TM 55-405

WAR DEPARTMENT TECHNICAL MANUAL

PREVENTIVE MAINTENANCE OF ELECTRIC MOTORS AND GENERATORS

WAR DEPARTMENT • SEPTEMBER 1945

WAR DEPARTMENT TECHNICAL MANUAL
TM 55-405

PREVENTIVE MAINTENANCE OF
ELECTRIC MOTORS AND GENERATORS

WAR DEPARTMENT • SEPTEMBER 1945

United States Government Printing Office
Washington : 1945

WAR DEPARTMENT
Washington 25, D. C., 11 September 1945

TM 55-405, Preventive Maintenance of Electric Motors and Generators, is published for the information and guidance of all concerned.

[AG 300.7 (8 Dec. 44)].

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL
Chief of Staff

OFFICIAL:
EDWARD F. WITSELL
Major General
Acting The Adjutant General

DISTRIBUTION:

AAF (2); ASF (2); T of Opn (2); S Div ASF (1); Tech Sv (2); PE (10); Sub PE (3); Dep 55 (5); USMA (2); T/O-E, 55-500 (BA) (3); Two (2) copies to the following, 55-37, 55-47, 55-100-1, 55-110-1, 55-120-1, 55-202, 55-225, 55-228, 55-235, 55-236, 55-237, 55-260, 55-302, 55-500 (HB), (HC).

Refer to FM 21-6 for explanation of distribution formula.

CONTENTS

SECTION I

INTRODUCTION

1. Purpose and Scope

It is the purpose of this manual to provide fundamental information necessary for effective maintenance of electric motors and generators by using organizations. The treatment is general and intended to apply, more or less, to all types and sizes of these machines. Operation and care of controllers and control accessories have not been considered in this manual, but are the subject of a companion volume, TM 55-410 (when published). Pertinent theory is covered in detail in TM 1-455. For instructions pertaining specifically to automotive applications, reference should be made to TM 9-1825A and TM 9-1825B.

2. Basic Principle

All types of motors and corresponding generators have many elements in common, for which, item for item, maintenance activities are fairly uniform. Insulated windings, brushes, collector rings, commutators, and bearings can be considered independently of the specific types of machines in which they are used. The same is true of external inspection and of general precautions in disassembly and assembly. The importance of periodic, systematic inspection and maintenance of motors and generators cannot be minimized, not only because of the possibility of break-down of these machines, but also because of the danger of impairing the general operation of the major end items. (See figs. 1, 2 and 3.) Lack of preventive maintenance of motors and generators will interfere seriously with radio reception on marine craft and rolling stock.

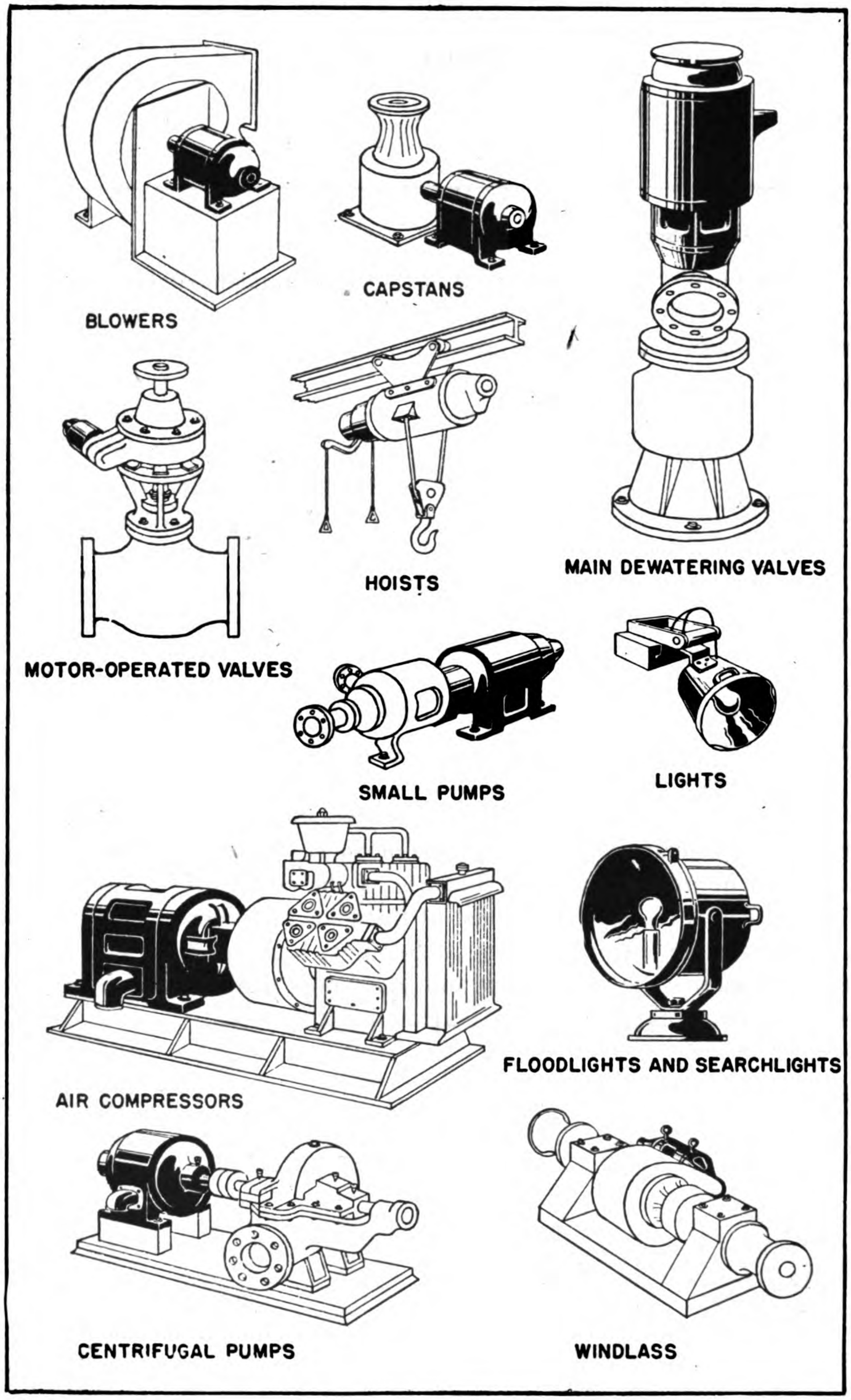


Figure 1. Motor and generator applications.

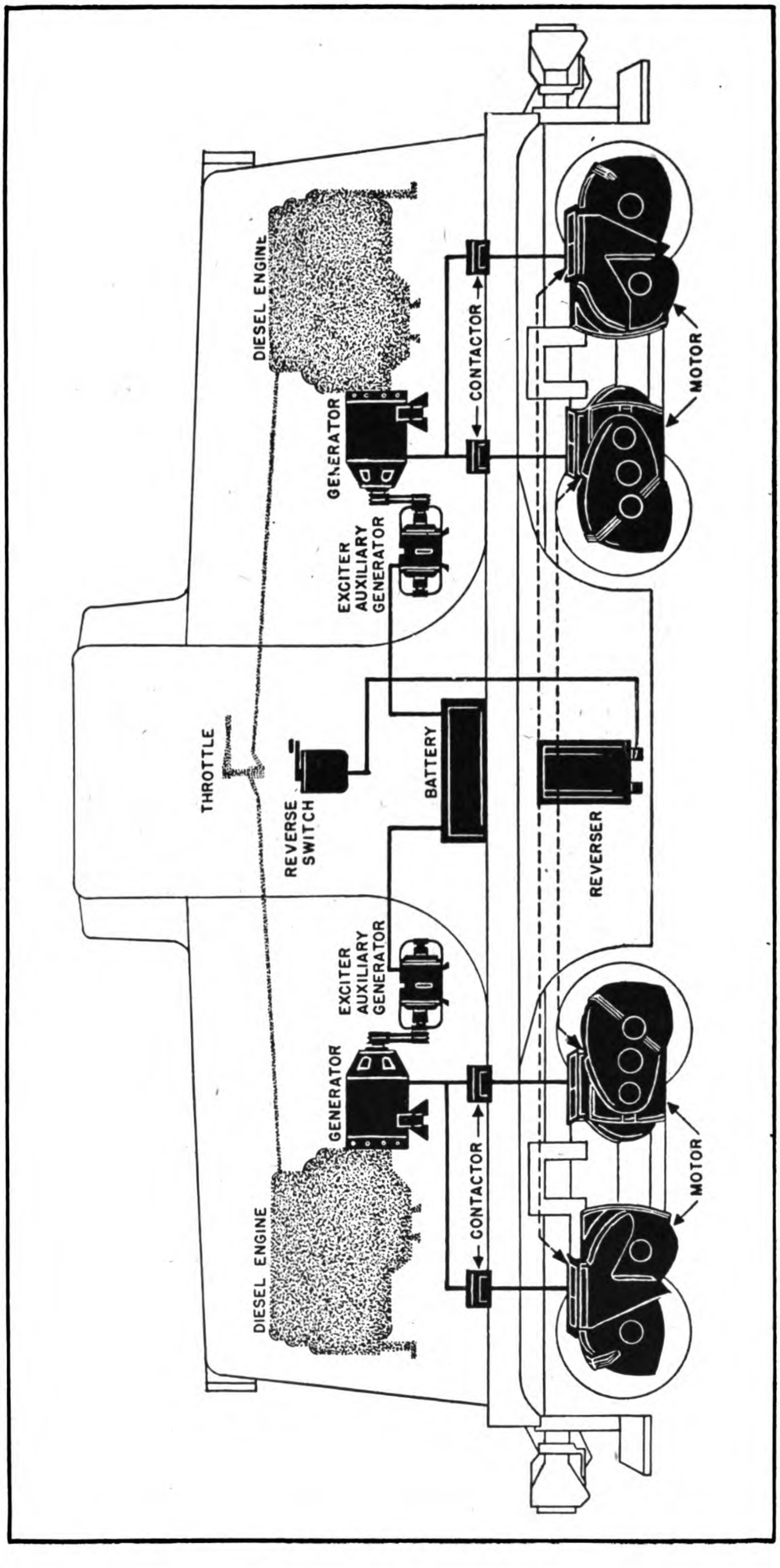


Figure 2. Sources of mechanical and electrical energy—Diesel-electric locomotive.

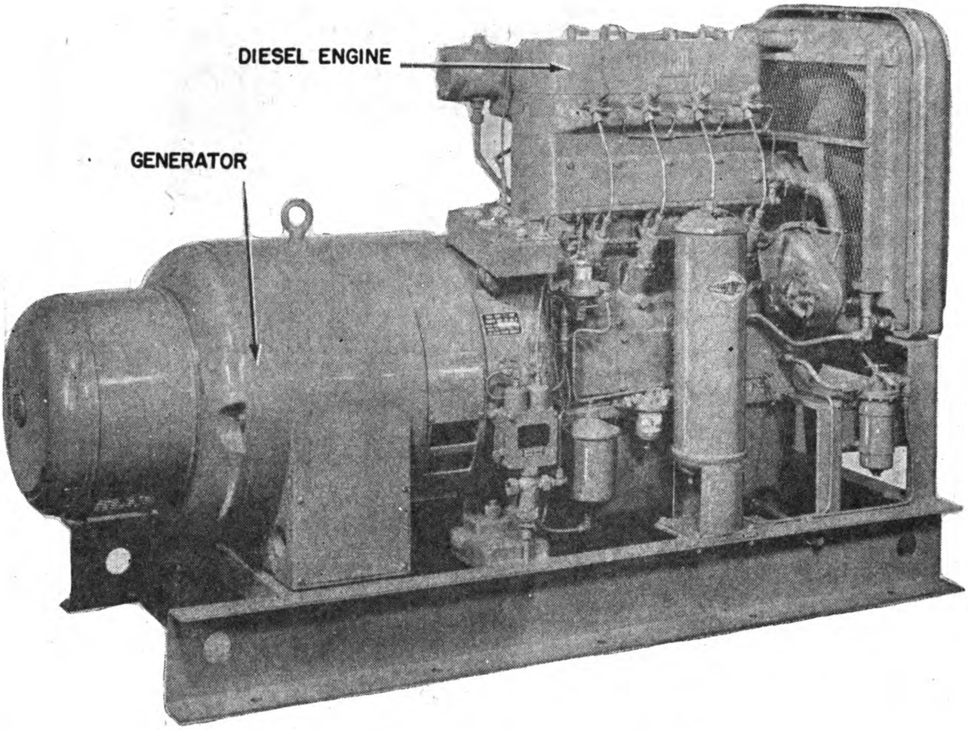


Figure 3. Diesel-engine generator unit.

SECTION II

FIRST ECHELON MAINTENANCE

3. General

First echelon maintenance (TM 37-250) of motors and generators is primarily a matter of proper operation. Starting devices are relatively simple, and after a motor or generator is in operation there is little to be done unless the operator sees, hears, feels, or smells something unusual. If unusual performance of any kind is noted, it is generally the responsibility of the operator to stop the equipment, if needed, and to take such action as he is authorized to take, or to report the condition through channels.

4. Starting Devices and Controls

a. SIMPLE SWITCHES. The simplest type of motor starter is a knife switch. Fuses provide short-circuit protection. There are also snap switches that flip up and down, "on" and "off". To these are added heater coils which provide overload protection. Both of the above types of starters are applied generally to the starting and stopping of fractional horsepower motors, although the snap-switch type is employed also with motors of relatively high horsepower ratings.

b. CONTROLLERS FOR D-C MOTORS. Direct-current motors must be rather small to risk starting directly across the line, because of the danger of the high starting current burning the brushes and commutator. For this reason a manually-operated rheostat may be provided. This controller has an arm that moves across a row of buttons and is held in place at the end of the swing by a magnet coil. When the voltage goes too low for safety, the magnet coil releases and the arm slides back to the "off" position. Such protection is called low-voltage protection. Sometimes these manual rheostats are further supplied with a disconnecting switch of the knife type, a relay to give overload protection, or fuses for short-circuit protection. High-powered direct-current motors are started by means of controllers that have several steps of resistors, with short-circuiting contactors to cut out the blocks of resistance in a given time lag. The responsibility of the operator is minimized; about all he has to do is press a button.

c. CONTROLLERS FOR A-C MOTORS. Controllers for alternating current motors are generally of the magnetic across-the-line type that start with a push button. The usual protection afforded consists of under-voltage and overload protection. Short-circuit protection may or may not be included in individual controllers, depending upon usage. In many cases group circuits are protected with circuit breakers. High-powered alternating-current auxiliary drives resort to the use of a transformer for reducing the voltage at the start, instead of resistors as in the case of direct current. Such reduced-voltage, transformer type controllers are frequently called compensator starters, or auto-starters. One, two, or three steps are provided depending upon the rating of the equipment involved. The higher the rating, the greater the number of steps, as a general rule.

d. GENERATOR CONTROLS. Several devices, such as the cut-out, current regulator, and voltage regulator are used to control the generator. Once they have been set, they are automatic and require practically no attention or adjustment by the operator.

