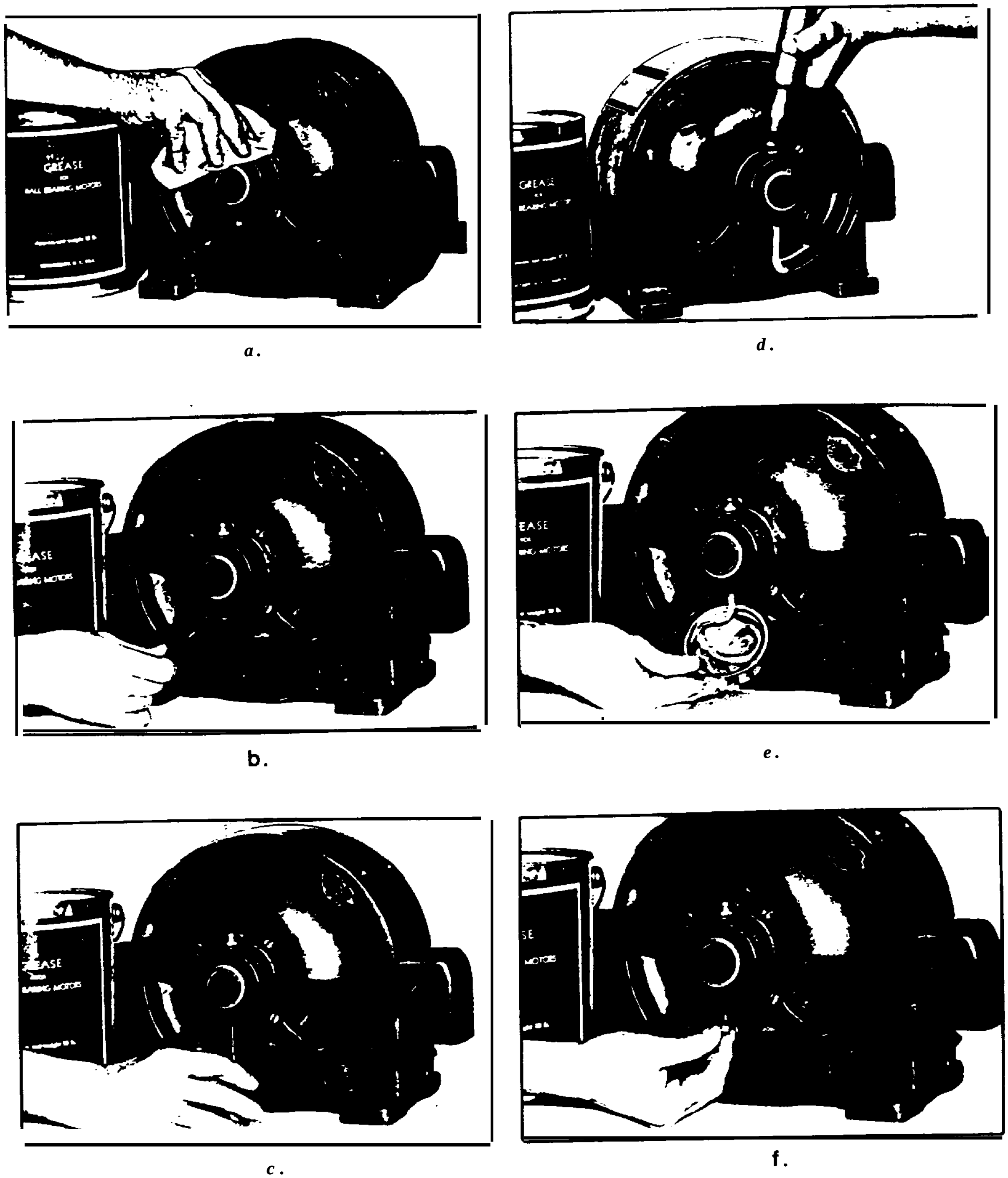


Figure 4-8. Greasing Bearings: a) Wipe away dirt from fitting or plug, b) Remove lower plug, c) Catch any run-out, d) Add new grease, e) Run motor and allow excess grease to escape, f) Install and tighten lower plug.

same as the armature voltage, however, special field voltage ratings of 15 to 600 volts are available for application as a modification. The shunt motor is characterized by its relatively small speed change under changing load.

b. Series motors. As the term implies, series motors have their field windings connected in series with the armature circuit, therefore, it carries full motor current (fig 4-11b). Series connection results in a characteristic whereby motor speed is a function of load. Thus, the series motor is a variable speed motor.

c. *Compound motors.* A motor which is built with both shunt and series fields is termed a compound wound motor (fig 4–11c). By proportioning the relative amounts of series and shunt windings, the designer may shift the motor characteristics to be more nearly shunt or more nearly series in nature.

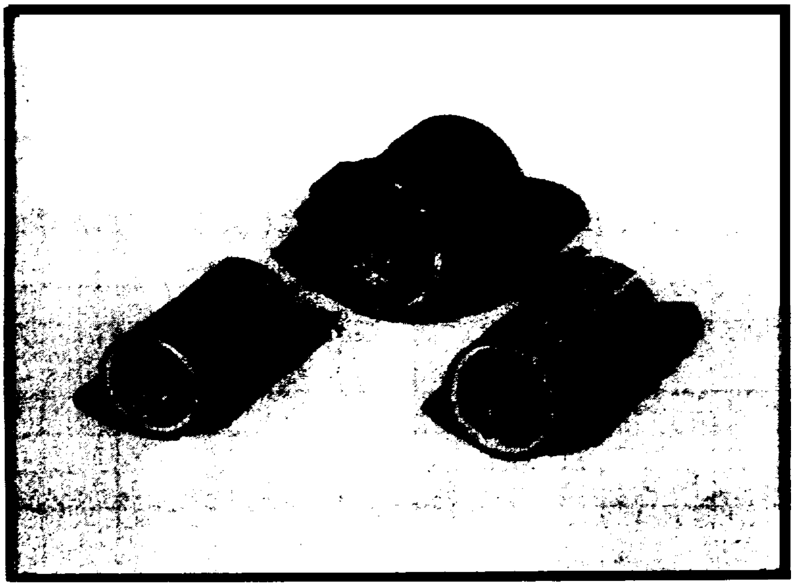


Figure 4-9. Typical sleeve bearings.