5. Basic Rules of Maintenance

If the following rules are carefully observed, the operator will fulfill his major responsibility for preventive maintenance of motors and generators:

a. Keep the equipment and its surroundings clean and dry. Inspect for drippings of water or other liquid; for dirt; for obstructions to proper ventilation; and for tools or other objects that may jam moving parts. (See figs. 4 and 5.)

b. Make sure that the equipment has been properly lubricated. Lubrication according to War Department Lubrication Orders or manufacturer's instructions may be a responsibility of some individual other than the operator. In such a case it is the function of the operator to ascertain that the equipment has been lubricated according to schedule. (See sec. XII.)

c. Know what loads the apparatus can carry. Prevention of over-loads is fundamental to good operation. On the other hand, with light or no loads, the speed of series-wound D-C motors may become dangerously high. Consequently, such motors never should be run without load. When the load is light, they should be operated only under close supervision.

d. Do not overwork starting motors or subject any motor to extremely frequent starting. Excessive heat will be developed and serious damage may result. Thus, because of the high compression and the speed of cranking necessary to start a diesel engine, an enormous amount of heat is generated in the starting motor, and cranking should not be continued longer than 30 seconds without allowing two-minute intervals for the starting motor to cool.

e. Never operate direct-current generators on an open circuit dis-

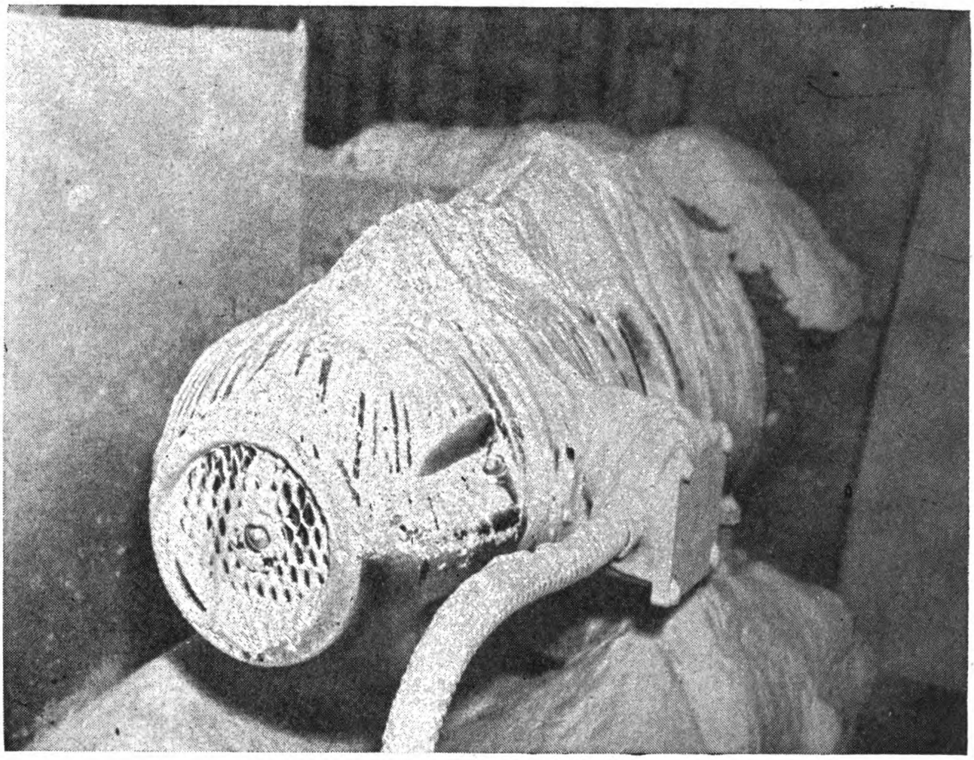


Figure 4. Result of failure to clean motor regularly.

connected from the battery. To do so will allow it to build up such a dangerously high voltage that generator failure and other damage may result.

f. For best results, operate induction motors at their normal voltage and frequency (this information is included on the motor nameplate). Some variation from normal is allowable, the voltage limits being approximately (±) 10 percent and the frequency limits (±) 5 percent. The voltage and frequency should never be varied simultaneously in opposite directions, and both should not be varied at the same time to the extreme limits allowed. With any variation of either the voltage or the frequency from normal conditions, the following changes from normal operating characteristics must be expected:

Effects of Variation of Voltage or Frequency

Condition	Power Factor*	Torque**	Slip**	Full load efficiency
High Voltage	Decreased	Increased	Decreased	Slightly higher
Low voltage	Increased	Decreased	Increased	Slightly lower
High frequency	Increased	Decreased	Same	Approx. same
Low frequency	Decreased	Increased	Same	Approx. same

* See p[illegible] 2 *a*, app. III.
** See par. 84, app. VII.
*** See par. 77, app. VII.

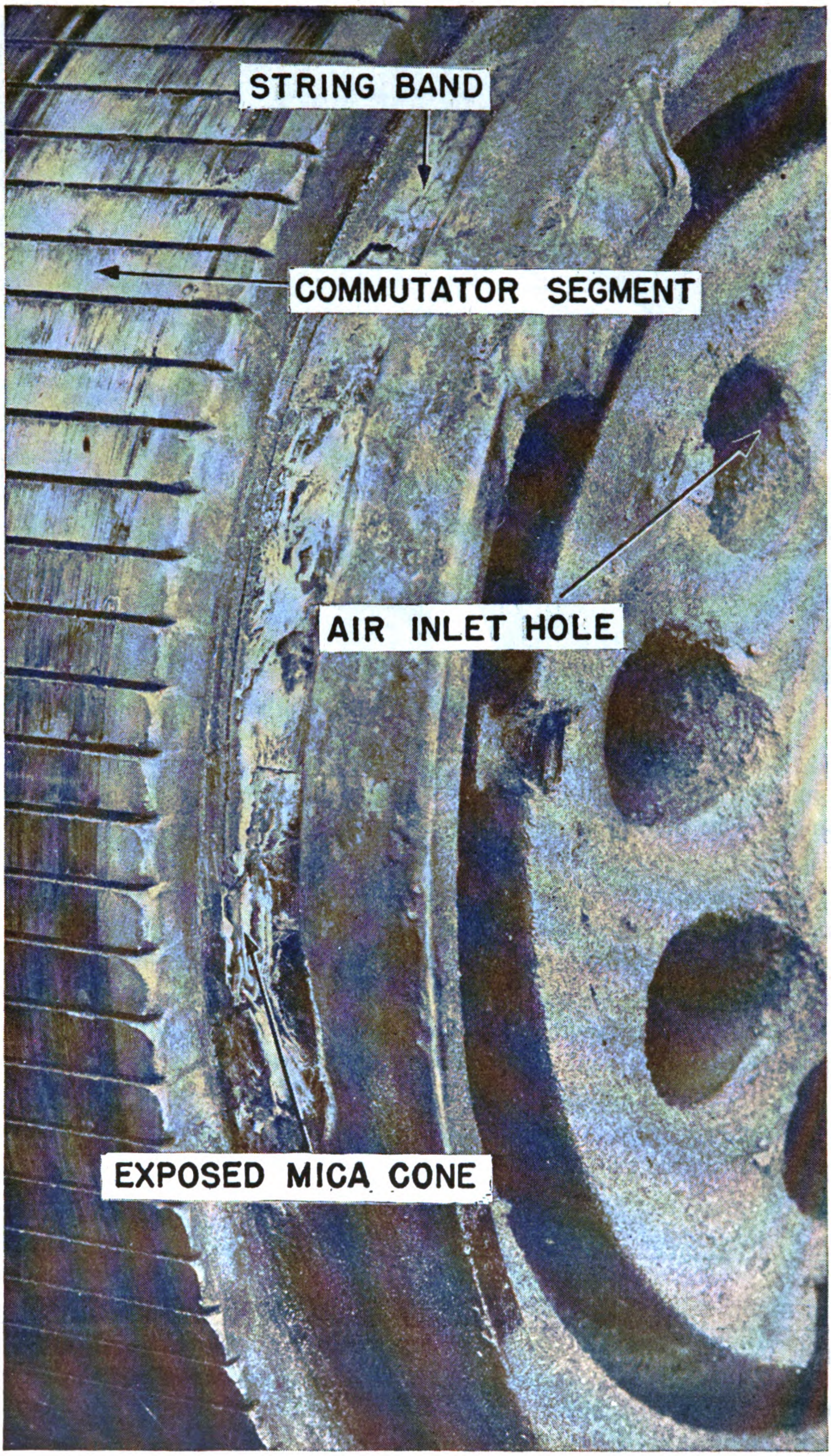


Figure 5. Results of grease and dirt accumulation: obstruction of the air-inlet holes, creepage failure, charring, burning through of the string band, exposure of the mica cone, and scoring of the commutator.

6. Preventive Maintenance Schedule

a. Before-operation Check. (1) *Exterior and surroundings.* Remove objects that may fall and jam moving parts; remove obstructions to proper ventilation; wipe dirt off exterior; make sure that there is no dripping water or other liquid in the vicinity and that exterior is dry.

(2) *Wiring and connections.* Check all accessible wiring and connections to see that they are clean and secure.

(3) *Lubrication.* Make sure that the equipment has been lubricated according to schedule sec. XII) and is not over-lubricated. Examine for grease or oil leakage.

b. During-operation Check. (1) *Starting speed.* See that the machine comes up to proper speed when power is applied. Report failure to do so.

(2) *Noise.* Note any unusual noise caused by metal-to-metal contact resulting from misalignment or other conditions; stop operation as soon as possible and report any such noise.

(3) *Odor.* Watch for odor from scorching insulation varnish; stop operation as soon as possible and report any such odor.

(4) *Sparks.* Observe any brush sparking, chatter, or hissing. If noted, stop operation for checking and adjustment of brush-spring pressure, spacing, and angle of brushes.

(5) *Vibration and heat.* Feel bearing housings for vibration and overheating; report if noted.

c. After-operation Check. (1) *Performance.* Investigate or report all abnormalities noticed during operation.

(2) *Wiring and connections.* Check all accessible wiring and connections to see that they are clean and secure.

(3) *Lubrication.* Examine for leakage. Lubricate as needed in accordance with instructions on the pertinent WDLO.

(4) *Exterior and surroundings.* Clean surroundings and wipe exterior of equipment with a dry cloth. Make sure equipment is securely mounted.

7. Efficiency in Operation of Auxiliary Motors

An operator should know not only how to start, stop, and properly care for an auxiliary motor, but also how to use it efficiently. For example, a centrifugal pump working against a frictional head and driven by a direct-current motor, in which the speed is varied by means of a field rheostat, presents an ideal arrangement for saving power and fuel, *depending on the operating situation.* The power of such pumps varies as the cube of the speed, the head as the square of the speed, and the delivery in direct ratio to the speed. This means that by reducing the speed from 100 percent to 80 percent, the gallons delivered will be reduced to 80 percent, the pressure from 100 percent to 64 percent, and the horsepower from 100 percent to 51.2 percent. Likewise, when the speed is reduced one-half, the power drops down to 12.5 percent. If the same centrifugal pump were driven by a single-speed alternating-current motor, the problem would be quite different. In such a case, the only way to save power would be to throttle the driven auxiliary. Centrifugal pumps consume less power when the valve on the delivery side is throttled than when it is wide-open. The saving is not as great as when the number of revolutions is varied, but it still may be appreciable. Where two- and four-speed alternating-current motors are used, the saving in horsepower corresponds to that which is saved with direct-current motors for a like speed change. A speed combination of 1800/1200 rpm on an A-c motor results in a reduction in delivery to 66⅔ percent, a pressure reduction of 44½ percent, and a power reduction of approximately 30 percent. Fans and blowers have about the same characteristics as centrifugal pumps; if provided with two-speed motors, they should be operated at the lower speed, *when possible*, in order to save power.

SECTION III

SECOND ECHELON MAINTENANCE

8. Scope

Second echelon maintenance of motors and generators includes servicing of the equipment (cleaning, lubrication, and adjustment), emergency repairs, and replacement of minor assemblies. Repairs and replacements beyond the scope of the using organization must be reported for action by a higher echelon.

9. Schedule

In general, second echelon responsibilities will be fulfilled if the following schedule is carried out regularly. The type of machine will determine whether or not any of the items listed (for example, collector rings) are to be omitted from the inspection, and any special services added. Size of the motor or generator and availability of maintenance equipment and of technically qualified personnel will determine, under normal operating conditions, whether a second echelon service (such as turning a commutator) is to be performed by the using organization or by a maintenance organization. In the schedule below, the symbols under the heading "When To Inspect" refer to periods of inspection and service, as follows:

W—Weekly.
M—Monthly.
S—Semiannually.

These periods may be modified somewhat by the extent of use of a motor or generator. Idle equipment should be given a test operation monthly, and inspected accordingly

Preventive maintenance schedule

When to inspect	What to inspect	What to look for	What to do	For detailed information see par.
W-M-S	Brushes.	(1) Wear to the extent that the copper lead connection is in danger of coming in contact with the commutator, or to a point where further wear may cause restriction of brush movement.	Replace.	18
M-S		(2) Damage (chipped toes or heels; heat cracks).	Replace.	18
M-S		(3) Proper pressure.	Adjust.	16
S		(4) Proper brush spacing.	Adjust.	19
S		(5) Correct angle.	Adjust.	14
S		(6) Good fit with commutator surfaces.	Sandpaper.	15
W-M-S	Commutators.	(1) Discoloration of dirt.	Clean.	23
		(2) High bars; high mica; scratches or roughness; eccentricity.	True or grind; in extreme cases, turning in a lathe is necessary and condition should be reported.	24
		(3) Broken or loose bars.	Report.	
		(4) Loose leads from rotor winding to commutator.	Tighten.	
W-M-S	Windings and connections.	(1) Dust and dirt.	Wipe off with dry cloth; if necessary, clean surfaces and ventilation passages by suction or mild blowing.	30
W-M-S		(2) Oil or grease near or on windings.	Clean with carbon tetrachloride in a well-ventilated room.	30
W-M-S		(3) Moisture on or near windings.	Dry by hand and report.	31
M-S		(4) Looseness of windings and of field spools on poles.	Report.	

When to inspect	What to inspect	What to look for	What to do	For detailed information see par.
M-S		(5) Loose connections, including field connections (shunt and series), line connections, and place where copper is bolted to brush-holder bracket.	Tighten.	33
S		(6) Dry cracks on insulation surfaces and other evidence of need for coating of insulating material.	Report.	
S		(7)	Test insulation resistance.	35
M-S	Collector rings.	(1) Accumulation of brush carbon and metal dust (from the rings) on insulation, ring to staff and studs (or leads) to rings.	Brush off and wash with carbon tetrachloride.	27
S		(2) Eccentricity.	True up the ring with a portable tool; in extreme cases report the condition.	28
S		(3)	Check insulation resistance, ring to shaft and studs (or leads) to rings; report cracked or otherwise defective bushings and collars.	26 and 35
W-M-S	Bearings.	(1)	*Lubricate as required*	57-63
M-S		(2) (Ball bearings) defects.	Report or replace.	41-42
		(3) (Sleeve-bearings) war and end play.	*a.* Report or replace.	41 and 43
			b. Measure air gap to determine sleeve-bearing wear.	43
M-S	Bearing housings.	(1) Grease or oil leaks.	Trace and correct or report.	
M		(2) (Sleeve-bearings) dirt or sludge in oil well.	Clean out and refill.	47 and 58
S		(3) (Ball-bearings)	Clean out and refill.	45 and 59

When to inspect	What to inspect	What to look for	What to do	For detailed information see par.
S		(4) (Waste-packed and wick-oiled sleeve-bearings) glazed or dirty waste or wicks.	Renew waste or wicks, making sure new waste bears well against shaft.	
W-M-S	Ventilating cooling system.	(1) Obstruction in air ducts or passages.	Clean.	
M-S		(2) Loose fan blades (if fan blades are not cast in place).	Tighten.	
M-S	Inclosed gears.	Bad oil.	Open drain plug and check oil flow for presence of metal scale, sand or water; if condition of oil is bad, drain, flush, and refill.	61
M-S	Gaskets (on water-tight equipment).	Leaks.	Adjust or replace.	
S	Frames and end bells.	....	Clean inside and outside.	
W-M-S	Shaft.	(1) Oil or grease creepage along shaft.	Clean, trace to source, and correct or report.	
M-S		(2) Misalignment or sprung shaft.	Turn rotor by hand; if friction is excessive, adjust alignment or report; if	

When to inspect	What to inspect	What to look for	What to do	For detailed information see par.
		(3) Slack.	motor is connected to a machine, turn both to see if the machine imposes an excessive friction load. Rock rotor and report any excessive slack.	
S	Couplings.	Alignment and tightness.	Insert feelers at four places in coupling joint before pulling up bolts to check alignment; tighten coupling bolts securely.	51
W-M-S W-M-S	Drive belt.	(1) Adjustment. (2) Wear.	Shorten or lengthen as required. Repair or replace.	49 49
W-M-S W-M-S M-S	Drive chain. Chain housing.	(1) Stretch. (2) Wear.	Remove link or links, as required to adjust properly. Replace link, links or chain. Clean inside; check lubrication, especially for excessive lubricant.	52 52 52
W-M-S	Drive gears.	Wear or damage.	Replace.	
W-M-S	Chain sprockets.	Wear or damage.	Report.	

When to inspect	What to inspect	What to look for	What to do	For detailed information see par.
M-S	Mounting.	....	Make sure equipment is securely mounted. Tighten holding-down bolts.	
M-S	Loads.	....	Read load on motor with instruments to check for changed conditions, bad adjustment, poor handling, or control trouble.	App. III

SECTION IV

BRUSHES AND BRUSH HOLDERS

10. General

Successful operation of motors and generators depends to a great extent on use of suitable brushes and their proper adjustment. Disregard of these two factors may cause high-temperature arcing between brushes and commutator and may result in melting of solder from commutator, burning of commutator, and opening of armature windings. On the other hand, when suitable brushes are used and these are properly positioned, there will be a minimum of sparking, or none at all, between brushes and commutator at full load.

11. Types

Different kinds of brushes are available for different atmospheric conditions. Graphite brushes are most widely used because of their lubricating qualities; however, some of them have little abrasive quality, and these require care in operation. Brush grade (hard or soft) depends on whether the commutator is flush or undercut respectively. Brushes must

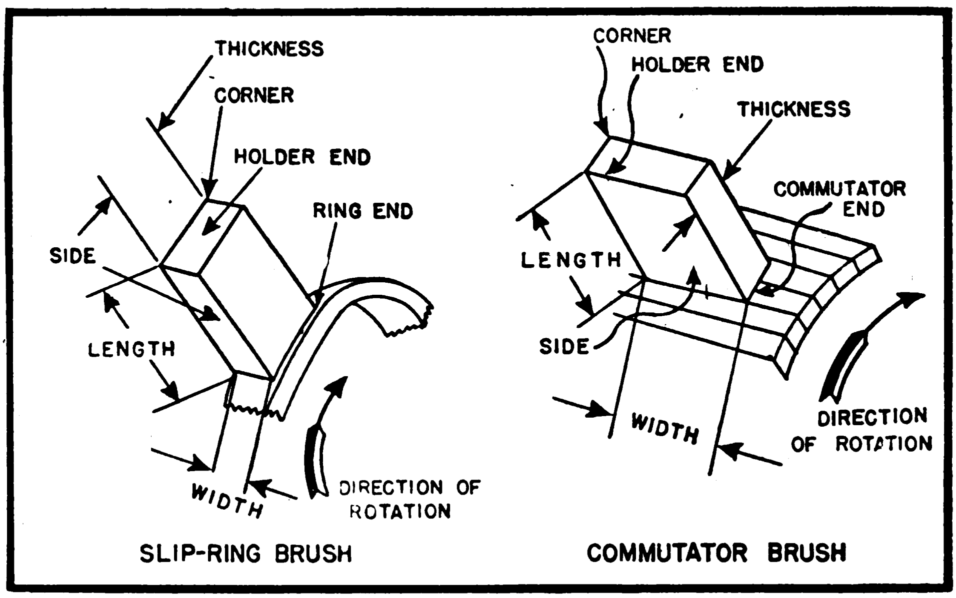
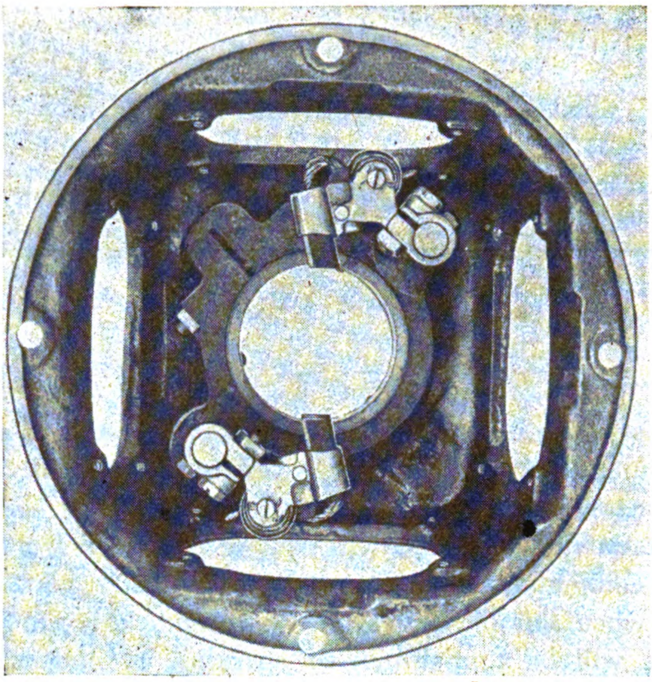
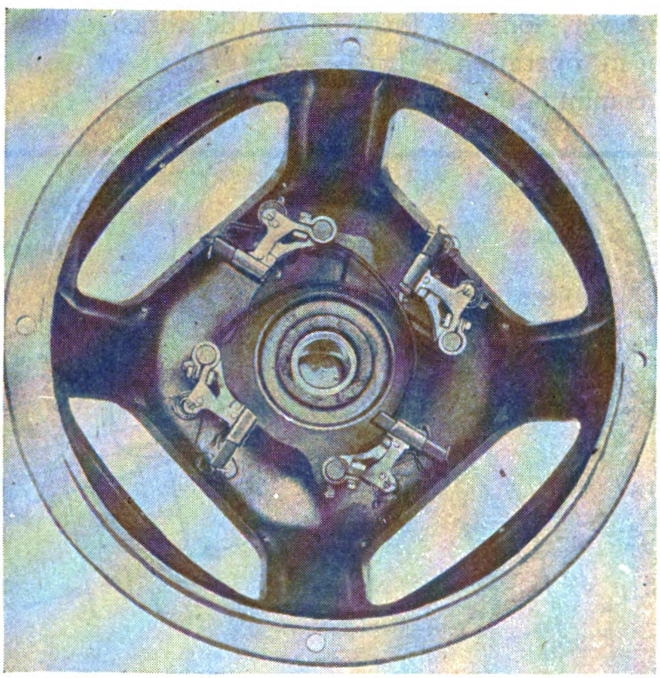


Figure 6. Surface areas of slip-ring and commutator brushes.

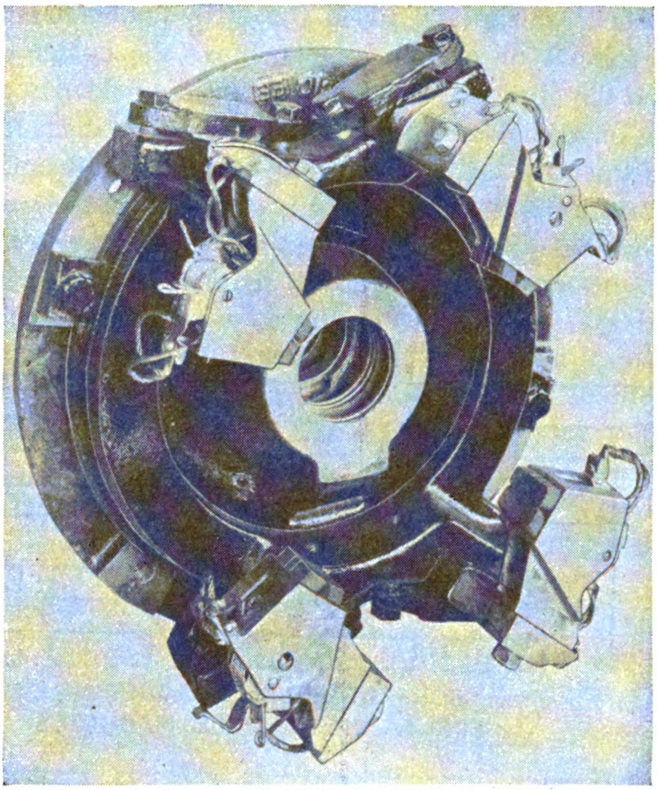


①
Commutator endshield with single brushes and brush-holders for ball-bearing D-C motors.



②
Commutator endshield with single brushes and brush-holders for sleeve-bearing D-C motors.

Figure 7. Setting of brushholders.



③
Multiple brushes and brush-holders for shunt-wound sleeve-bearing D-C motor.

Figure 7. Setting of brush holders—Continued.

have sufficient cross-sectional area and be of sufficient number to carry the maximum current of the machine. (See fig. 6.)

12. Staggering Brush Holders

Setting of brush holders with relation to the commutator varies slightly with the type of brush holder. (See fig. 7.) In all cases only brush pairs of different polarity should track each other. Stagger the brush holders so that the brushes on one pair of studs ride on the space between the brushes in an adjacent pair, as at A. (See fig. 8.) This distributes brush wear across the commutator. Brushes of the same polarity should not be set so as to track each other, as at B, because excessive wear results. On 4- or 8-pole machines correct brush staggering is done as at A; but on 6-pole machines, set brushes as at C.

13. Setting Brush Holders

Setting of brush holders with relation to the commutator (fig. 14) varies slightly with the type of brush holder, but in all cases the holders should be set equal distances from the commutator. Usually this distance is trom $\frac{1}{16}$ inch to $\frac{3}{32}$ inch, or less than $\frac{1}{8}$ inch. Use a strip of fiber to obtain the proper thickness. Place the strip under the brush holder, loosen the setscrews or clamping bolts, move the holder down until it rests firmly on the fiber, and then securely fix the holder in place. Repeat this operation on all holders. If the brush rigging is dismantled, manipulate the adjustment of each brush holder and its stud until the desired angle of the brush on the commutator is obtained. If the wearing face of the brushes has been cut to the proper angle, adjust one holder and its stud until the brush face is tangent to the commutator, with the holder about $\frac{1}{8}$ inch away. Use this setting as a guide for the others. With

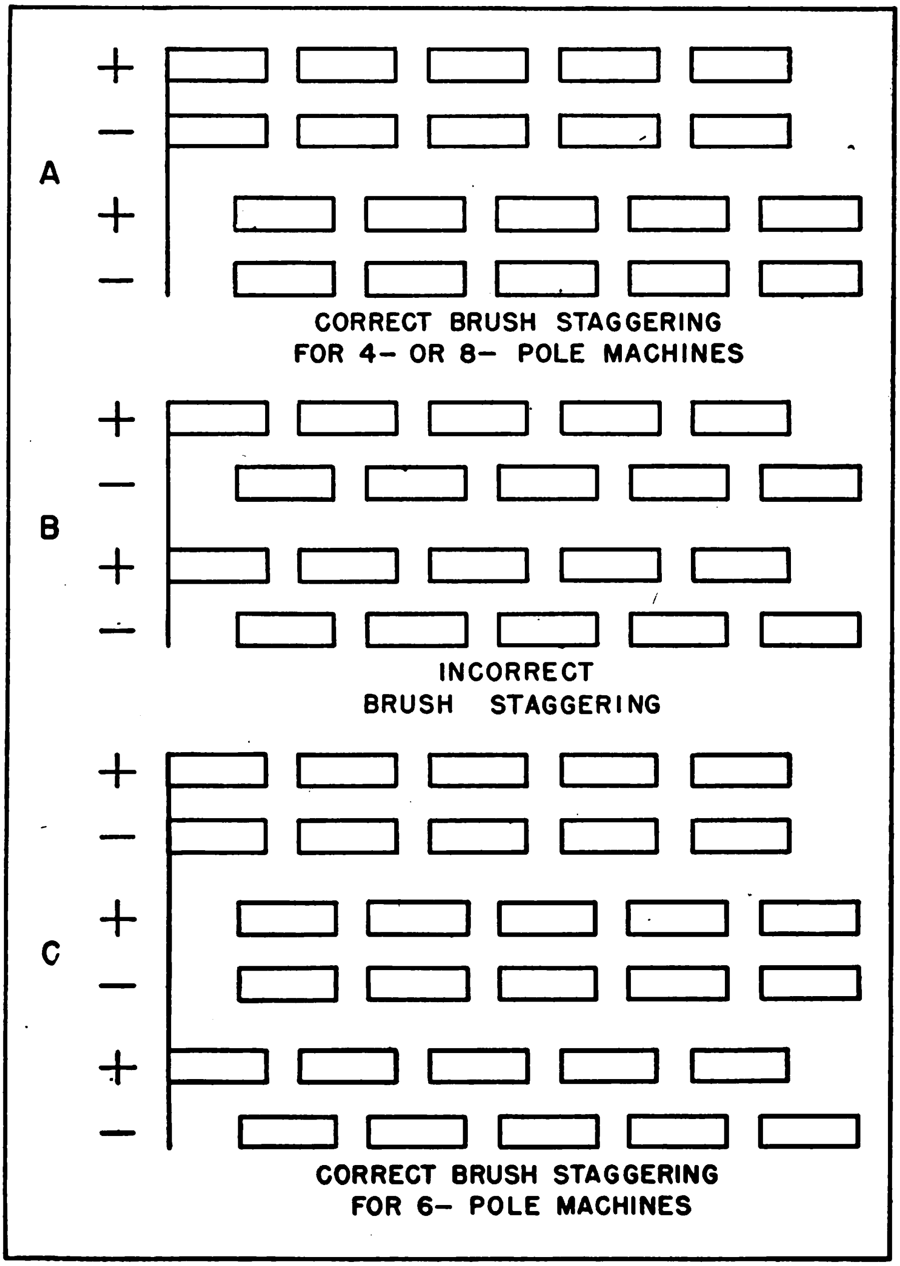


Figure 8. Correct and incorrect staggering of brushes.

double brush-holder construction, the distance from the holder to the commutator is usually less than ⅛ inch. This prevents the brushes from chattering.

14. Setting Brushes at Correct Angle

On direct-current motors and generators, brushes are set so as to approach the commutator in one of three different ways—radially, leading, and trailing. (See fig. 9.) The brush angle depends upon the commutator speed, the direction of rotation, and upon the service requirements with respect to rotation in either direction. For low speeds, in feet per minute of the commutator surface, the brushes should be set leading at an angle of approximately 20°. For high speeds, in feet per minute on the commutator, the brushes also should be set leading from about 30° to 40° from the vertical. Double type brush holders made for reversing machines have brush angles of approximately 20° and 20°, while those for nonreversing machines have angles of approximately 10° and 30°.

15. Fitting Brushes

Brushes must be fitted to the contour of the commutator. (See fig. 14.) Lift the brushes in their holders sufficiently to insert a sheet of sandpaper underneath. Draw the sandpaper in the direction of armature rotation while applying pressure to the brushes. Each time the sandpaper is pulled, lift the brush and return the sandpaper to its original position for another pull. Continue until the brush face makes a good fit with the commutator curvature. Experience shows that a better fit can be obtained by using a medium-coarse grade of sandpaper, as fine grades clog with carbon. Brush fit can be improved by applying a brush-seating stone after using the sandpaper. With the motor or generator operating at medium

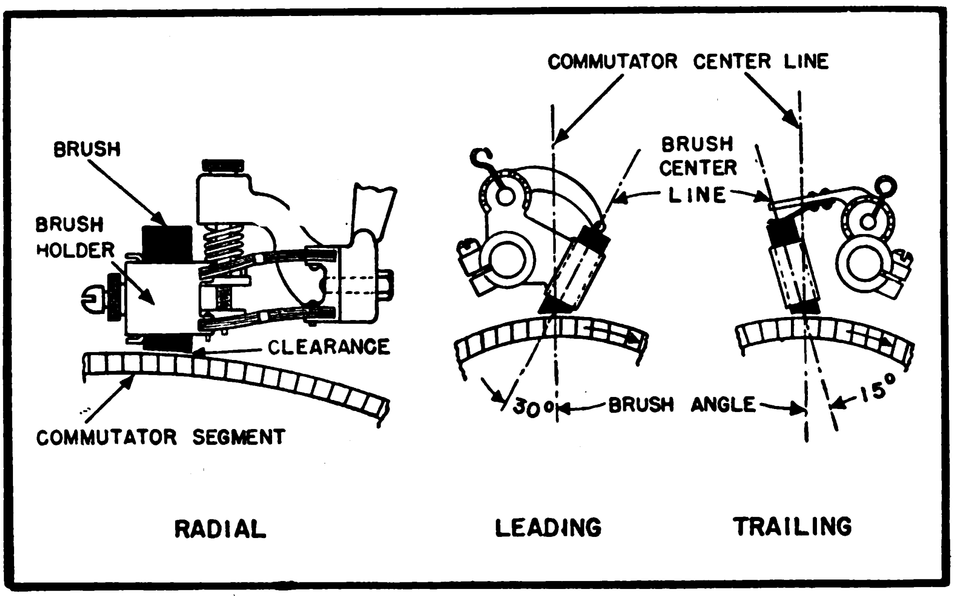


Figure 9. Types of brush settings and measurement of brush angle.

speed, press the stone firmly against the commutator and move it back and forth along the commutator to cover the area contacted by the brushes. After the brushes have been fitted, wherever possible blow out the machine with compressed air, blowing from the back toward the commutator. With double brush holders, brushes should be fitted individually, taking the angle into account.