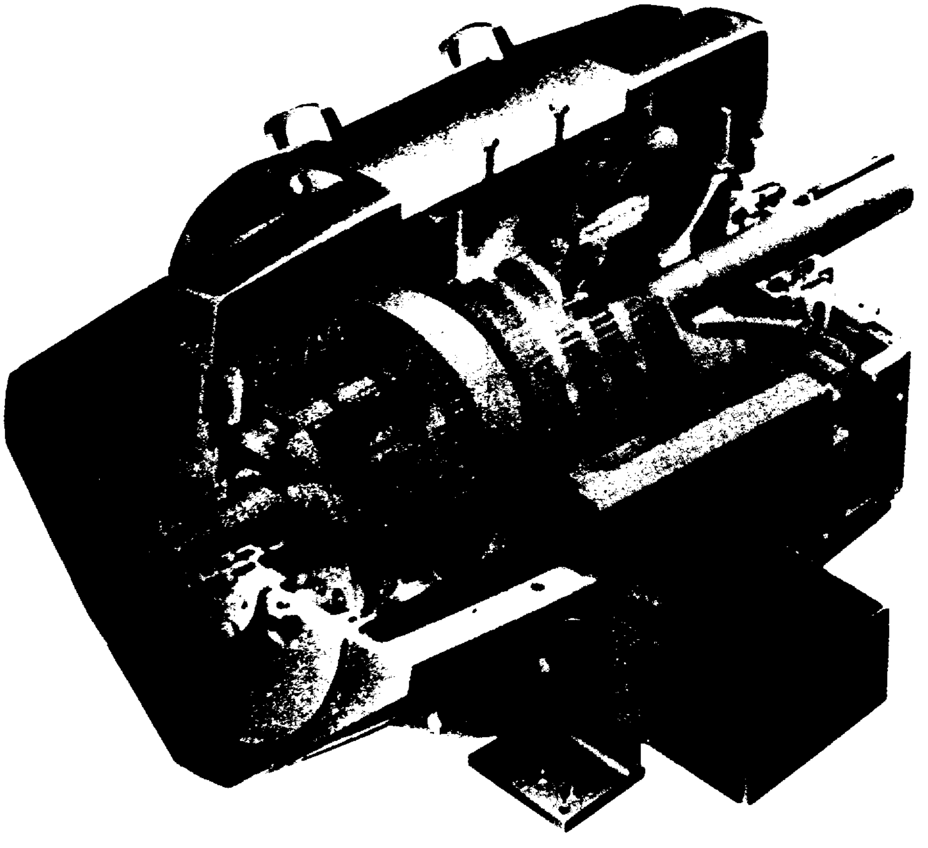
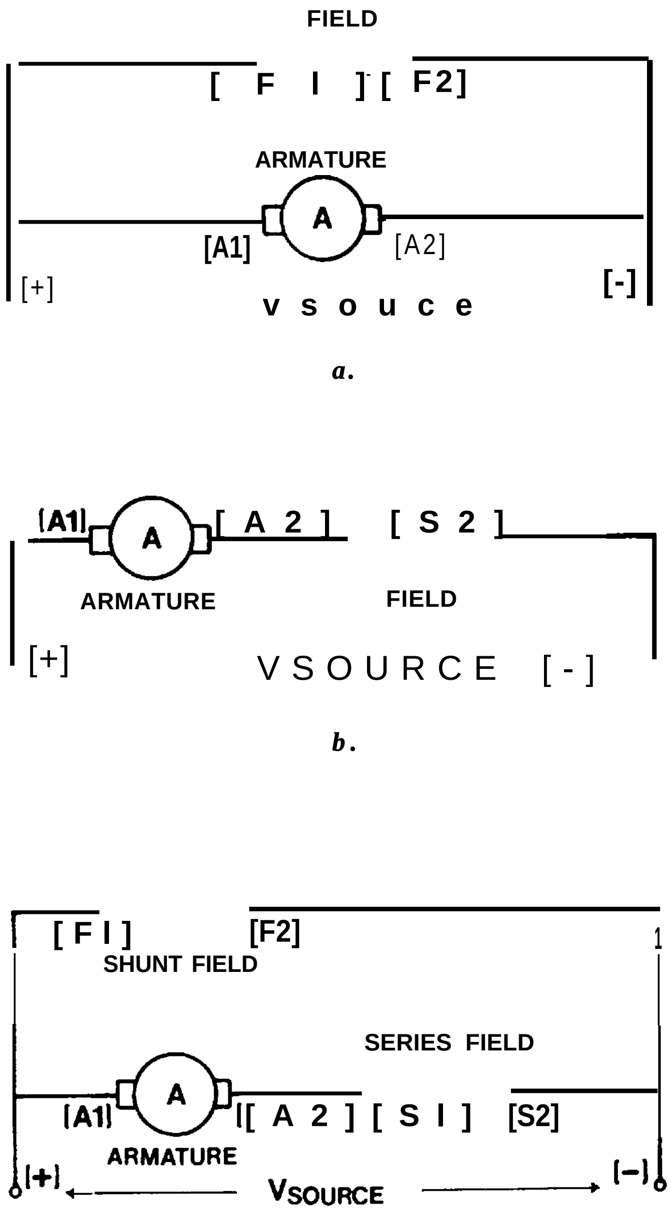


Figure 4–10. Cutaway views of a typical DC motor



c.

Figure 4–11. Main Types and Connections of DC Motors: a) Shunt motor b) Series motor c) Compound motor

d. Components of DC machines. The basic operating and maintenance requirements for DC motors are similar to those for AC motors. There are some special requirements due to the peculiar construction features of the DC motor. The recommendations that follow, particularly those for the armature (fig 4–12), also apply to AC synchronous motors, It is important that the armature be kept clean. Dust, grease, corrosive gases, moisture and oil are particularly harmful.

(1) *Field windings.* The field is made up of a frame with field poles fastened to the frame's inner circumference. The field windings, mounted on laminated steel poles, furnish excitation for the motor. Inspect field winding insulation and determine if they are dirty and oil-soaked. Check for malfunctioning controls which cause excessive field current that can cause excessive heating and failure. Other causes of winding heating are excessive voltage, insufficient speed, off-neutral brushes, overloads and partial short circuit in a field coil. Never run a DC motor with the field circuit open. If the field winding is open-circuited, the motor will fail to start or will operate at excessive speeds at light loads, and excessive sparking will occur at the commutator. Check the insulation resistance of the windings (para 4-5).

(2) *Brushes.* Maintenance and inspection of brushes should be performed regularly to ensure the following (fig 4-13):

(a) Brushes are not loose in their holders. Replace worn brushes. NOTE: Replacement brushes are of several types and grades. Successful motor operation depends upon proper selection of the replacement brush best suited for the service requirements of the motor.

(b) Brushes are not sticking in their holders. Clean brushes and holder.

(c) The tools and/or heels of the brush face are not chipped or cracked. Replace brush if damaged.

(d) Brush shunt leads are properly attached to the brushes and their holders. Replace brush if shunt lead is loose at the brush. Tighten if lead is loose at the holder.

(e) Correct brush tension is maintained. Readjust the brush spring pressure in accordance with the manufacturers' instructions when adjustment is provided. When adjustment is not provided, replace the spring.

(f) Brush holder studs are not loose. Tighten, if loose.

(g) Brushes are not discolored. Brushes should have a highly glazed or very dull finish. Clean the brushes when they become black or grey.

(h) Reset brushes at the correct angle.

(i) Reset brushes in the neutral plane.

(j) Properly space brushes on the commutator to 1/32 inch.

(k) Correctly stagger the brush holders.

(l) Properly space brush holders from the commutator (usually l/16 to 3/16 inch.). If the proper spacing is not maintained, the brushes will ride the surface of the commutator poorly. This is especially applicable to the motor using an inclined brush holder since the brush will be shifted to the neutral position, leading to poor commutation.

(m) Check to ensure that the correct grade of brush, as recommended by the manufacturer, is being used.