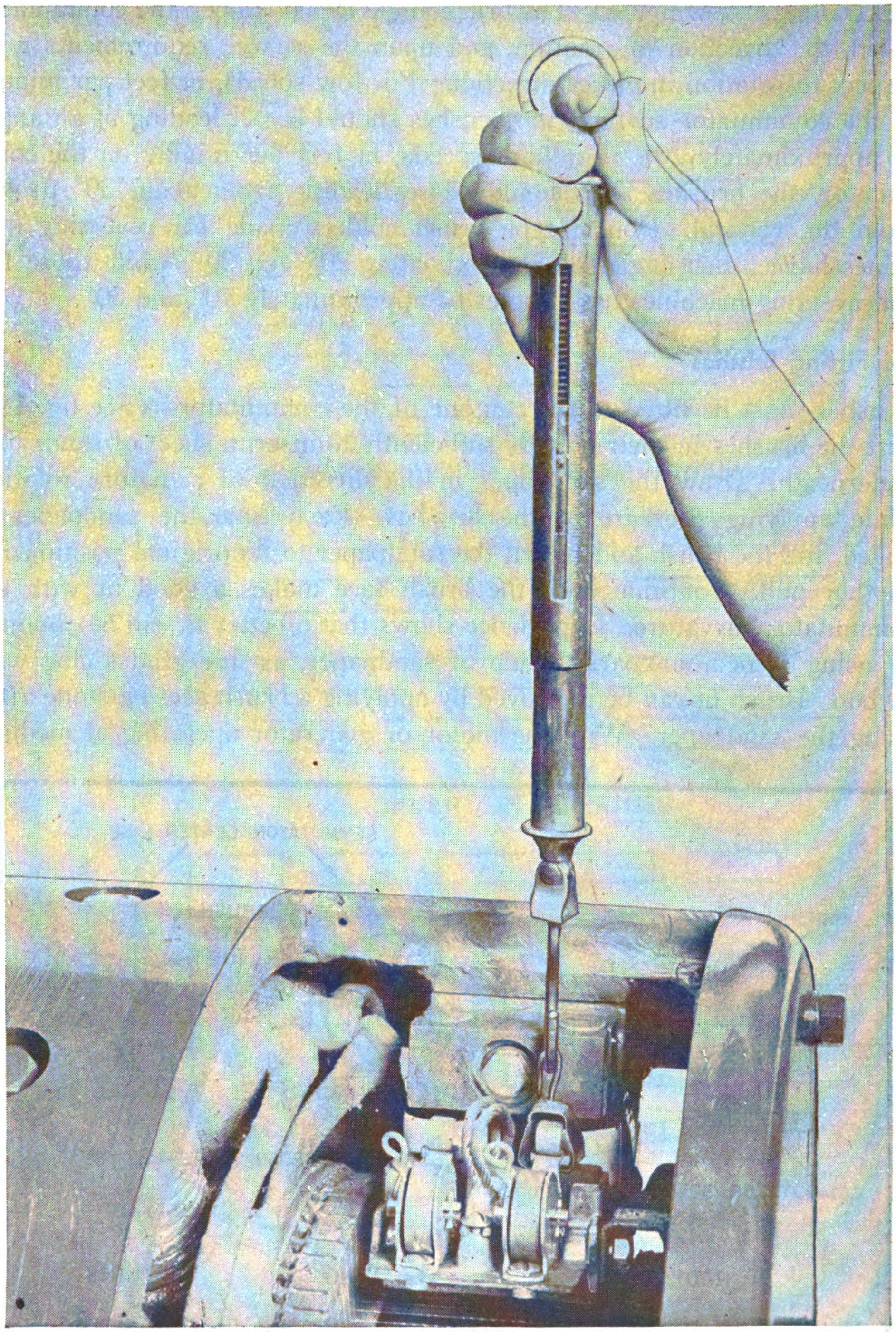


Figure 10. A reliable method for checking brush-spring pressure.

16. Adjusting Pressure

Brush-spring pressure should be from 1¾ to 2½ pounds per square inch of contact area between the brush and the commutator for light metalized and carbon or graphite brushes, and from 3 to 5 pounds per square inch for heavy metalized brushes on collector rings. Pressure should be checked by means of a spring balance held parallel to the direction of brush travel and attached to the brush-pressure arm or spring at the point of contact with the brush directly under the head of the screw holding the brush to the spring. (See figs. 10 and 11.) A direct pull should be given and the reading taken just as the brush leaves the surface of the commutator (or when a slip of paper may be drawn between brush and commutator). Excessive spring tension will cause commutator and brushes to wear rapidly because of increased friction. Low spring tension will cause arcing, due to poor contact, and may therefore result in burning of commutator and brushes. (See fig. 12.) In making adjustments for brush pressure, allowance should be made for the weight of the brush. This is particularly important in the case of heavy metalized brushes. Experience has shown that in the case of heavy metalized brushes on

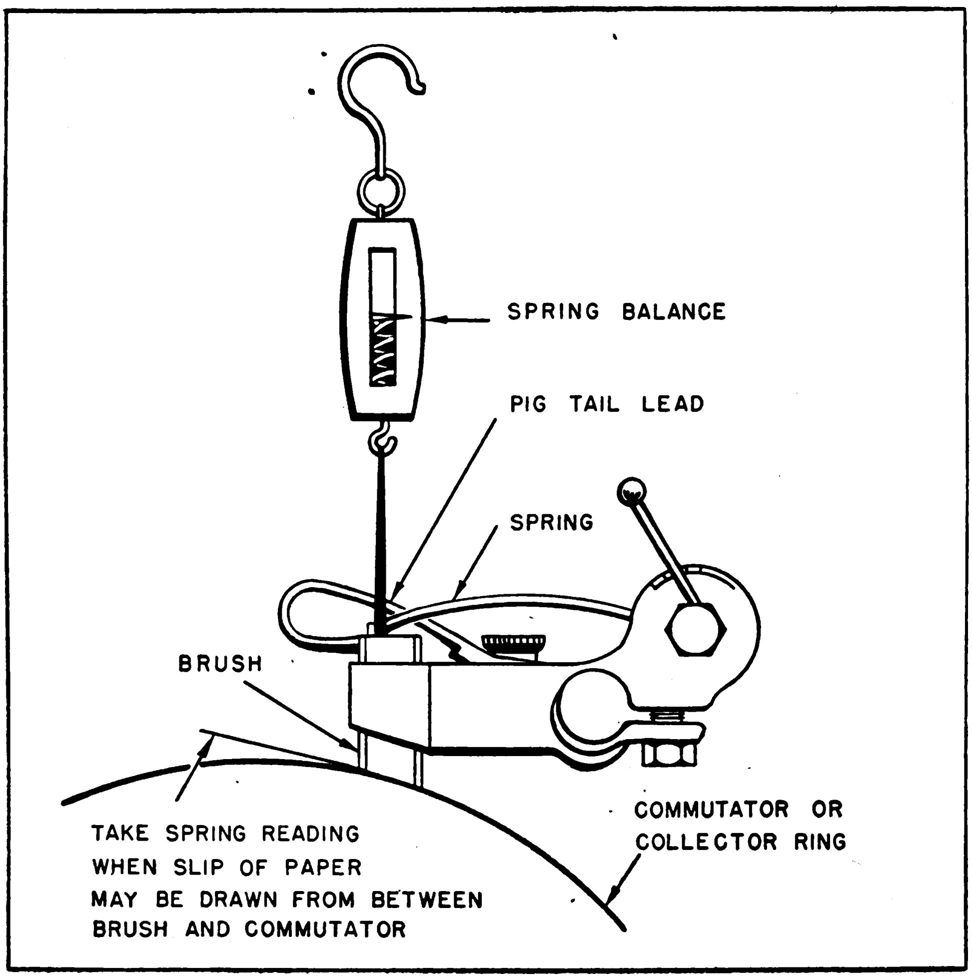


Figure 11. Method for obtaining brush pressure with an ordinary spring balance.

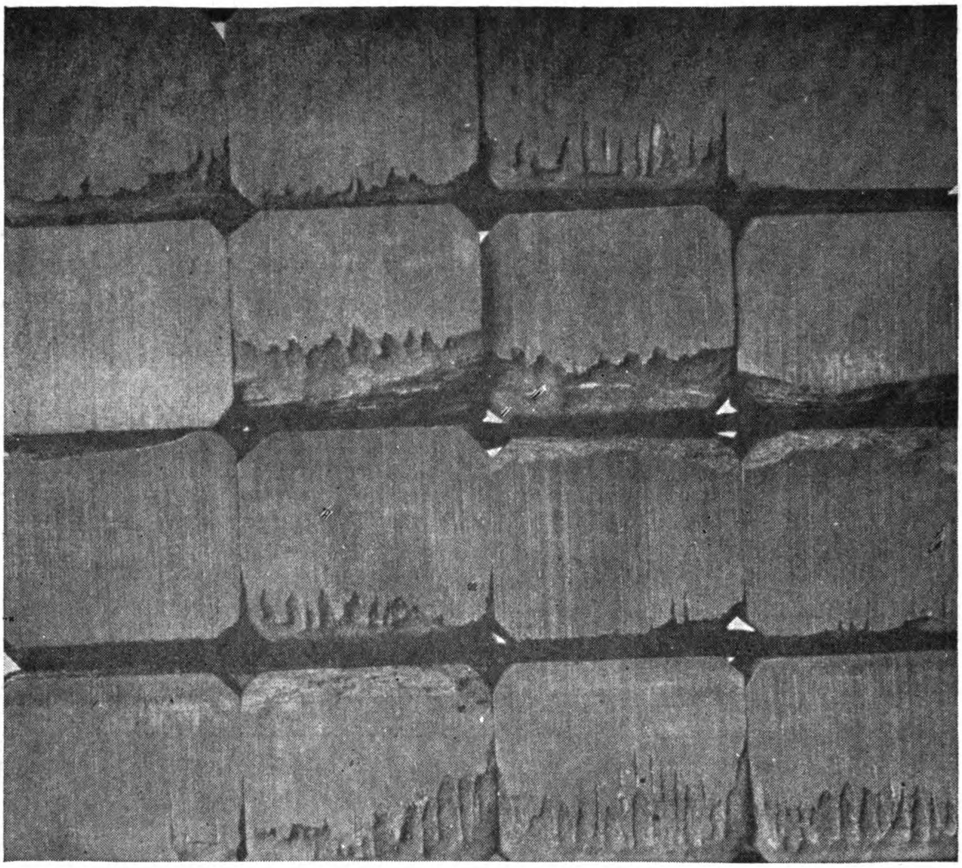


Figure 12. Brushes damaged by sparking caused by incorrect and ununiform brush-spring pressure.

collector rings, a heavy brush pressure may give less brush wear than a light brush pressure. (On some brush-holders used with A-C collector rings, a different type of holder is sometimes used. This type employs a measuring pin and a notched projection to change pressure. The measuring pin is marked with rolled projections so that the brush pressure can be easily observed by counting the number of projections on the measuring pin above the fulcrum. The first projection on the measuring pin corresponds to approximately 1½ pounds pressure, and each additional notch to an additional ½ pound).

17. Cleaning Brushes and Brush Holders

Brushes must not stick in their holders. To clean brushes, use a dry piece of canvas or other hard, nonlinty material. If brushes are caked with any substance, remove this substance with fine sandpaper glued to a flat piece of wood. Do not sandpaper excessively or round the contact of any brush. If the inside of a brush holder shows any roughness, it should also be cleaned with fine sandpaper on a flat surface before the brush is replaced.

18. Replacement of Brushes

a. GENERAL. Brushes should be replaced before they wear to the extent that the copper lead connection is in danger of coming in contact with the commutator, or when further wear may cause restriction of brush movement. (See fig. 13.) Replacement periods will vary with operating conditions. Rapid wear may result from dust, rough commutator surface, and excessive spring pressure.

b. REMOVAL OF BRUSHES. Lift up lever to relieve spring pressure; then remove brush from holder. Do not pull on the brush "pigtail" against the spring pressure, as this may damage the brush.

c. INSTALLATION OF BRUSHES. Proceed as follows:

(1) Inspect the brush-holders inside and out for spots that may have been caused by flashing at the commutators. Remove any inside roughness with sandpaper glued to a flat piece of wood. (See fig. 14①.)

(2) Make sure the brush holders and replacement brushes are clean and of the right kind.

(3) Insert the brushes in the holders, making sure that the brushes can move freely. They should not be so loose that there is any appreciable side-play; on the other hand, they should not fit so tight that they may expand and stick at operating temperatures. (See fig. 14②.)

(4) Make sure the brushes are properly spaced (par. 19) and at the correct angle.

(5) Fit the brushes to the commutator one at a time with a strip of sandpaper. (See fig. 14③.)

(6) See that the brushes and holders are clean. Snapping the brush spring-tension arms will help to free the brushes in the holders and to release dust that may be lodged between the brushes and brush-holders. If necessary, blow the dust out with moisture-free compressed air.

(7) Adjust the brush-spring pressure.

(8) Check the pigtail wire terminal screws or connections for tightness and examine the pigtail wire insulation. The pigtail wires must not touch any metal except the brush-holders to which they are attached. Make sure that all shunts are properly secured to the brushes and holders. If the connections are defective, current will flow from the sides of the brushes into the holders and cause side-burning, wear, overheating, and improper brush operation. (See fig. 14④.)

19. Spacing of Brushes

To check the brush spacing, place a strip of paper tightly around the commutator, and mark it to the exact commutator circumference. Remove the paper, and accurately divide the circumference length into as many divisions as there are brush groups. Draw a line across the paper at each division, as a guide in locating the brushes. After the studs and brushes have been set accordingly, it may be necessary to make some adjustments because of slight differences in the brush rigging and also

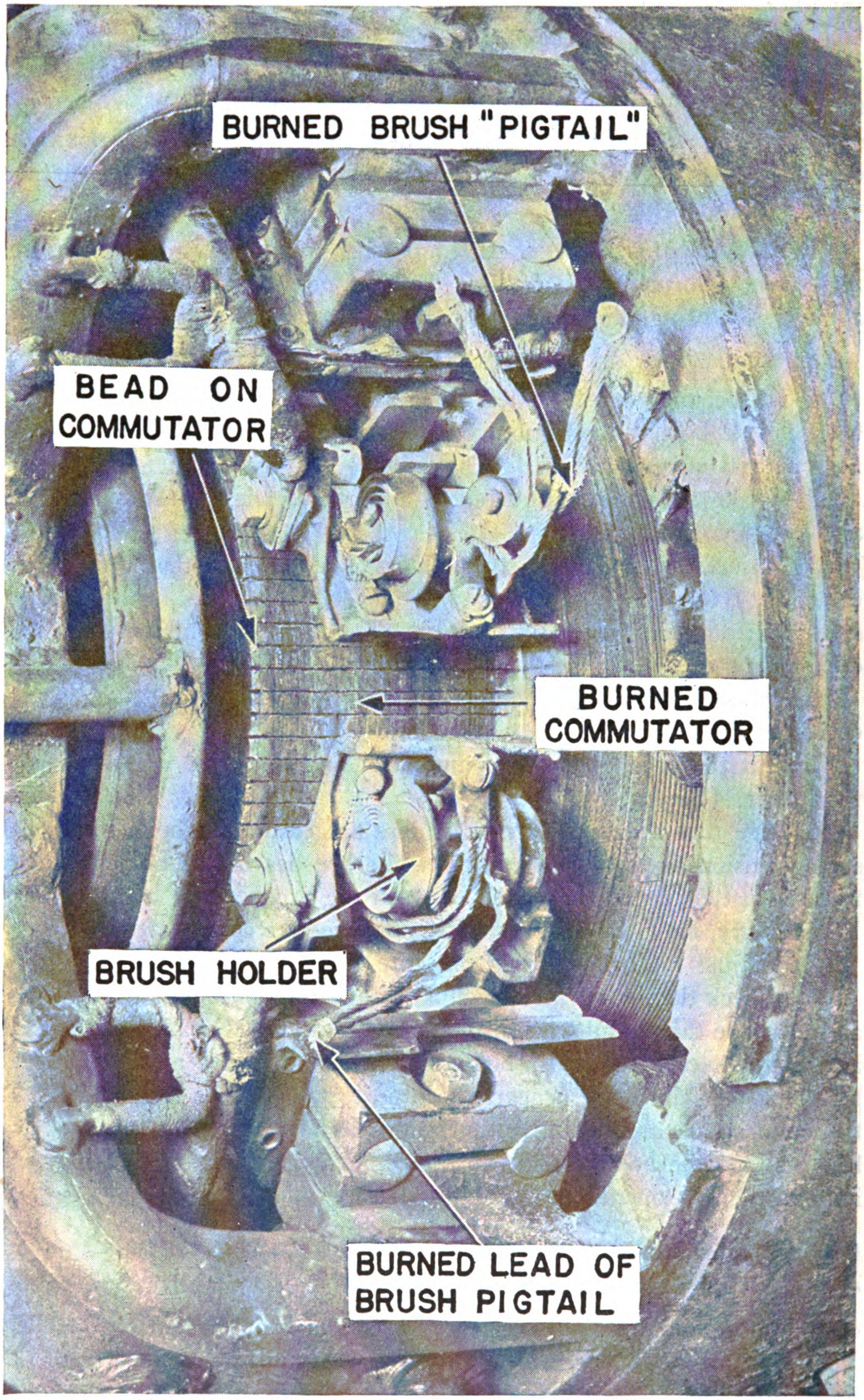


Figure 13. Traction motor damaged because brushes had been allowed to wear too short before being replaced.

because the commutator bars and the insulation between them may vary in thickness. Loosen the holders of improperly spaced brushes and move them up or down slightly to correct the spacing. Check each brush group to see if the toes of the brushes line up with the edge of the same bar. When a set of brushes is too far out of location, it may be necessary to correct the stud position.

20. Setting Brushes on Neutral

a. Direct-current motors have their brushes set on the commutator at the neutral point, where the armature current reverses direction. At this point, the best commutation is usually obtained. In most instances, the brushes have been carefully set at the neutral position at the factory. However, the neutral point may shift under load, particularly on machines that do not have commutating poles. One method of determining mechanical neutral is as follows (see par. 56):

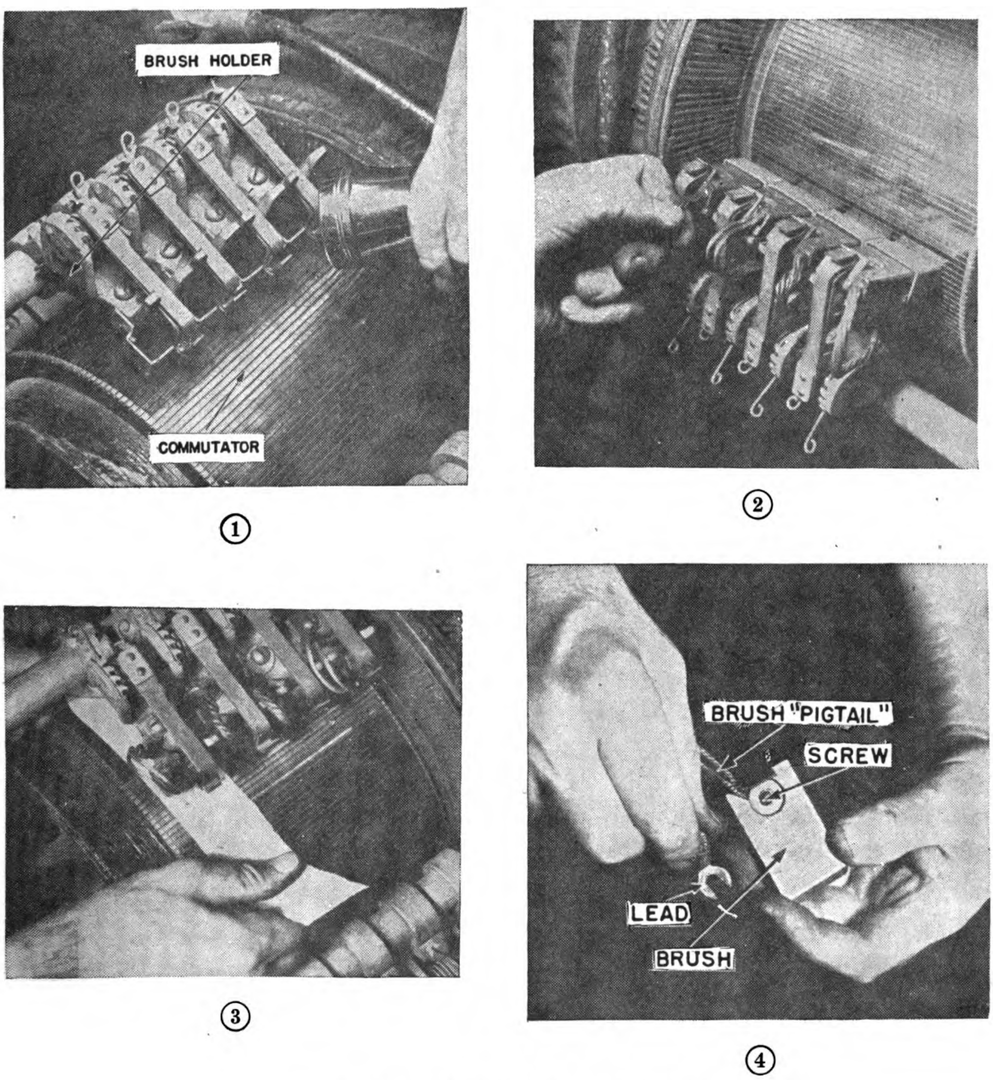


Figure 14. Installation of brushes.

(1) Turn the armature over until the two slots which are painted red are directly under the center lines of two commutating poles, or equidistant from them. Where there are no commutating poles, the armature should be turned until the two painted slots are midway between the two main poles, and equal distances from them. The center of the group of commutator bars, which are stamped and painted red at the end, indicates mechanical neutral.

(2) In some instances, the neutral is marked by a straight line drawn across the yoke and across the bearing or end shield, with an arrow indicating the direction of rotation.

b. The brushes of commutating-pole machines are often set slightly off this mechanical neutral. If necessary, the brushes can be shifted slightly from the neutral point, in order to secure the best commutation. Brush shifting should be done with the machine disconnected from the source of power. It is not safe to shift the brushes very far.

c. The brushes of D-C generators are not set in the vertical plane, or in the shifted neutral plane. Instead they are set just beyond the shifted neutral plane, to prevent sparking between the brushes and the commutator.

SECTION V

COMMUTATORS

21. General

Satisfactory commutation of D-C machines and of commutator types of A-C machines means operation under reasonable service conditions without excessive sparking, burning of commutator bars or brushes, or other conditions requiring excessive maintenance. The primary requirement is continuous contact between commutator and brushes. The commutator must be mechanically true, the unit in good balance, and the brushes in good shape and well-adjusted.

22. Inspection

When good commutation cannot be obtained, or when scheduled inspection is called for (par. 9), check as follows:

a. Inspect all connections and make sure that none is loose.

b. Check the brush spacing and alignment. In general, the more accurate the brush spacing, the better the commutation.

c. Inspect the adjustment of brushes in the holders.

d. Inspect the brush contact surfaces for burning or roughness.

e. Check brush-spring pressure and brush fit.

f. Check the neutral. Very often a slight shift of the brushes away from neutral is advantageous. (Such shifting should be considered in relation to regulation of speed of motors and division of load on generators.)

g. Make sure that no part of the commutating field is reversed, and that none of the main windings is reversed.

h. Check the centering of the commutating poles between the main poles; also check the main- and commutating-pole air gap.

i. Wipe the commutator clean with dry canvas so that it may readily be inspected, and rotate the armature by hand in order to inspect all bars.

(1) The surface should be smooth and have a high polish.

(2) Eccentricity of the commutator, high and low bars, high mica, pitted mica (usually caused by the presence of oil, grease, dirt, or minute particles of carbon and copper), and grooves in the commutator (usually caused by incorrect staggering of brushes or by use of brushes having too high an abrasive quality) are conditions that must be corrected by

turning the commutator (par. 24), and removing the cause. (See figs. 15 and 16.)

(3) The commutator should also be examined for indications of excessive heat, such as solder flakes, burned bars, and burned insulation at the point where the armature windings are soldered to the commutator. Here, too, corrective action must be related to both cause and effect.

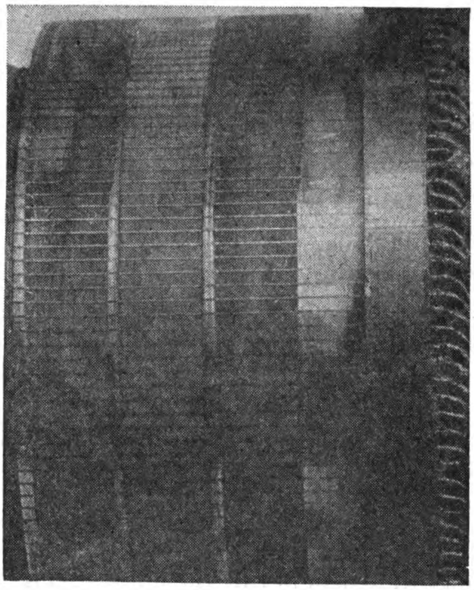


Figure 15. Commutator showing high mica and burning of the surface because of the attendant sparking.

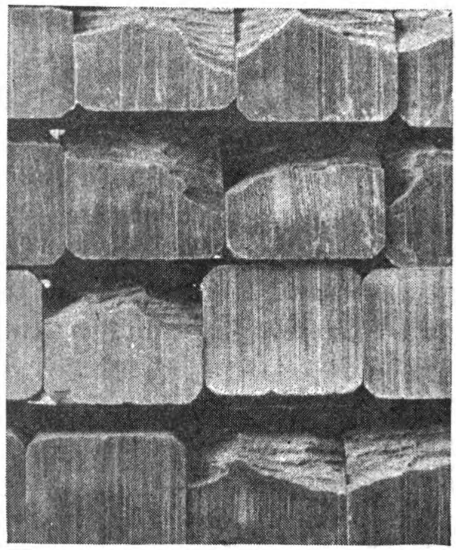


Figure 16. Example of a set of brushes fractured by rough commutator surface.

23. Cleaning the Commutator

A stable, copper oxide-carbon film on the commutator is desirable. Such a film may vary in color all the way from copper to straw, from chocolate to black. Fumes and oil vapors tend to smudge, gum, and discolor the commutator. Oil and grease will create a mottled appearance on the surface film. Dirt and particles of carbon and copper may accumulate and damage the commutator surface. When operating conditions tend to have such effects, regular cleaning is desirable. To clean the commutator, proceed as follows:

a. Cut a stick of wood to a length of about 6 inches and trim it to the same width as the commutator and to a thickness of about ¼ inch.

b. Fold a piece of dry canvas or other hard, nonlinty material (or No. 00 sandpaper) over the end of the stick and fasten it securely. (See fig. 17.)

c. With the armature rotating, hold the stick squarely against the commutator and press lightly for a few seconds. (See fig. 18.)

d. If the commutator is not clean after this procedure, repeat procedure one or more times.

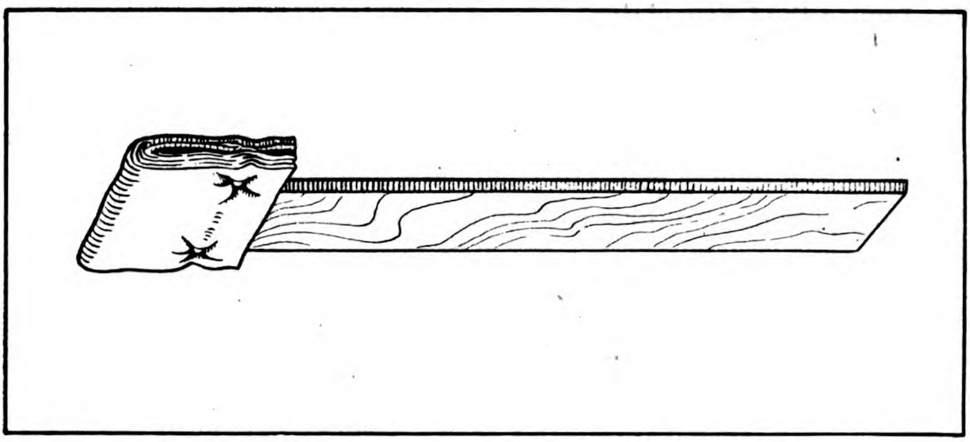


Figure 17. Device and cleaning a commutator—dry canvas fastened to a wooden stick.

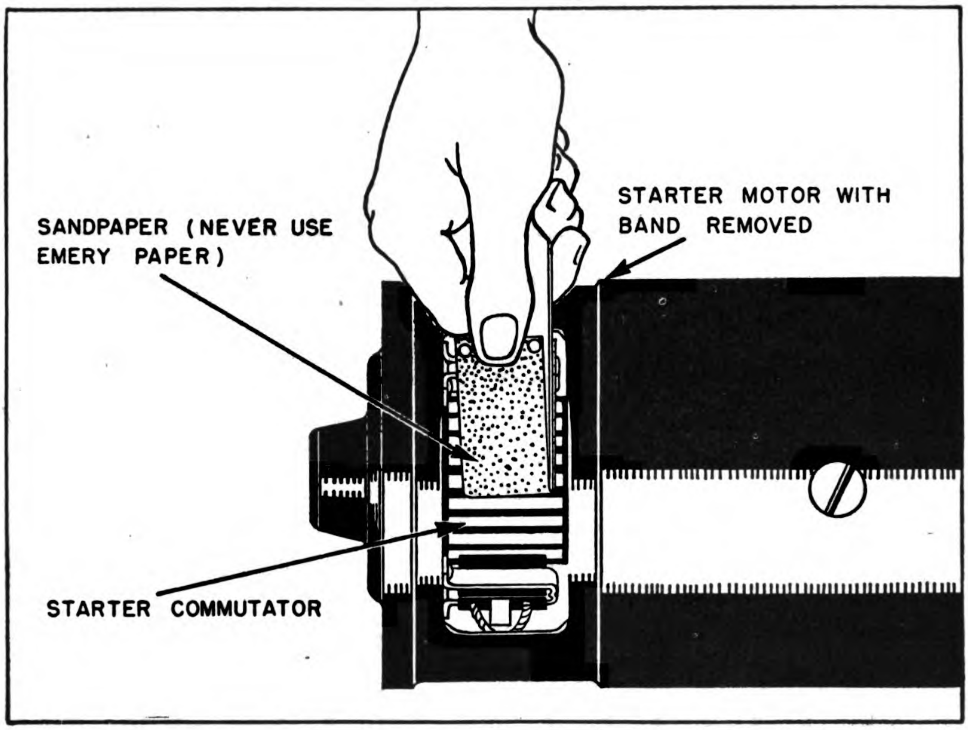


Figure 18. Cleaning a starter-motor commutator.

e. Wipe the dust off with canvas, or if necessary, blow dust out with moisture-free compressed air.

f. If, after cleaning, the commutator does not have a polished appearance, the machine should be run with a light load for several hours in order to establish a high and uniform polish.

Warning: *Never use emery paper, a lubricant, or gasoline or other inflammable fluid to clean or polish the commutator.*

24. Turning the Commutator

Where the conditions referred to in paragraph 22*i*(2) are apparent, one or more of the following corrective procedures may be employed:

a. UNDERCUTTING HIGH MICA. Depth of undercut varies with different sizes of machines, and care should be taken not to undercut too deeply. Various types of tools may be used to undercut high mica. (See fig. 19.)

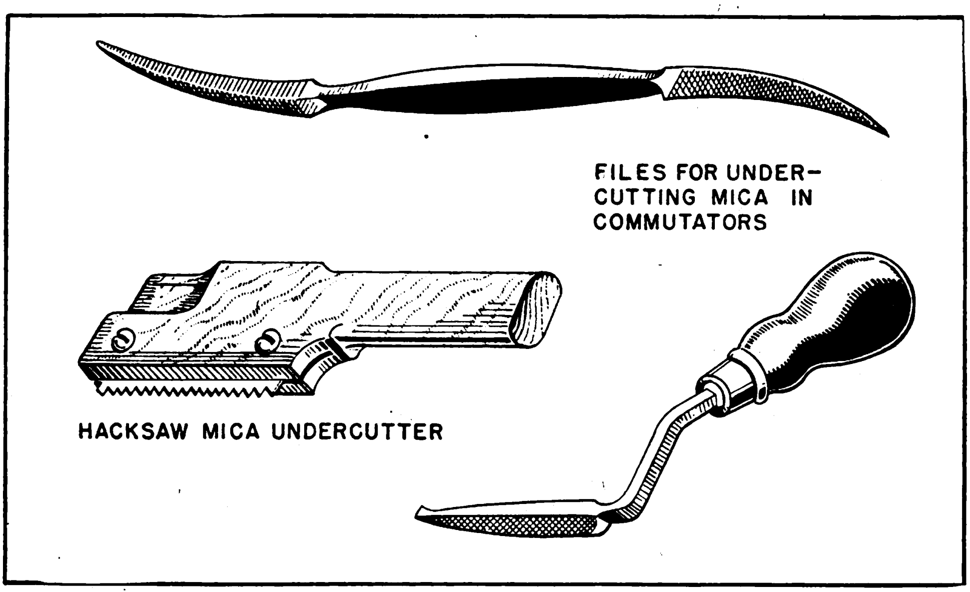


Figure 19. Tools for undercutting mica.