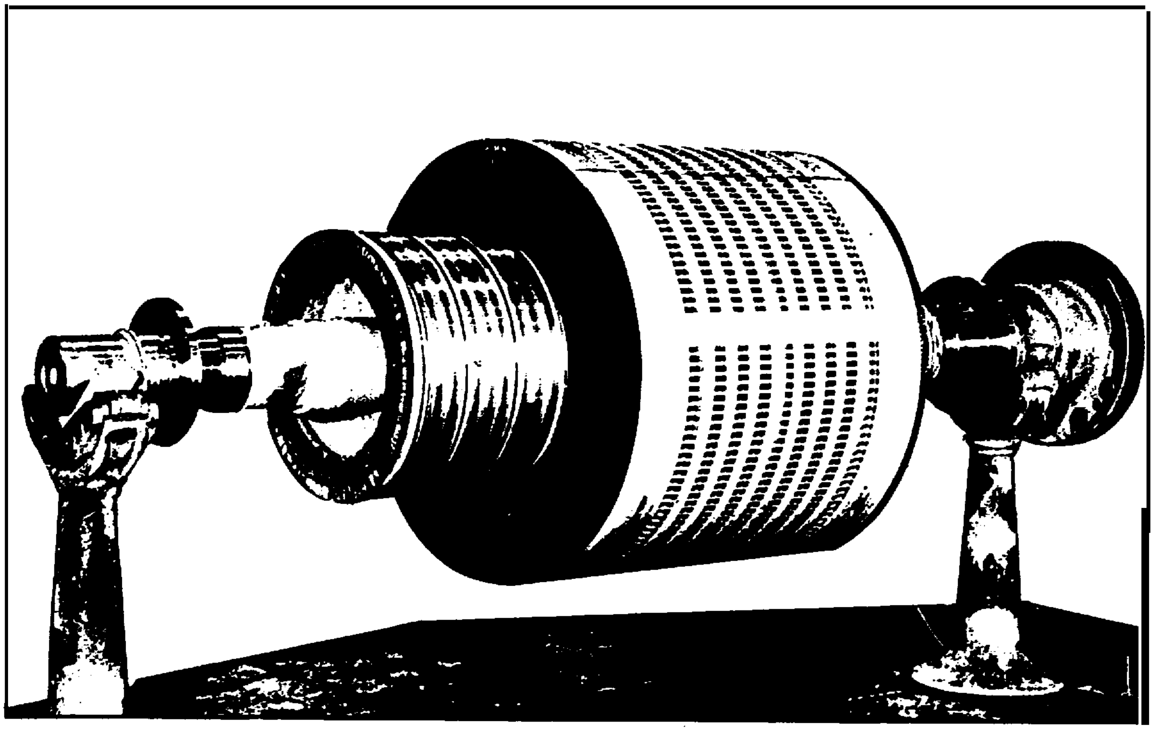


Figure 4-12. Armature of a large DC motor on stands.

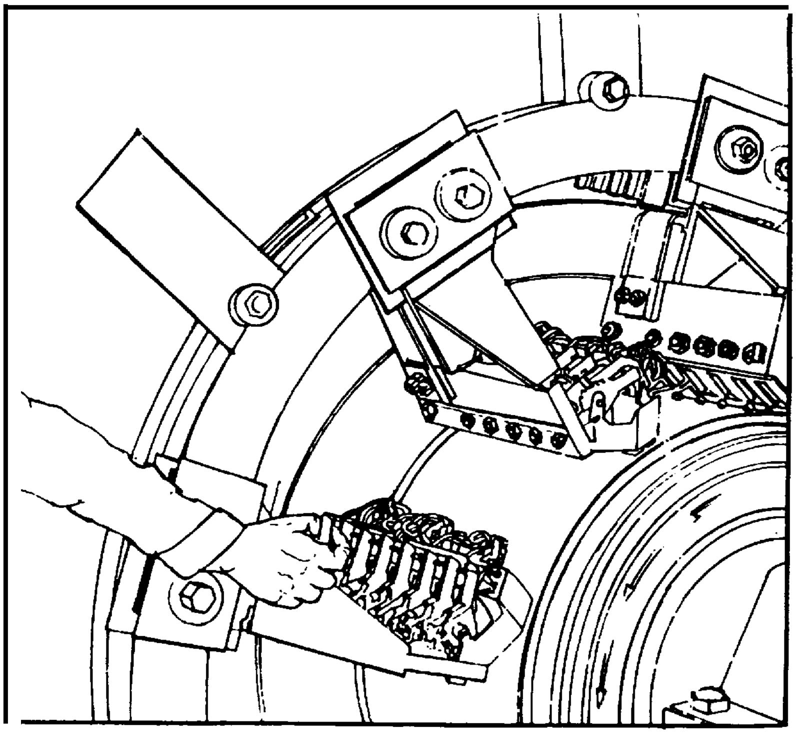


Figure 4-13. Inspecting and installing brushes on a large DC motor.

(3) *Commutators.* A cutaway section of a commutator is shown in figure 4-14. The primary source of unsatisfactory commutation is due to faulty operating conditions. Therefore, the principal maintenance function is that of keeping the commutator surface clean, concentric, smooth, and properly undercut. Surfaces of the commutator bars must be even and free of ridges so that the commutation is concentric, thus allowing any object held against it to react as though it were held against a smooth surface cylinder. Inspection and maintenance methods are as follows:

(a) Check for indication of brush chatter (fig 4-15). Brush chatter is most evident by chipped brushes. This condition results from either a poor commutator surface or high friction between the brush and commutator. High friction is normally caused by operating the motor under a light load, operating the motor under a load that exceeds the commutator's rated capacity for prolonged periods or, film build-up on the commutator. Remedies are: increase the load; reduce the load; and, clean the commutator respectively.

(b) Check for threading or streaking (fig 4-16). Threading or streaking of commutator surfaces is characterized by fine lines inscribed around the commutator. It results when copper particles transfer to the face of the brush. These particles cut through the commutator film, creating areas which carry more than their share of current. They also cause rapid wearing of the brushes and lead to commutator resurfacing. Use of natural graphite brushes, which have cleaning action, cuts down on the formation of film that hinders passing current. Maintenance personnel should check for any evidence of the lack of uniformity in brush action on the commutator surface and film. Evidence of such action should be corrected as soon as possible.

(c) Check for sparking. Sparking often results from poor commutation. This condition may be improved by repositioning the brushes so that they are slightly against rotation. When repositioning the brushes that do not provide better commutation, the commutating-pole air gap must be adjusted.

(d) Check for flashing. Flashing normally results from conditions that cause a sudden change in the field strength of the motor's current or voltage. Flashing can be prevented by frequent checks and elimination of conditions that contribute to short-circuiting.