If the slots are accessible to easy cleaning, a square slot is preferable. Where the slots are likely to collect dirt, as in low-speed machines or in a dirty atmosphere, the V-shaped slot may be more satisfactory. It is well to bevel slightly the segment corners. (See fig. 20.)

b. STONING THE COMMUTATOR. To even the surface of the commutator and to polish it, a dressing stone may be used. (See fig. 21.) The

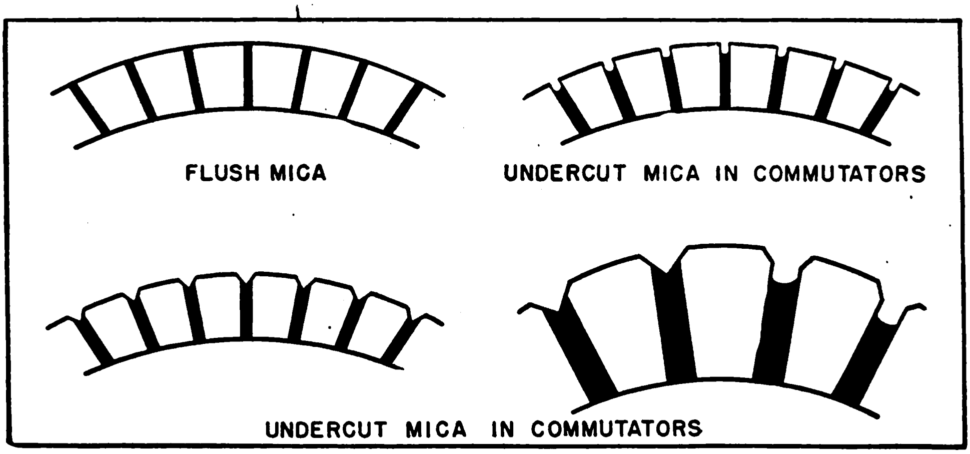


Figure 20. Flush mica and types of undercut mica.

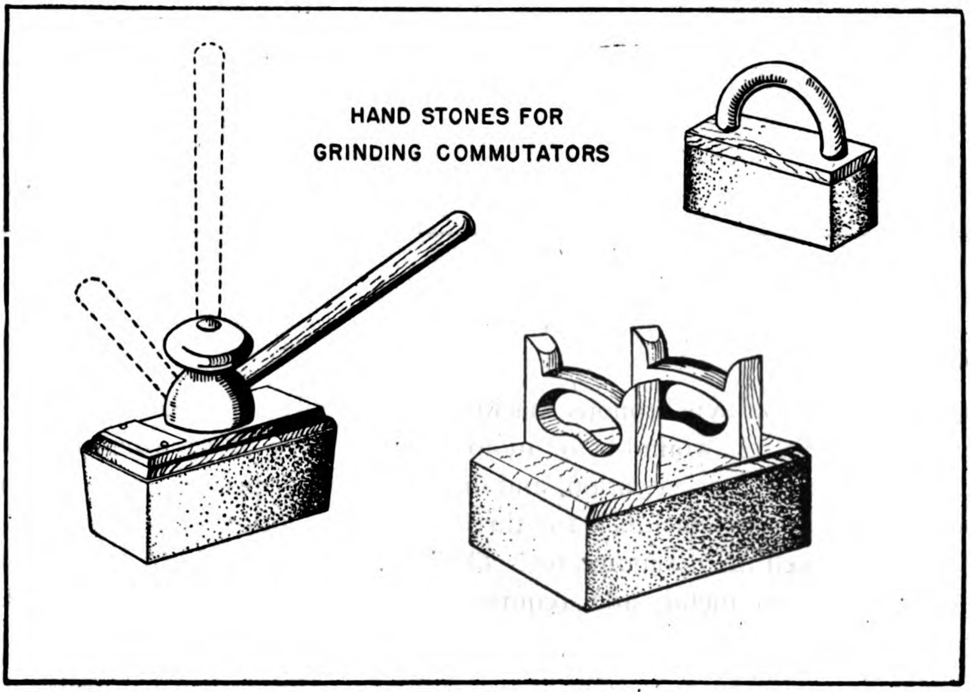


Figure 21. Hand stones for grinding commutators.

stone may be held in the hands or mounted in adjustable rests. Proceed as follows:

(1) Remove all traces of oil or grease from the stone and the commutator.

(2) Lift the brushes away from the commutator.

(3) If the machine is a generator, drive it with the prime mover at normal speed; if a motor, drive it by mechanical power from some external source.

(4) Work the stone against the commutator from end to end until the surface is ground down evenly. (If the commutator is too rough or eccentric to be stoned successfully by hand, the stone can be held by a pair of clamps in a tool post, or it may be advisable to turn the commutator in a lathe.)

(5) After stoning, smooth the commutator with a very fine grade of sandpaper, and then polish it by using the back of the paper.

(6) Clean the commutator of every trace of copper, carbon, or dust, preferably by suction.

(7) To check on eccentricity, a dial-indicator reading of .001 on high-speed machines to several thousandths on low-speed machines may be considered normal.

SECTION VI

COLLECTOR RINGS

25. General

Collector rings on synchronous machines carry only D-C excitation current. The rings on wound-rotor motors carry heavy alternating current during starting and acceleration, and during reduced-speed operation. On some direct-current machines for three-wire distribution of power, there are rings as well as a commutator. These rings are usually of bronze or other nonferrous metal, and require special care when being turned. (See fig. 22.)

26. What to Check

Insulation resistance, ring to shaft, and studs (or leads) to rings, should be checked at regular intervals to detect cracked or otherwise defective bushings and collars. Resistance and creepage space may have been reduced by an accumulation of brush carbon and metal dust from the rings. Thorough cleaning is frequently required.

27. How to Clean

Stiff brushes can be used to remove the major part of any accumulation. Washing with carbon tetrachloride, using a cloth or paint brush, should follow. Dirt from external sources may indicate the need for a cover over the rings. However, rings should not be inclosed unless designed for an inclosure.

28. When to Resurface

End play and brush staggering should prevent wearing of grooves in the rings, or the formation of ridges along the edges. The wearing surface of the rings should be bright and smooth. Under normal conditions, the surface will require little care. When the rings have worn excessively, so that they are eccentric with the shaft, the ring faces should be trued up with a portable tool. In extreme cases the unit should be dismantled and the rings faced in a lathe. After turning, the tool marks should be dressed out so that a polish is attained.

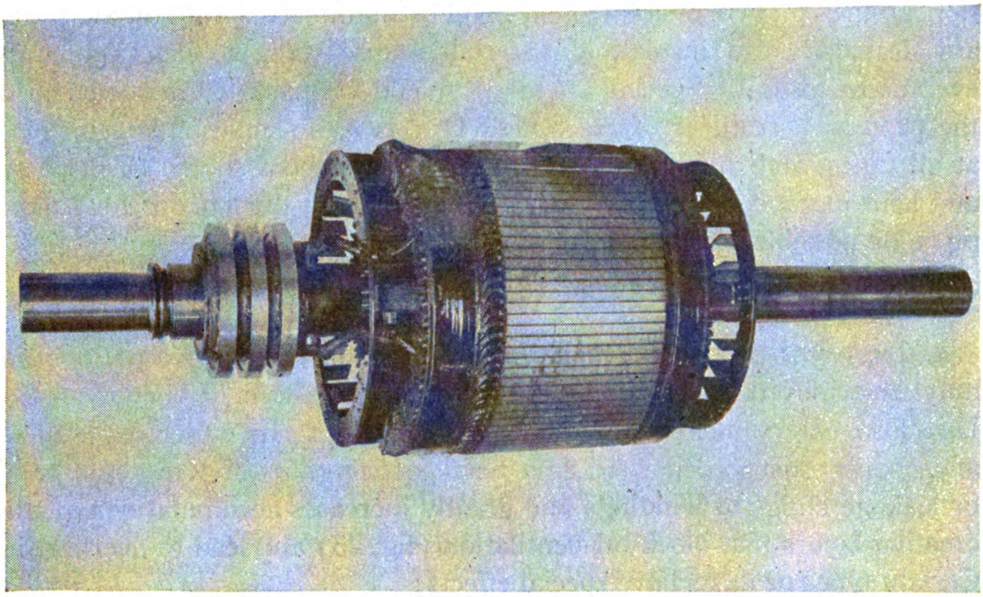


Figure 22. Collector and rotor of wound-rotor induction motor.

SECTION VII

CARE OF WINDINGS AND CONNECTIONS

29. General

A primary rule for the care and maintenance of insulated windings is to keep the apparatus clean and dry. If this precaution is observed, insulation failures and corrosion troubles will be minimized. Both oil and water are destructive to insulating materials, cause them to deteriorate and eventually to fail. Special attention should be paid to maintenance of the protective features of machines. Drip-covers should be kept in place at all times, and the gaskets of watertight equipment should be inspected and kept in good condition. Operators must be on the lookout for leaking pipes or possible sources of splashing or spraying.

30. Cleaning Windings

a. IMPORTANCE. Dirt will accumulate in spite of all precautions and must be removed periodically. This is particularly true of open machines. Dirt also enters inclosed motors and generators. In either case carbon and copper dust is deposited as a result of commutator wear. Oil vapor or leakage clings to windings and greatly increases accumulations of dirt, creating layers that block off ventilation (fig. 23) and lead to overheating. Certain types of dusts have special effects:

(1) Conducting dusts shorten creepage distance and penetrate windings, causing short circuits and grounds.

(2) Hard, sharp dusts cut into insulation and shorten its useful life.

(3) Cast-iron dust is magnetic and is agitated by stray fields.

b. METHODS. The method of cleaning will depend upon the nature of the accumulation. In all cases, however, care must be taken to avoid using anything which may injure the insulation. For this reason soap and water, wire brushes, and metal scrapers are not to be used. Cotton waste should *not* be used because thread and lint will be left on the surface and will collect new dirt.

(1) Light dusts can be blown out with low-pressure, dry air. (The air pressure at the nozzle should not exceed 15 to 25 pounds per square inch. Excessive pressure may cause damage to windings.) Grit, iron dust, carbon dust, and copper dust should be removed by suction. Hose tips for either pressure or suction should not be of metal.

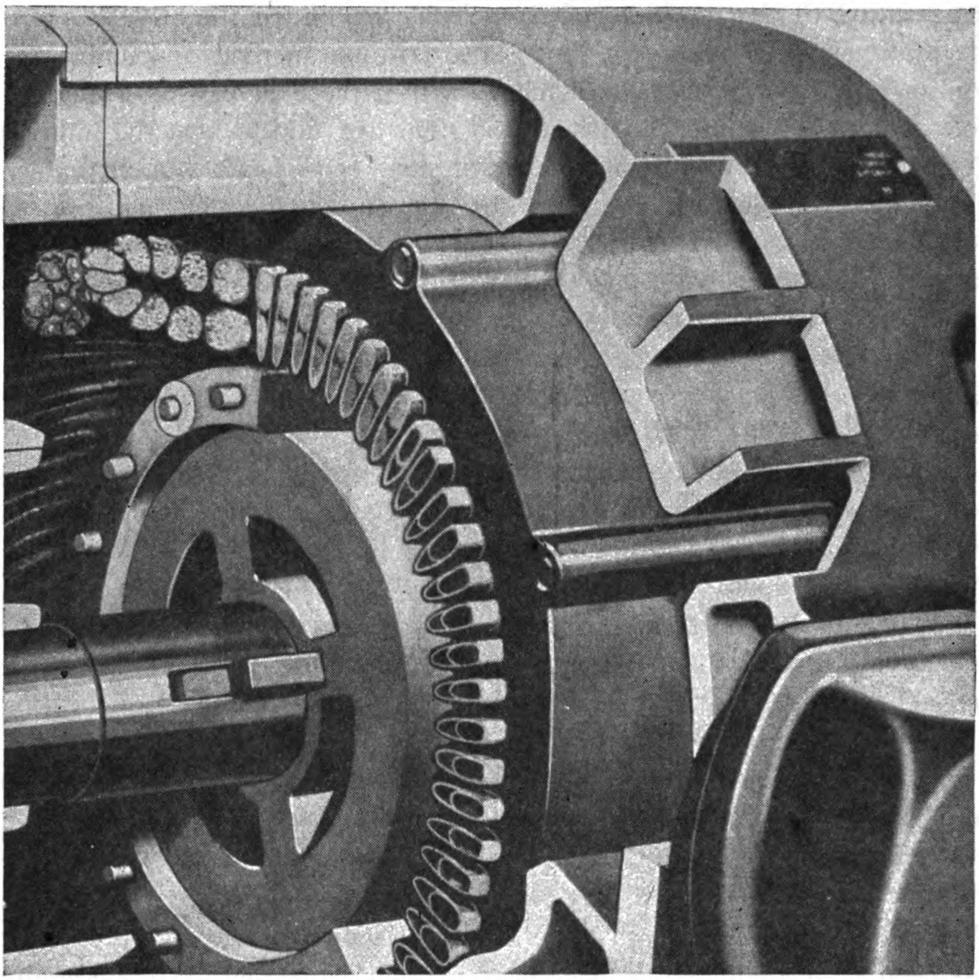


Figure 23. Motor frame with two separate sets of air ducts, internal and external, arranged adjacent to each other in order to provide efficient heat transfer.

(2) Grease and oil can be removed by the conservative use of a solvent such as carbon tetrachloride, which evaporates quickly. (Gasoline and benzine are noncorrosive solvents but constitute a fire hazard.) The vapor of carbon tetrachloride has toxic effects, however, and good ventilation must be present when this solvent is used. After cleaning, dirt should be blown out. If the accumulation is excessive, this process must be repeated several times. However, care should be taken to use the solvent sparingly. It may soak into inaccessible places and evaporation may be delayed long enough to soften and harm insulation.

31. Drying Windings

a. Machines in continuous operation will stay at a temperature sufficiently above room air to prevent condensation of moisture on and about the windings, even if the location is very steamy. However, cold motors and generators readily accumulate moisture, causing gradual deterioration of insulation. This may happen either in service or in storage when the temperature of the machine is below the dew point of the air. Where a machine has to be idle for a long time, a simple method of keeping the windings dry is to cover the machine with a piece of canvas, leaving a hole at the top for escape of heat and moisture, and to heat the interior of the "tent" with incandescent lamps or small space heaters, so as to keep the windings a few degrees higher than the surrounding temperature.

b. TREATMENT OF DAMPNESS. Dampness will be indicated by low insulation resistance. Deep penetration of dampness calls for special treatment.

(1) External heat can be applied under a well-ventilated canvas cover. Heating should not go beyond 194° F. (90° C.), as water must not be boiled in the insulation.

(2) Current can be circulated through the windings by applying a low voltage to the windings. Current should be only a fraction of full-load current, and the temperature limitation of 194° F. (90° C.) should be observed.

(3) Insulation resistance tests should be taken at intervals to note the trend. The machine can be put into load service somewhat below the recommended reading in megohms (million ohms), because load heating will continue the drying-out process.

c. TREATMENT OF SUBMERGED MACHINES. If the machine has been submerged for some time, it must be carefully checked to see if rewinding is necessary. (In the case of D-C machines, water between the commutator bars and the shell may be the source of low-ground resistance.) Rewinding is almost certain to be required, sooner or later, if the motor has been "drowned" in salt water. After cleaning, some salt may remain, and if so, it will combine with moisture from the air.

d. CARE OF INCLOSED MACHINES. Totally inclosed machines, if idle in a damp place, should be examined periodically, as the insulation may gradually absorb moisture from the entrapped air. Presence of water in inclosed motors almost invariably indicates leakage at shield joints, handhold covers, lead entrances, etc. Such leakage may be avoided by use of sealing greases or compounds.