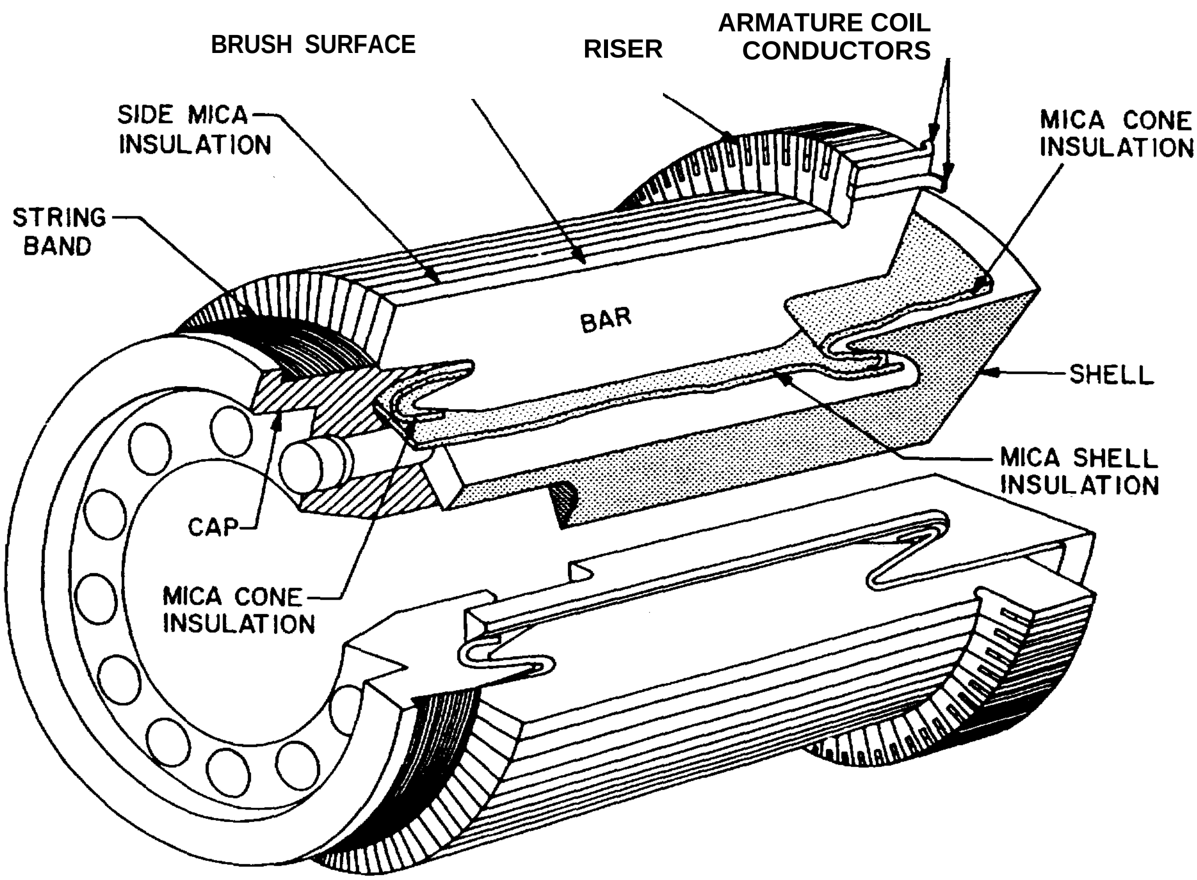


Figure 4-14. Cutaway section of a commutator.

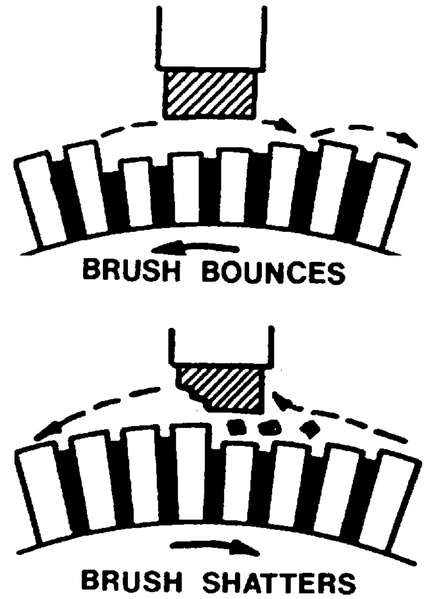


Figure 4-15. Brush "Chatter" Action.

(e) Check film on commutator for even and uniform color (fig 4-17). The color should be between light to dark brown. Clean the commutator as frequently as required to maintain the proper color.

(f) Copper pickup from the commutator surface, indicated when copper fragments become embedded in the brush faces, constitutes a danger signal and, unless corrected, becomes progressively worse. The condition can be corrected by providing proper bar-edge bevelling, sanding the brush faces, and thoroughly blowing out the motor after all other work has been completed.

(g) Check the commutator concentricity with a dial gauge (fig 4-18). A dial reading of .001 inch on high speed machines to several thousandths of an inch on low speed machines can be considered normal. When evidence indicates that the commutator is out of round or eccentric (fig 4-19), it can be restored by grinding" with a grinding rig. While grinding, vacuum frequently to prevent copper and stone grindings from getting into the windings. Grinding should be performed only by experienced personnel when the proper tools are available.

(h) After grinding the commutator, the mica insulation separating the copper segments must be undercut (fig 4-20). Bevel the edges of the bar and clean the commutator slots. Bevelling eliminates the sharp edge under the brush at the entering side. Again, follow the manufacturer's instructions in this repair function. Do not attempt this operation unless proper tools, instruments, and qualified personnel are available.

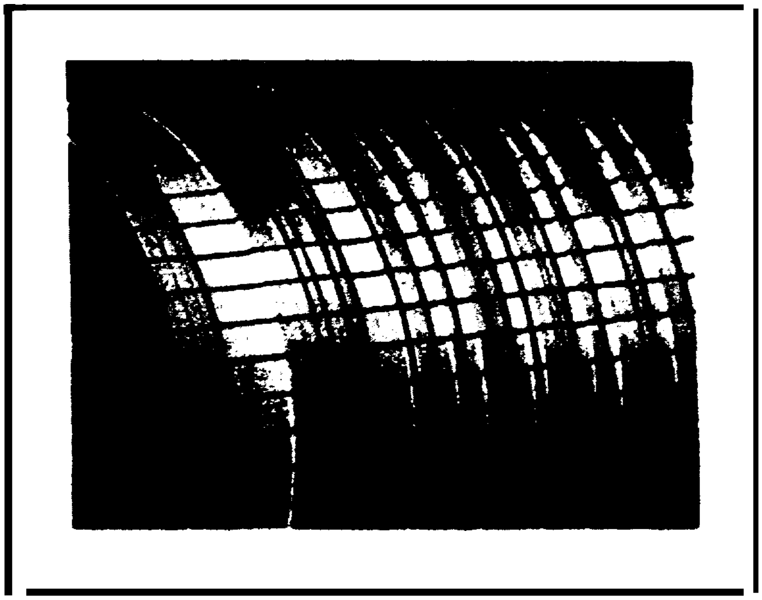
(i) After conditioning a commutator, ensure that it is clean of traces of copper, carbon, or other dust.

4-4. Motor operating considerations.

Often problems that cause motor breakdown and premature failure can be traced to inadequate consideration of operation and application of the motor. To enhance motor operation and improve longevity consider application, type of motor, horsepower, speed, voltage rating and environmental conditions (table 4-1). The following paragraphs reiterate the major causes of motor failures.

a. Dirt. Dirt can: plug ventilating spaces, interfering with proper cooling; glaze the faces of commutator brushes, resulting in harmfiul sparking; blanket windings, interfering with heat radiation and causing dangerous temperature rises; build into a hazard of shorting or grounding, if metallic particles are present and, cause complete motor breakdown.

b. Dust. In open-type motors, use every possible means of keeping out dust. Under no condition should dust be allowed to come in contact with the bearings. Keep the oil-fill caps closed at all times; maintain the dust seals and gaskets in good condition and replace them when worn. Keep plenty of clean rags available for wiping off the motor housings, cleaning commutators and removing dust from wound sections. Vacuum loose dirt within the motor. If vacuum cleaning is not effective, blow out the windings with dry compressed air at a pressure not



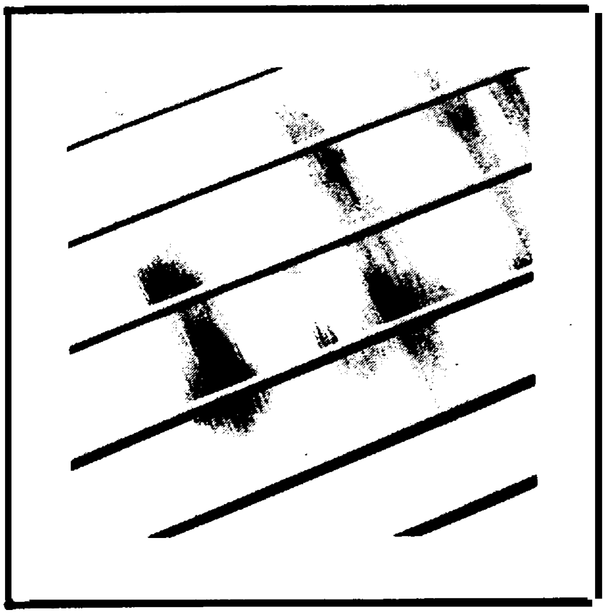
a.

b.

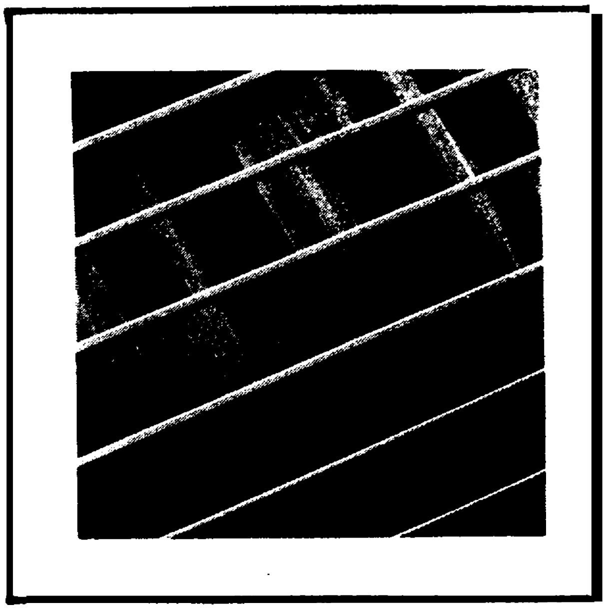
Figure 4-16. Poor Commutator Conditions: a) "Threading", b) "Streaking".

to exceed 30 psi. Greater pressure may loosen the insulation and blow dirt under it. If blowing or vacuuming will not remove accumulated dirt, use solvents as recommended by the motor manufacturer.

c. Moisture. Moisture soaks into and softens winding insulation until it is no longer adequate as an insulator. When moisture gets inside a motor, it unites with dirt to form a sticky mass. This mass absorbs acid fumes and alkali fumes present in the air. These fumes quickly change the mass into an active destructive agent and a conductor of leakage currents. Moisture preventive measures are simple and therefore will not be discussed in detail. However, close attention to good housekeeping methods is necessary. Open-type motors should not be exposed to intrusion of water from drip or splatter. Standby motors should be run for a short time at least once a week to guard against moisture condensation during periods of idleness. Before using an



a.



b.

Figure 4-17. Good Commutator Films: a) A light, mottled surface, b) Heavy film of nearly uniform color.

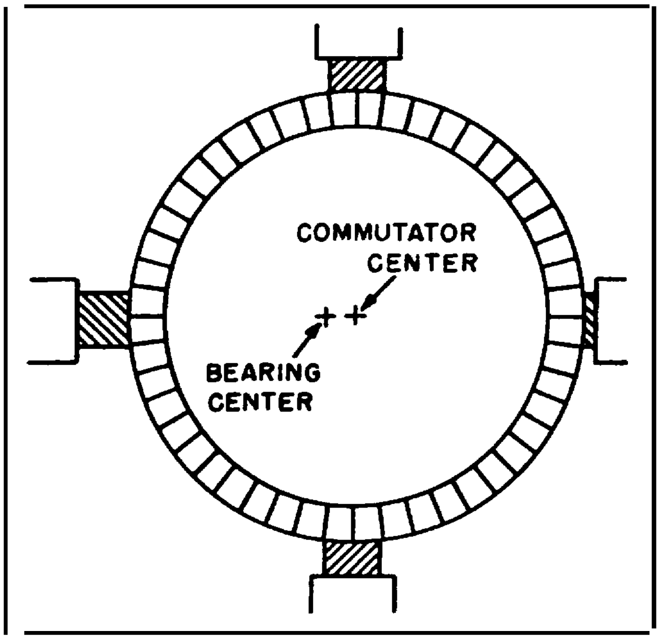


Figure 4-18. Example of eccentric commutator.

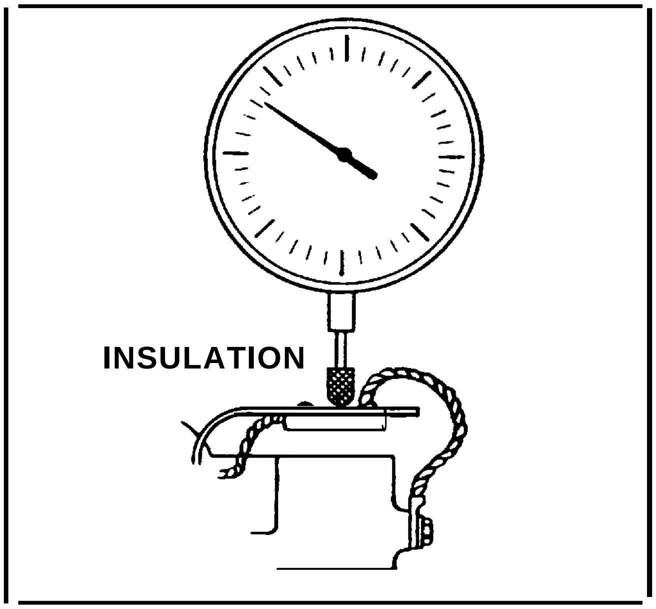


Figure 4-19. Dial gauge to measure commutator concentricity.

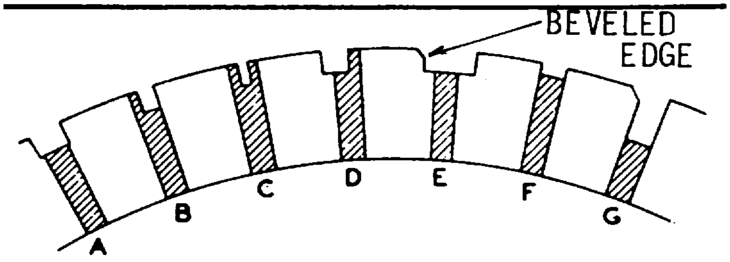
air line to blow out motor windings, first check to be sure that water has not condensed in the line.

d. Friction. Many motors fail because of excessive friction. Oil in sleeve bearings adheres to the shaft and is dragged along by rotation, forming a lubricating film that prevents friction. It is important to use the right oil at the right time and not too much. Follow the manufacturer's instructions. Do not add new oil while the motor is running since it is easy to add too much. Check the oil while the motor is stopped and, if required, add oil to the full level. Excess oil is apt to leak into the motor and cause damage such as:

(1) Deteriorate the mica-insulating segments between commutator bars.

(2) Foul the commutator bars.

(3) Soak windings to the point where rewinding may be the only way to prevent burnout breakdown of the motor.



A. MICA PROPERLY UNDERCUT.
B. UNDERCUTTING TOOL TOO NARROW, LEAVING FIN AT ONE SIDE OF SLOT.
C. UNDERCUTTING TOOL VERY NARROW, LEAVING FINS AT BOTH SIDES OF SLOT.
D. SLOT IMPROPERLY INDEXED. PART OF BAR CUT AWAY AND FIN OF MICA LEFT.
E. TOOL TOO WIDE. PART OF BAR CUT AWAY.
F. UNDERCUTTING T00 SHALLOW. SERVICE LIFE SHORTENS BEFORE NEXT UNDERCUTTING.
G. UNDERCUTTING TOO DEEP. POCKET COLLECTS CARBON AND COPPER DUST, SHORT-CIRCUITING BARS.