32. Reinsulation

Insulation should be thoroughly cleaned and varnished at intervals of several years, or when required by its condition. Periodic varnishing of the armature will prolong its life by providing a strong, resistant coating and thereby preventing deterioration of the insulation. This should be done when the machine is given a major overhaul in a well-equipped shop since two or more varnish treatments are generally required, each followed by oven baking at a temperature and for a period of time specified by the manufacturer. Field coils should receive the same treatment. If a thorough varnish and baking treatment is not possible, various weak or damaged spots can be varnished with special air-drying material. (See app. VI.)

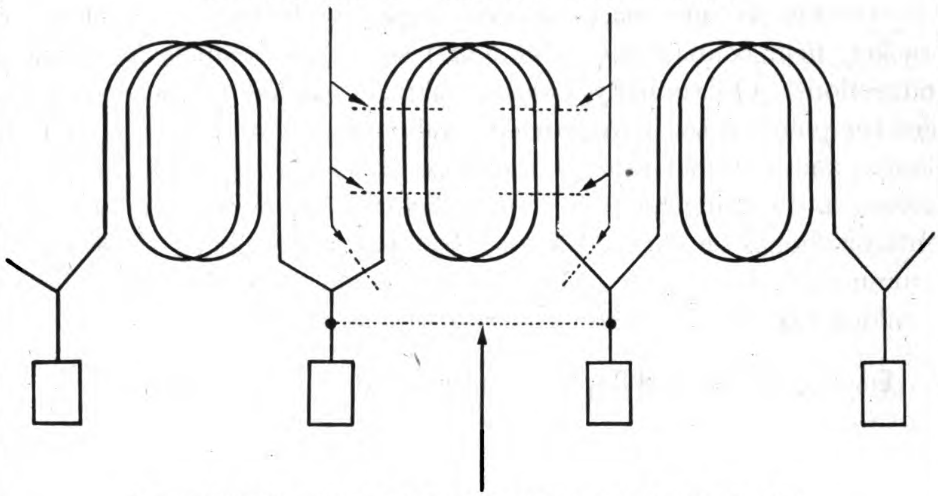
33. Care of Connections

Connections include places where copper is bolted to a brush-holder bracket, field connections (shunt and series), machine cables, and line connections. Occasionally contact surfaces should be cleaned, scraped, filed, or polished so as to provide good contact. All fastenings, including clamps and terminal nuts and screws, should be tightened, as alternate heating and cooling tends to loosen them. Leads from armature to commutator should be checked to see that they are properly soldered to the commutator. Loose ends should be resoldered with rosin flux. Acid flux should *not* be used to solder electrical connections.

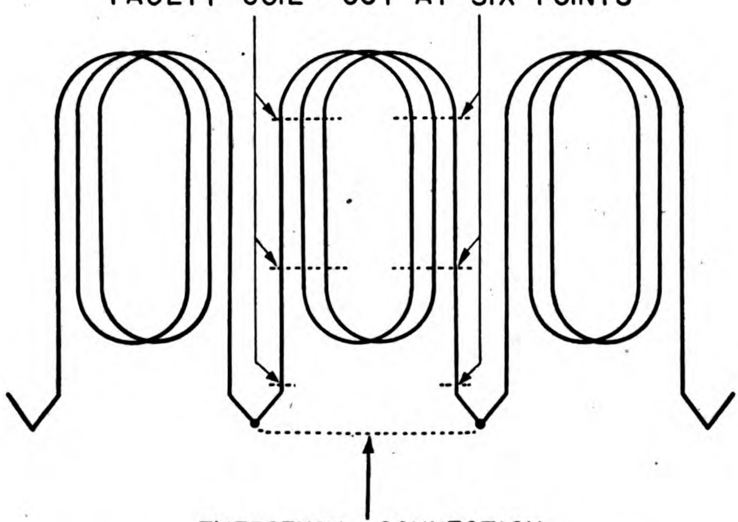
34. Emergency Use and Replacement of Field Coils and Armatures

a. Emergency Use. In the event of the failure of an armature coil, particularly on smaller units, the armature may be kept in emergency service until repair can be made, by cutting out the damaged coil. This is done by cutting the coil leads to the commutator bars and short-circuiting the bars to which this coil was connected. (See fig. 24.) The field-circuit connections should be carefully checked before it is assumed that the field is at fault.

b. Replacement Precautions. When armatures are being removed or replaced, care should be taken to protect the commutator, windings, and journals from bumping or scraping against other objects. An armature should never be lifted by means of the commutator. Large armatures should be lifted by means of a rope sling around the shaft. When replacing a field coil, the polarity of poles should be checked. (See par. 37.)



HOW TO MAKE AN EMERGENCY REPAIR ON A MOTOR WITH A COMMUTATOR, SO THAT THE MOTOR CAN BE PUT BACK INTO SERVICE. THIS IS A TEMPORARY EXPEDIENT ONLY.



HOW TO MAKE AN EMERGENCY REPAIR ON A COIL OF A MOTOR THAT HAS NO COMMUTATOR, SO THAT THE MOTOR CAN BE RETURNED TO SERVICE. THIS IS A TEMPORARY EXPEDIENT ONLY.

Figure 24. Emergency repair of faulty coil.

SECTION VIII

TESTING INSULATED WINDINGS

---

35. Tests For Determining the Condition of Insulation

a. Megohms (million ohms) of resistance between a winding and ground are a good indicator of the condition of insulation. Comparison with several previous readings will give an indication of improvement or deterioration. Readings should be taken with the machine at normal working temperature. Readings, to have comparative value, should be taken under the same conditions. Two methods of obtaining resistance readings are commonly used, and either may be applied to any high resistance, such as that of a group of coils, as well as to the resistance of a whole machine.

b. MEGOHMMETER METHOD. A megohmmeter is a self-contained instrument which gives a direct reading of insulation resistance. If one is available, follow the instructions furnished with the instrument. Although cranked by hand, the megohmmeter provides constant voltage while the clutch is slipping. The index should read "infinity." When connected across the resistance to be measured and cranked beyond the slipping speed, the resistance is indicated indirectly.

c. VOLTMETER METHOD. The voltmeter method requires a voltmeter having a resistance of about 100 ohms per volt. A 500-volt instrument is preferred. Disconnect all leads of the motor from the line. In the case of heavy loads, line power can be broken at the circuit breakers or disconnecting switches, but proper precautions *must* be taken to prevent power from being turned on accidentally while work is being done on the machine. Read the line voltage (E in the formula below). Connect the ungrounded D-C line through the voltmeter to a motor lead, and the other D-C line through a 10-amp fuse to the motor frame. With E_1 representing the meter reading, r representing the meter resistance, and R the insulation resistance in ohms:

$$R = \frac{r(E-E_1)}{E_1}$$

Example: $R = 50{,}000\,\frac{(230-60)}{60} = 141666$ ohms (.142 megohms) *d.* STANDARDS. AIEE Standards establish the "Normal Insulation Resistance Value" through the formula:

$$\text{Megohms} = \frac{\text{Rated voltage of machine}}{\frac{\text{Rating in kva} + 1000}{100}}$$

This works out as follows:

220-volt motor — .2 megohm
440-volt motor — .4 megohm
550-volt motor — .5 megohm

36. Testing for Grounds

a. D-C WINDINGS. If a low-resistance ground in armatures with commutators has been developed, it may quickly and accurately be located by the following method: A low-voltage current, which is sufficient to give a readable deflection on a galvanometer or millivoltmeter, is passed through the armature windings from one commutator bar to the next. (See fig. 25.) A line is connected from the galvanometer to the ground, and the other galvanometer connection is placed on one of the commutator bars. The supply and galvanometer leads are then passed from segment to segment. When a full deflection is obtained, the coil is grounded.

b. A-C WINDINGS. (1) If a ground develops, a resistance measurement will generally locate the point at which it occurs, unless each phase has two or more multiple circuits. In this case, it may be located more readily by opening one or more of the end-connection joints, and separating the circuits.

(2) A measurement may be taken as shown in figure 26 which represents a single circuit or phase of an alternating current machine, with the ground as shown. If the resistance between A and B is one ohm, between A and G is 0.35 ohm, and between B and G is 0.65 ohm, the location of the ground is 0.35 of the distance between A and B, from A. $\left(\frac{.35}{.35 + .65} = .35\right)$. Since 10 coils are in the circuit, the measurements show that the fourth coil is grounded, counting from A.

(3) In the case of an alternating-current winding, the ohmic-resistance measurement will not always detect a wrong connection, such as a reversed coil, pole section, or phase. Although the copper resistance would be measured correctly, the total winding might be partly reversed and, therefore, inoperative. Such faults can be discovered by a polarity test with direct current.

(4) Short-circuited coils on moderate-size machines can readily be tested by using a wound electromagnetic yoke, or "growler", excited with alternating current. This yoke is placed over a portion of the winding with the coils in their slots. If the current is maintained for a short time,

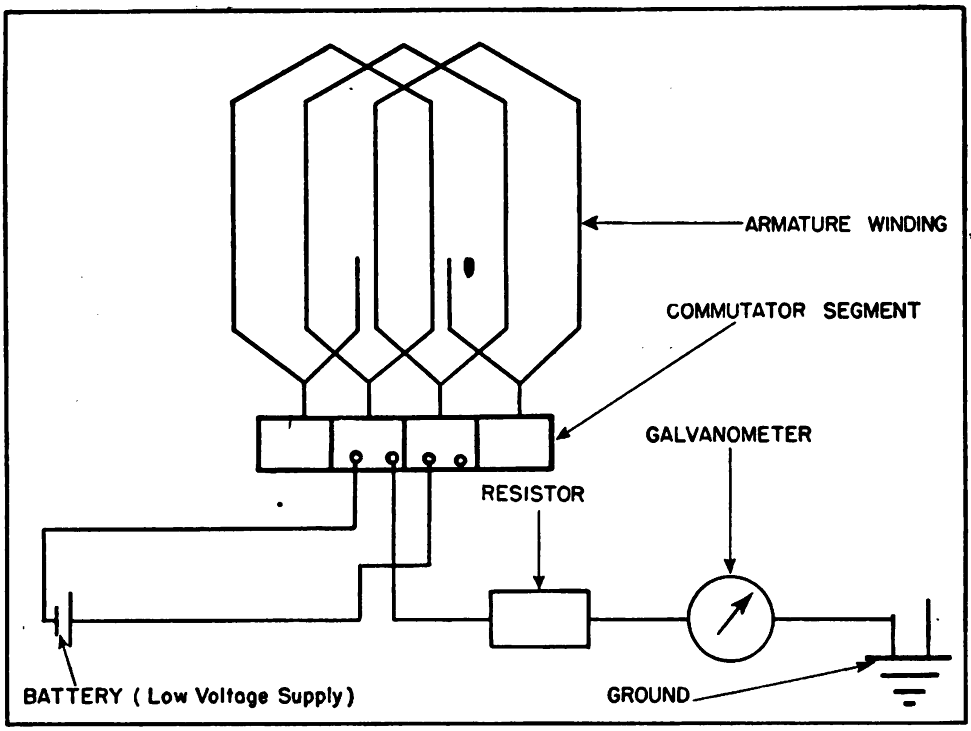


Figure 25. Connection hook-up which can be used to test for grounds.

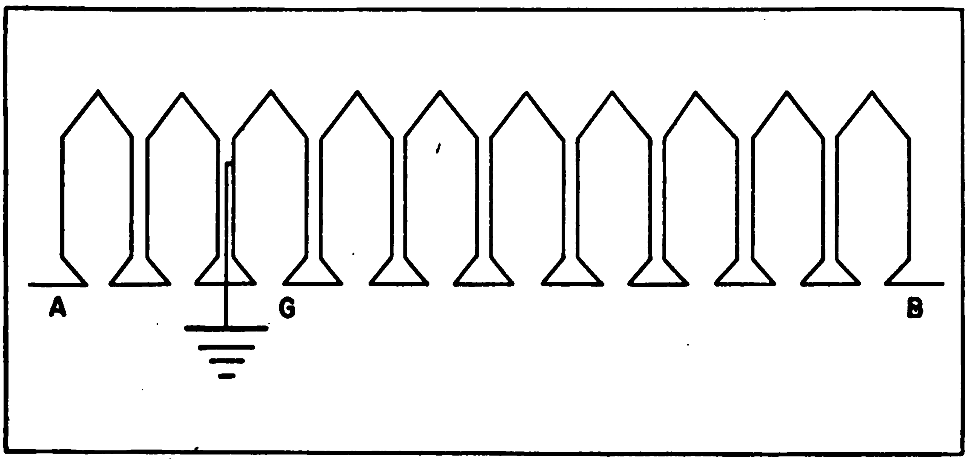


Figure 26. A connection hook-up for testing an alternating current winding with 10 coils in series.

the insulation of the short-circuited section will warm up appreciably, or burn sufficienly to indicate the defective coil.

37. Testing for Polarity

To test for the opposite polarity of alternating poles, bridge two pole tips with a piece of soft iron. If the polarities of the poles differ, the piece will be strongly attracted; if the poles are of the same polarity, there will be no attraction. Polarity can be tested by use of a compass, but the compass must not be carried too near the poles, as it may be demagnetized or even reversed.

38. Voltage Drop

With a given current flowing through the field, the voltage drop on any one coil of a direct-current machine should never be more than 5 percent higher or lower than the average drop, except in the case of single-turn series coils, which may have a variation of 10 percent. In alternating-current machines, no coil should vary more than 5 percent either way from the average. If the drop is outside these limits, the matter should be reported.

39. Record Keeping

When testing a machine, a very careful record must be kept of the resistances of all the windings. For measuring the shunt-, commutating-, and series-field resistances, the voltage-drop method may be used. In recording drop on coils in alternating-current machines, number them in a clockwise direction (facing the collector end), counting as coil No. 1 the coil next to the opening in the field. In direct-current machines, for report purposes, coil No. 1, either main or commutating, is the top coil or the next adjacent in the clockwise direction facing the commutator end.

SECTION IX

BEARINGS

40. General

a. Motors and generators may be selected for different uses according to the types of bearings installed.

b. Ball or Roller Bearings. Motors with ball or roller bearings are used most widely on shipboard, because such bearings are designed to take care of end thrust and permit operation of the machine at any angle, an important advantage when the pitch and roll of a vessel are considered. (See fig. 27.) These bearings are generally grease-lubricated. They are also required in motors for certain types of equipment, such as close-coupled centrifugal pumps, where axial thrust may be imposed on the motor bearings. Standard grease-lubricated ball-bearing motors may be mounted in the vertical position, since such bearings generally have sufficient thrust capacity to take care of the weight of the motor rotor. On applications such as deep-well turbine pumps, which usually impose heavy external thrust loads, special high-thrust bearings may be required.

c. Sleeve Bearings. Sleeve-bearing motors are not designed to carry end thrust. They generally may be mounted at an angle not exceeding 10°, although an angle not exceeding 15° is considered permissible on shipboard. Sleeve bearings, oil-lubricated, are provided with a deep chamber underneath as a reservoir for the oil, together with a fill pipe on the side of the chamber and a drain plug in the bottom. (See fig. 28.)

d. Reference. For detailed information on bearings, see TM 37-265.