Figure 4-20. Common undercutting mistakes.

e. Installation. One of the most important antifriction precautions for motors with ball or roller bearings is to ascertain that the bearings are properly installed. The inner race should be tight enough on the shaft to rotate with it, but not so tight as to cause frictional distortion. Ball or roller bearings are normally lubricated with grease, and as in the case of oil lubricants mentioned above, apply grease in accordance with the manufacture's instructions.

f. Vibration. Excessive vibration can loosen various parts, break electrical connections, crystallize portions of the metallic structure and contribute to an increase in frictional wear. Checks should be made regularly to identify conditions that contribute to vibration such as misalignment, settling of the foundation, heavy floor loading, and excessive bearing wear particularly when records indicate frequent motor failures. Check to determine whether vibration in the driven machine is being transmitted to the motor. Check that the motor is properly applied for a particular load. Check for excessive belt or chain tension. The trouble may lie in the push-apart effect inherent in spur gears. Check for motor-shaft oscillation resulting from a loose bearing. Check for loose motor-mounting bolts.

g. Applied voltages. For general purpose applications, a range of five percent under to five percent over the nameplate voltage may be applied with satisfactory results. A motor with a nameplate rating of 230 volts will give reasonable performance on: 220, 230 and 240-V systems. A motor with a single voltage rating of 230V will probably overheat if run on 208V. Most manufacturers recognize this problem and build extra capacity into the windings to give a dual or triple voltage rating on the nameplate, that is: 208/230/240 volts. There are some cases where motors fail due to low voltage. If a given motor is fully loaded or slightly overloaded, it will operate within its temperature limits for normal voltages. For voltages 90 percent and less of the nameplate rating, the same motor will severely overheat. The motor will fail if the low voltage condition is applied for long periods of time. The important thing to remember is that, in the example given above, a fully loaded motor must have 100 percent of its nameplate conditions in order to deliver 100 percent of its capacity. A motor that only needs to deliver 80 percent of its nameplate horsepower rating will most likely survive a prolonged low voltage condition resulting in a somewhat higher than normal temperature. This is sometimes referred to as "service factor". Motor performance guarantee is based on its nameplate rating and not the system nominal voltage. The relationship between the nominal and nameplate rating is shown in table 4-2.

h. Choice. There is usually some choice in the substitution of voltages for the motors and applications shown in table 4-2. It is not necessary to

Table 4-2. Nameplate voltage ratings of standard induction motors.

Nominal System Voltage	ANSI/NEMA MG1-1978 Nameplate Voltage
Single-phase rotors	
120	115
240	230
Three-phase motors	
208	200
240	230
480	460
600	575
2400	2300
4160	4000
4800	4600
6900	6600
13,800	13,200

(a) From ANSI/IEEE Std. 141-1984

"special order" rewinding repairs or replacements for general purpose work. There are some cases where substitution cannot be used. An exact voltage replacement should be ordered if:

(1) The motor is known to be delivering 100 percent or more, continuously.

(2) Motor has a duty rating other than "continuous" or "24 hours".

(3) Motor is marked, "special purpose", or "severe duty" on nameplate.

(4) A non-standard voltage is shown and no horsepower rating is given.

4-5. Motor insulation testing.

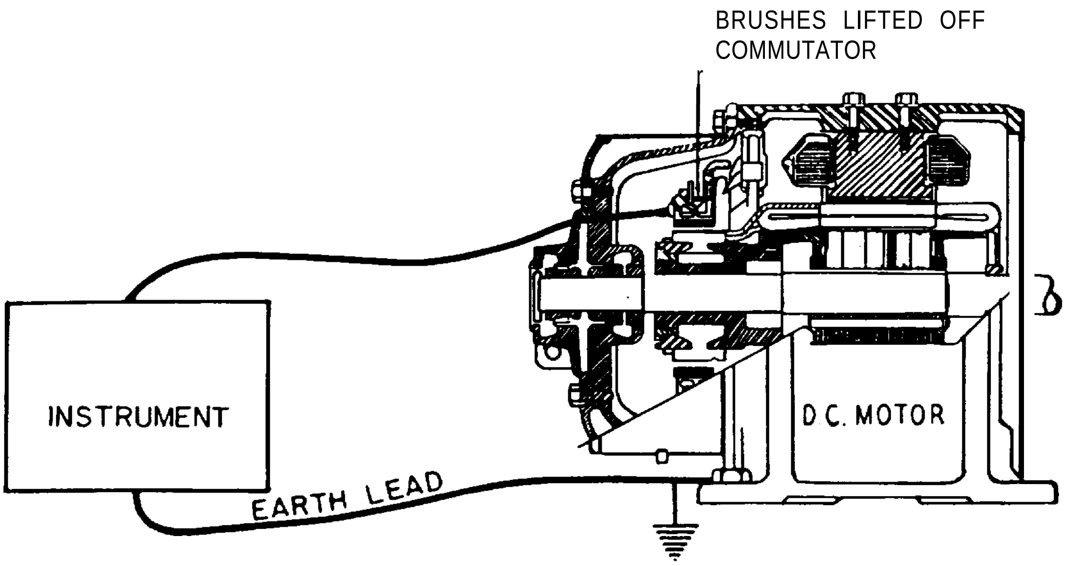
The electrical test most often conducted to determine the quality of low voltage motor armature and winding insulation is the insulation resistance test. There are other tests available to determine the quality of motor insulation, but they are not recommended for low voltage motor testing because they are generally too complex or destructive. An insulation resistance test should be conducted on rotating machinery immediately following their shutdown when the windings are still hot and dry. A megohmmeter (para 13–4) is the recommended test equipment. It should be applied to armature and rotating or stationary field windings. Before testing the motor insulation, de-energize the circuit. Then disconnect any potentially low insulation sources, such as lightning arresters, capacitors and other voltage sources. Lead-in cables or busses and line-side circuit breakers or starters can be tested as a part of the circuit provided a satisfactory reading is obtained. Motor test connections for AC and DC motors are shown in figure 4-21. If the insulation resistance is below the established minimum, the circuit components should be tested separately to isolate the source of low impedance. All data should be recorded and compared to previous periodic readings. Any persistent downward trend is an indication of insulation trouble even though the values may be higher than the recommended minimum acceptance values which are:

AC and DC motor (250V or less) 500,000 OHMS

AC and DC motor (1OOOV or less) 1 MEGOHM

4-6. Motor trouble-shooting.

Tables 4-3, 4-4 and 4-5 provide detailed data on troubleshooting motor breakdowns. Motor troubles along with their probable cause(s) and recommended maintenance or corrective actions are also given.



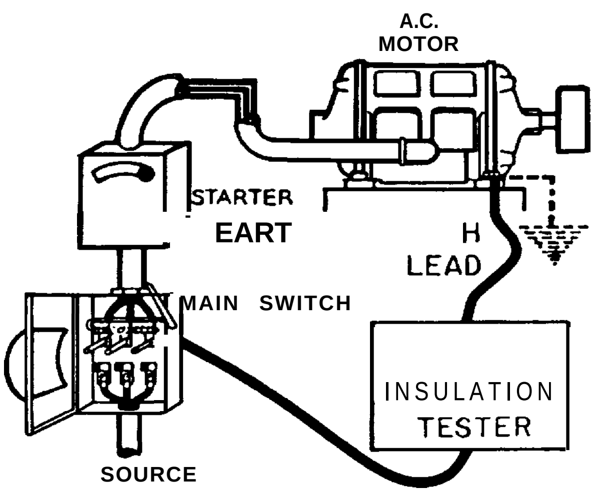


Figure 4-21. Connections for Testing Motor Insulation Resistance: a) (Top) connections for a DC motor b) (Bottom) connections for an AC motor.

Table 4-3. AC induction motor trouble-shooting.

Trouble	Probable Cause	Maintenance
Motor will not start	Overload Control Trip	Wait for overload to cool. Try starting again. If motor still does not start, check, all the causes as outlined below.
	Power not connected to motor.	Connect power to control, check control sequence and power to motor.
		Check Connections.
		Test fuses and circuit breakers.
	Faulty (Open) fuses.	Check motor-nameplate values with power supply. Also check voltage at motor terminals with motor under load to be sure wire size is adequate.
	Low voltage.	
		Check connections with control wiring diagram.
	Wrong conrol connections.	Tighten Connections.
	Loose Terminal- lead connction.	Disconnect motor from load. If rotor starts satisfactorily, check driven machine.
	Driven machine Locked.	Check for open circuits.
	Open Circuit in stator or rotor windi ng.	Check for shorted coil.
		Test for grounded winding.
	Short circuit in stator winding.	Free bearings or replace.
		Use special lubricant for special conditions
	Winding grounded.	Troubleshoot the control
	Bearing Stiff.	Reduce Load
	Grease too stiff.	Isolate and discharge capacitor check impedance. If opened or shorted, replace.
	Faulty control.	Stop motor, than try to start. It will not start on single phase.
	Overload.	
	Failed starter capacitor.	Check for "open" in one of the lines or circuits.
		Check current balance.
Motor noisy.	Motor running single phase.	Check aligment and condition of belt. On pedestal-mounted bearing, check cord play and axial centering of rotor.
	Electrical load unbalanced.	
	Shaft bumping (sleeve-bearing motors).	

Table 4-3. AC induction motor trouble-shooting-continued

Trouble	Probable Cause	Maintenance
Motor vibrates.	Vibration from unbalanced or misalignment	Balance or align machine.
	Possible mechanical system resonance.	Remove motor from load. If motor is still noisy, rebalance motor.
	Air gap not uniform.	Center the rotor and if necessary replace bearings.
	Noisy ball bearings.	Check lubricants. Replace bearings if noise is persistent and excessive.
	Loose punchings or loose rotor on shaft.	Tighten all holdings bolts.
	Rotor rubbing on stator.	Center the rotor and replace bearings if necessary.
	Objects caught between fan and end shields.	Disassemble motor end clean it. Any rubbish around motor should be removed.
	Motor loose on foundation.	Tighten holding-down bolts. Motor may possibly have to be realigned.
	Coupling loose.	Check coupling joint. Check alignment. Tighten coupling.
At higher than normal temperature or smoking.	Overload.	Measure motor Loading with watt-meter. Reduce toad.
	Electrical Load unbalanced.	Check for voltage unbalance or single phasing.
	Fuse blown, faulty, control, etc.	Check for "open" in one of the lines or circuits.
	Restricted ventitation	Clean air passages and windings.
	Incorrect Voltage and frequency	Check motor-nameptate values with power supply. Also check voltage at motor terminals with motor under full load.
	Motor stalled by driven machine or by tight bearings.	Remove power from motor. Check machine for cause of stalling.
	Stator winding sorted.	Use insulation testing procedures.
	Stator winding grounded.	Use insulation testing procedures.

Table 4-3. AC induction motor trouble-shooting-continued.

Trouble	Probable Cause	Maintenance
At higher than normal temperature or smoking (Cont'd)	Rotor winding with Loose connections.	Tighten, if possible, or replace with another rotor.
	Belt too tight.	Remove excessive pressure on bearings.
	Motor used for rapid reversing service.	Replace with motor designed for this service.
Bearings Hot	End shields loose or not replaced properly.	Make sure end shieds fit squarely and are properly.
	Excessive belt tension or excessive gear side thrust.	Reduce belt tension or gear pressure end realign shafts. See that thrust is nott being transferred to motor bearing.
	Bent shaft.	Straighten Shaft.
Sleeve Bearings hot.	Insufficient oil.	Add oil - if oil supply is very low - drain, flush and refill.
	Foreign material in oil or poor grade of oil.	Drain oil, flush, and relubricate using industrial lubricant recommend by a reliable oil company.
	Oil rings rotating slowly or not rotating at all.	Oil too heavy; drain and replace. Oil ring has work spot; replace with new ring.
	Motor titled too far.	Level motor or reduce tilt and realign, if necessary.
	Rings bent or otherwise damaged in reassembling.	Replace rings.
	Ring out of slot (oil ring retaining clip out of place).	Adjust or replace retaining clip.
	Defective bearings or rough shaft.	Replace bearings. Resurface shaft.
Ball bearings hot.	Too much grease	Remove relief plug and let motor run. If excess grease doe not come out, flush and relubricate.
	Wrong grade of grease	Add proper grease
	Insufficient grease.	Remove relief plug and regrease bearing.
	Foreign material in grease	Flush bearings, relubricate; make sure that grease supply is clean. (Keep covered when not in use).
	Bearings misaligned	Align motor and check bearing-housing assembly. See that races are exactly 90 degrees with shaft.

Table 4-3. AC indution motor trouble-shooting-continued.

Trouble	Probable Cause	Maintenance
Ball bearings hot (cont'd.)	Bearings damaged (corrosion, etc.)	Replace bearings.
	Coupling loose.	Check coupling joint. Check alignment. Tighten coupling.
Wound rotor motor troubles		
Motor runs at low speed with external resistance cut out.	Wires to control too small.	Use larger cable to control.
	Control too far from motor.	Bring control nearer motor.
	Open circuit in rotor circuit (including cable to control).	Test to find open circuit and repair.
	Brushes sparking.	Check for looseness, overload, or dirt.
	Dirt between brush and ring.	Clean rings and insulation assembly.
	Brushes stuck in holders.	Use right size brush, clean holders.
	Incorrect brush tension.	Clean brush tension and correct.
	Rough collector rings.	Sand and polish.
	Eccentric rings.	Turn in lathe or use portable tool to true up rings without disassembling motor.
Excessive vibration and noise.	Open rotor circuit.	Correct open connectons or control.
	Current density of brushes too high (overload).	Reduce load. (If brushes have been replaced, make sure they are of the same grade as originally furnished.
	Ring threading	Low current density. Consult manufacturer for different brush recommendation.
Motor will not start	Faulty Connection.	Inspect for open or poor connect ion.
	Open circuit one phase.	Test, locate and repair.
	Short circuit one phase.	Open and repair.
	Voltage falls too low.	Reduce the impedance of the external circuit.

Table 4-3. AC induction motor trouble-shooting--continued.

Trouble	Probable Cause	Maintenance
Motor will not start (cont 'd)	Friction high	Make sure bearings are properly lubricated.
		Check bearing tightness.
		Check belt tension.
		Check load friction.
		check alignment.
	Field excited.	Be sure field-applying contactor is open and field-discharge contractor is closed through discharge resistance.
	Load too great.	Remove part of load
	Automatic field relay not working.	Check power supply to solenoid.
		Check contractor tips.
		Check connections.
	Wrong direction of rotation.	Reverse any two main leads of 3-phase motor.
		Single-phase, reverse starting winding leads.
Motor will not come up to speed.	Excessive load.	Decrease the load.
		Check operation of unloading device (if any) on driven machine.
	Low voltage.	Increase voltage.
	Field excited.	Be sure field-applying contactor is open, and field-discharge contactor is closed through discharge resistance.
Fails to pull into step.	No field exc itation.	Check circuit connections. Be sure field applying contactor is operating.
		Check for open circuit in field or exciter.
		Check exciter output.
		Check rheostat.
		Set rheostat to give rated field current when field is applied.
		Check contacts of s witches.

Table 4-3. AC induction motor trouble-shooting-continued.

Trouble	Probable Cause	Maintenance
Fails to pull into step (cont'd).	Load excessive	Reduce load
		Check operation of loading device (if any) on driven machine.
	Inertia of load excessive.	May be a misapplication - consult manufacturer.
Motor pulls out of step or trips breaker.	Exciter voltage low.	Increase excitation.
		Examine exciter as shown in D. C. motors. Check field ammeter and its shunt to be sure reading is not higher than actual current.
	Open circuit in field and exciter circuit.	Locate and repair break.
	Short circuit in field.	Check with low voltage and polarity indicator and repair field.
	Reversed field spool.	Check with low voltage and polarity indicator and reverse incorrect leads.
	Load fluctuates widely.	See motor "hunts", below.
	Excessive torque peak.	Check driven machine for bad adjustment, or consult motor manufacturer.
	Power fails.	Re-establish power circuit.
	Line voltage too low.	Increase if possible. Raise excitation.
Motor "hunts".	Fluctuating load.	Correct excessive torque peak at driven machine or consult rotor manufacturer.
		If driven machine is a compressor check valve operations.
		Increase or decrease flywheel size.
		Try decreasing or increasing motor field current.
Stator overheats in spots .	Rotor not centered.	Realign and shim stator or bearings.
	Open phase.	Check connections and correct.
	Unbalanced currents.	Loose connections; improper internal connections.
Field overheats.	Short circuit in a field coil.	Replace or repair.
	Excessive field current.	Reduce excitation until field current is at nameplate value.

Table 4-3. AC induction motor trouble-shooting-continued.

Trouble	Probable Cause	Maintenance
All parts overheat (cont'd).	Overload	Reduce load or increase motor size.
		Check friction and belt tension or alignment.
	Over or under excitation.	Adjust excitation to nameplate rating.
	NO field excitation.	Check circuit and exciter.
	Improper voltage.	See that nameplate voltage is applied.
	Improper ventilation	Remove any obstruction and clear out dirt.
	Excessive rooms temperature.	Supply cooler air.

Table 4-4. AC synchronous motor trouble-shooting.

Trouble	Probable Cause	Maintenance
Motor will not start.	Faulty connection.	Inspect for open or poor correction.
	Open circuit one phase.	Test, locate and repair.
	Short Circuit one phase.	open and repair.
	Voltage falls too low.	Reduce the impedance of the external circuit.
	Friction high.	Make sure bearings are properly lubricated.
		Check bearing tightness.
		Check belt tension.
		Check load friction.
		Check alignment.
	Field excited.	Be sure field-applying contactor is open and field-discharge contactor is closed through discharge resistance.
	Load too great.	Remove part of load.
	Automatic field relay not working.	Check power supply to solenoid.
		Check contactor tips.
		Check connections.
	Wrong direction of rotation	Reverse any two main leads of 3-phase motor.
		Single-phase, reverse starting winding leads.
Motor will not come up to speed.	Excessive load.	Decrease the load.
		Check operation of unloading device (if any) on driven machine
	Low voltage	Increase voltage.
		Be sure field-applying contactor is open, and field-discharge contactor is closed through discharge resistance.

Table 4-4. AC synchronous motor trouble-shooting-continued.

Trouble	Probable Cause	Maintenance
Fails to pull into step.	No field excitation.	Check circuit connections. Be sure field-applying contactor is operating.
		Check for open circuit in field or exciter.
		Check exciter output.
		Check rheostat.
		Set rheostat to give rated field currant when field is applied.
		Check contacts of switches.
	Load excessive.	Reduce load
		Check operation of reloading device (if any) on driven machine.
	Inertia of load excessive.	May be misapplication - consult manufacturer.
Motor pulls out of step or trips breaker.	Exciter voltage low.	Increase excitation.
		Examine exciter as shown in D. C. motors. Check field ammeter and its shunt to be sure reading is not higher than actual currant.
	Open circuit in field and exciter circuit	Locate and repair break.
	Short circuit in field.	Check with low voltage and polarity indicator and repair field.
	Reversed field spool.	Check with low voltage and polarity indicator and reverse incorrect leads.
	Load fluctuates widely.	See motor "hunts" below.
	Excessive torque peak.	Check driven machine for bad adjustment, or consult motor manufacturer.
	Power fails.	Re-establish power circuit.
	Line voltage too low.	Increase if possible, raise excitation.

Table 4-4 AC synchronous motor trouble-shooting-continued.

Trouble	Probable Cause	Maintenance
Motor "hunts".	Fluctuating load.	Correct excessive torque peak at driven machines or consult motor manufacturer.
		If driven machine is a compressor check value operations.
		Increase or decrease flywheel size.
		Try decreasing or increasing motor field current.
Stator overheats in spots.	Rotor not centered.	Realign and shim stator or bearings.
	Open phase.	Check connections and correct.
	Unbalanced currents.	Loose connections: improper internal connections.
Field overheats.	Short circuit in a field coil.	Replace or repair.
	Excessive field current.	Redutce excitation until field current is at nameplate value.
All parts overheat.	Overload	Reduce load or increase motor size.
		Check friction end belt tension or aligment.
	Over or under excitation.	Adjust excitation to nameplate rating.
	NO field excitation.	Check circuit and exciter.
	Improper voltage.	See that nameplate voltage is applied.
	Improper ventilatiion.	Remove any obstruction and clean out dirt.
	Excessive room temperature.	Supply cooler air.

Table 4-5. DC motor or generator trouble-shooting.

Trouble	Probable Cause	Maintenance
Motor will not start.	Open circuit in control.	Check control for open in starting circuit, open contacts, fuse or breaker.
	Low terminal voltage.	Check voltage with nameplate rating.
	Bearing frozen.	Recondition shaft and replace bearing.
	Overload.	Reduce load or use larger motor.
	Excessive friction.	Check lubricaton in bearings to make sure that the oil has been replaced after installing motor.
		Disconnect motor from driven machine, and turn rotor by hand to see if trouble is in motor.
		Strip and reassemble motor; then check part by part for proper location and fit.
		Straighten or replace bent or spring shaft (machines under 5 hp).
	Brushes not down on commtator.	Held up by brush springs, need replacement.
	Brushes worn out.	Replace brushes.
	Brushes stuck in holders.	Remove and sand, clean up brush boxes.
	Power may be off.	Check line connectons to starter with light.
		Check contacts in starter.
Motor starts, then stops and reverses direction of rotation.	Reverse polarity of generator that supplies power.	Check generating unit for cause of changing polarity.
	Shunt and series fields are bucking each other.	Reconnect either the shunt or series field in order to correct the polarity. Then connect armature leads for desired direction of rotation. The fields can be tried separately to determine the direction of rotation individually and connected so that both give same rotation.