41. Operating Precautions

During operation of a motor or generator, it is well occasionally to feel the housing for unusual vibration and to listen for any grinding noise. These symtoms indicate a defective bearing which should be replaced. A rapid rise in temperature or an unusually high temperature also indicates trouble. If a bearing begins to run hot, the load should be taken off the machine. If possible, the machine should be run at low speed until the bearing cools off, in order to prevent seizing of the shaft. Frequently the cause of overheating is excessive grease. If a housing is packed too full of grease there is a churning action causing internal friction and resulting

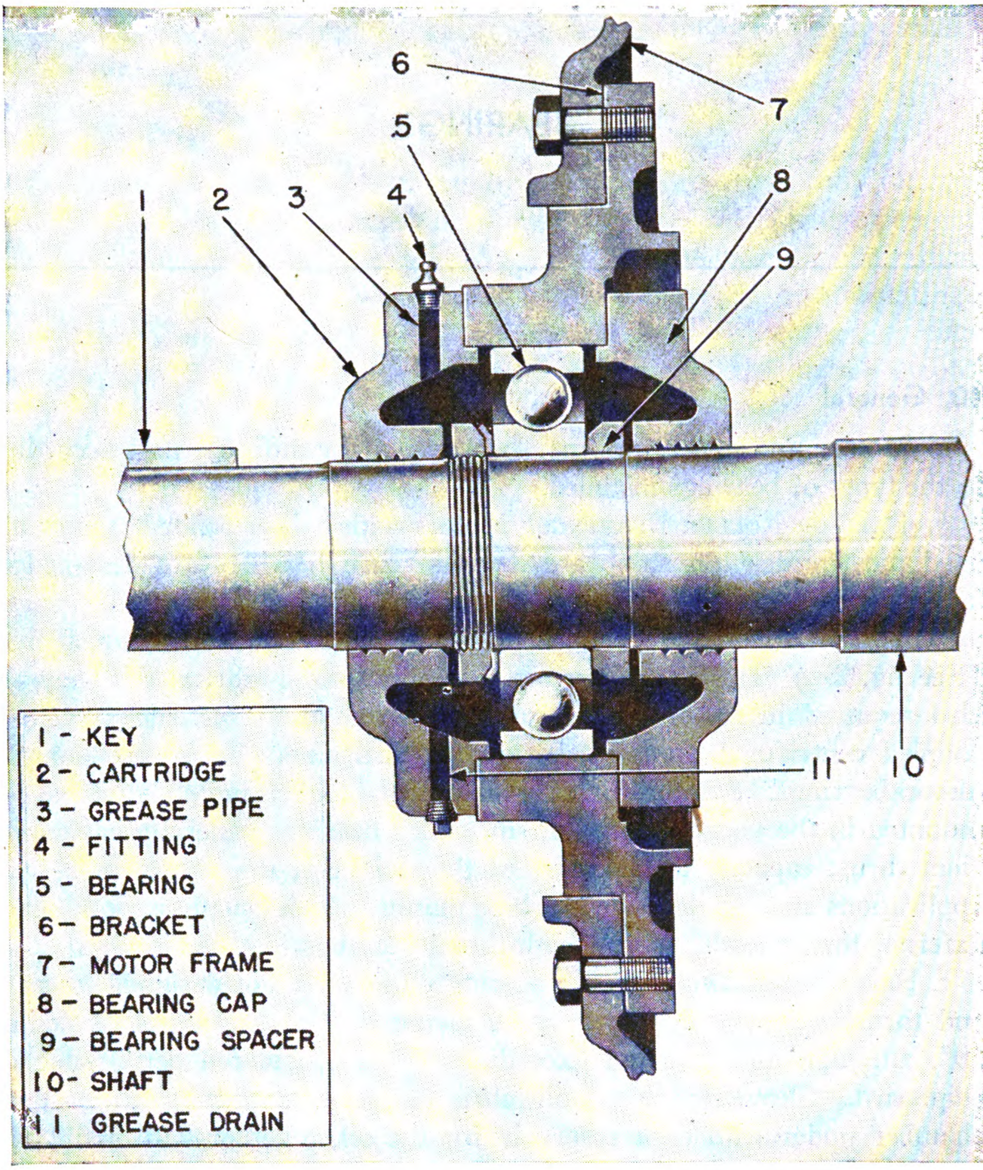


Figure 27. Typical ball-bearing, grease-lubricated type.

in heat that either ruins the grease or causes it to leak into the windings. Other causes of bearing failure are:

a. Insufficient oil or stuck oil rings.

b. Foreign material in the lubricant.

c. Excessive end thrust due to load or magnetic pull on the armature.

d. Excessive side force because the armature is off-center. The cause of the trouble should be found and corrected. (See sec. XIV.) Lubrication of bearings is considered in detail in section XII.

42. Ball Bearings

a. Removal. Ball bearings should not be removed unnecessarily inasmuch as damage may easily result. Dirt or other foreign material will affect the finely polished surface. These bearings should be removed only

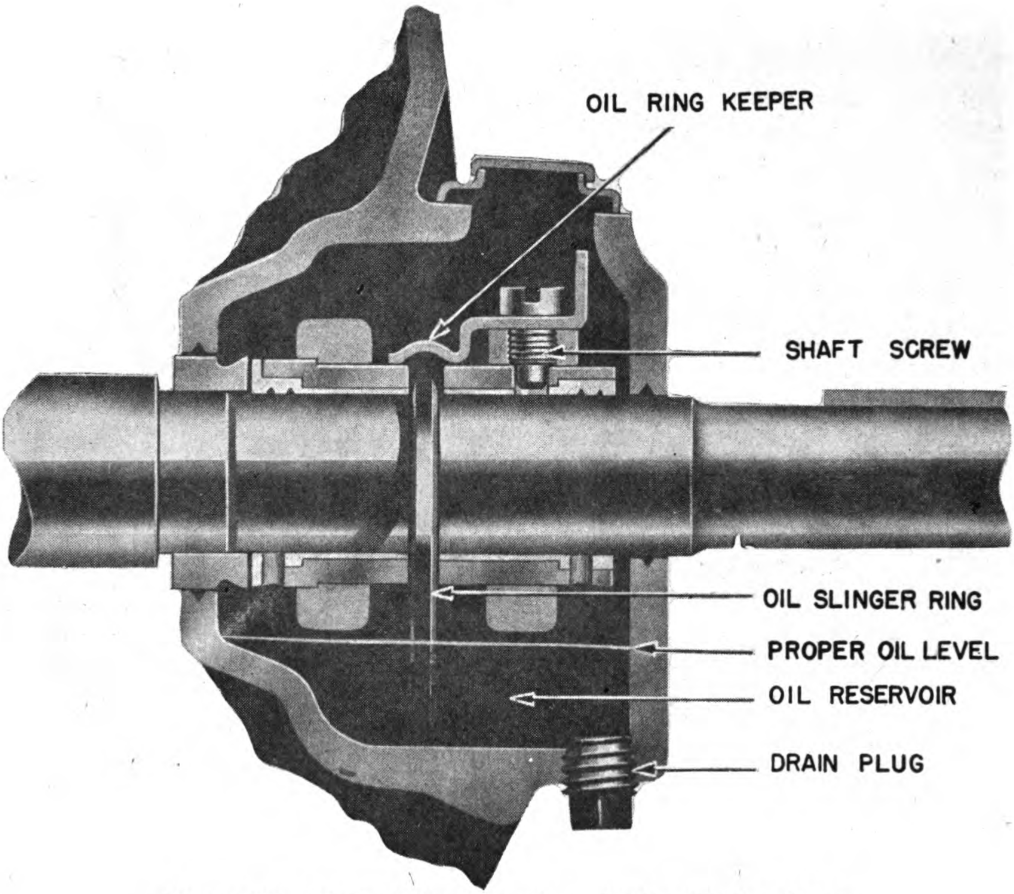


Figure 28. Typical sleeve-bearing, oil-ring-lubricated type.

when they are damaged or when it is necessary to remove the shaft from the rotor. Invariably before removing a ball bearirg, the end bells of the machine are removed, and the rotor, shaft, and bearing assembly are taken from the stator. If the bearing housing happens to have a removable outer cap, the bearing may be removed in some cases without removing the end shield. In general, when removing a ball bearing, *exert pressure only on the inner race.* If this is not possible, be sure that pressure on the outer race is evenly distributed. Pressure should be applied steadily, parallel to the shaft and at a right angle to the bearing. Other details of removal will vary according to the instruments employed. Bearing pullers (figs. 29 and 30) may be used, or the press method or the hammer-and drift-pipe method may be employed.

b. INSTALLATION. A ball-bearing race must be assembled on a shaft so that the race is exactly square with the shaft. Pressure must be applied to the race evenly all around, and only on the inner race. Pressure or light tapping should suffice. Heavy pounding must be avoided. The bearing should not be forced on a shaft that is badly worn, or is too large. Finally, care should be taken that the grease retainers and oil slingers are in place. After installation, the bearing should be rotated by hand to see if it rolls freely and without noise. Protective covers should be tight to prevent entrance of dirt.

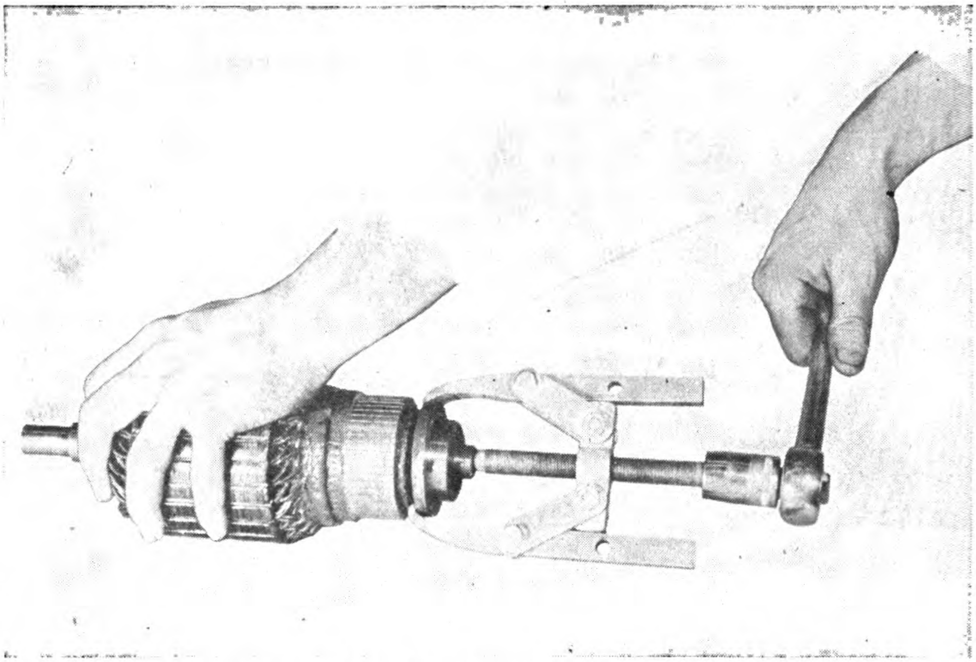


Figure 29. Pulling bearing with a hook-type puller.

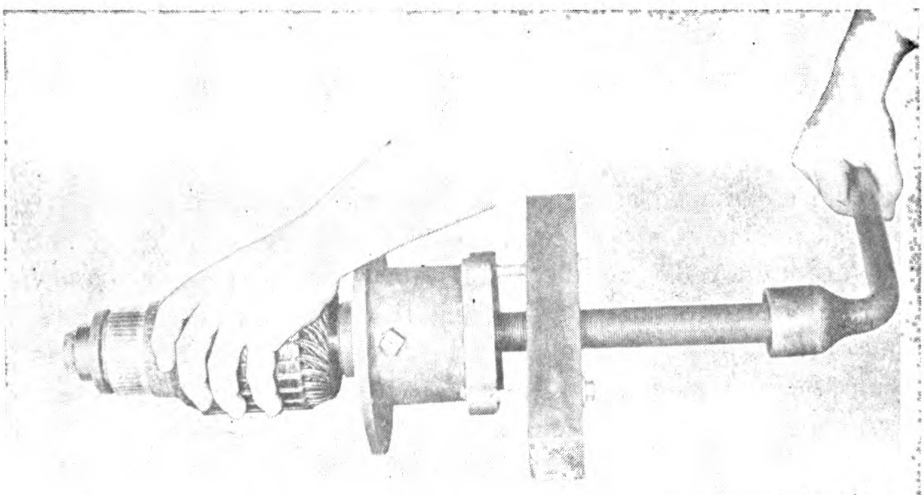


Figure 30. Pulling bearing with a bar type puller.

43. Sleeve Bearings

a. MEASUREMENT OF AIR GAP. Measurement of air gap is made primarily as part of maintenance procedure to indicate sleeve-bearing wear. Quiet operation, adequate torque, desired power factor and efficiency, as well as motor temperature, depend upon a reasonably concentric air gap. Measurements made at the lowest part and on the sides will usually indicate any nonconcentricity. To measure air gap, preferably use a tapered air-gap gauge. Air gaps of larger machines, such as synchronous motors and generators of low speed design, and in D-C machines, are substantially greater than for smaller machines, particularly induction motors.

However the air gaps should be within 10 percent as measured under like poles. On large, open machines where the air gap is accessible, revolving air-gap measurements are made by taking the measurement at one reference point on the rotor and then revolving the rotor to measure four points on the stator. Stationary air-gap measurements are made by measuring four points on the rotor from one point on the stator.

b. Removal. Sleeve-bearing linings seldom need to be removed. When necessary, it is desirable to drain all oil (in order to avoid spillage and waste) and to remove the baffle inside the end shield, the oil-well cover plate, the oil-ring clip, and the oil ring, before tapping out the bearing lining. To remove the lining, one of the following methods is commonly employed:

(1) A relatively simple method of removing bearing linings involves the use of a piece of steel key stock and a short length of round bar or pipe slightly smaller in diameter than the outer hole in the bearing housing. The key stock must be thin enough to enter the housing at an angle, and just long enough to bear on the end of the steel shell. Pressure should be applied to this key at points as far from the center as possible.

(2) The split-arbor type of bearing-lining remover has a projection on one side which fits into the oil ring slot. This arbor is particularly useful in removing linings of 2 inches or larger diameter. Pressures required to remove small linings are well within the range of hand arbor presses.

(3) For the larger bearing sizes, pullers may be necessary.

c. Installation. Sleeve bearings should be pressed in place without pounding or distortion. Check the end play of the rotor or armature. Be sure that the bearing is properly located with reference to the lubricating system, and that the oil ways are clean and unobstructed by burrs. Make sure, also, that slingers and retainers are in place and have free play. After completing the assembly, turn the bearing by hand to detect any binding. If binding is apparent, check the end-bell fit to see that the end bell is pulled up tight to the frame on all sides. A chip or a burr can cause misalignment.

44. Handling Bearings

The following precautions should be observed when handling bearings:

a. Handle bearings with clean, dry hands or clean canvas gloves. Corrosion may be caused by handling a bearing with hands that are perspiring. Fingerprint patterns are sometimes found rusted into bearing surfaces.

b. Work with clean tools in clean surroundings.

c. Keep bearings in their packages or in oil-proof paper until they are to be installed.

d. Use clean rags to wipe bearings. Do not use linty cotton waste or dirty cloth.

e. Make sure not to scratch or nick bearing surfaces.

f. Do not spin bearings with compressed air.

g. Before replacing bearings, clean the inside of the housing and remove all outside dirt.

45. Cleaning Installed Ball Bearings

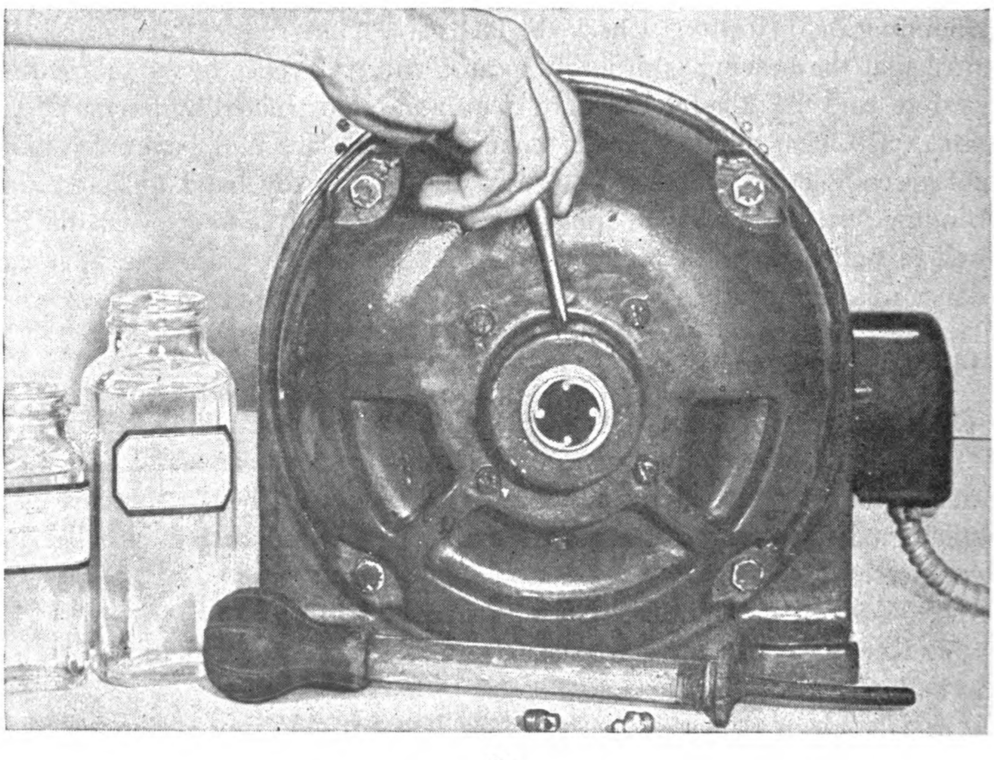
a. HORIZONTAL STANDARD MACHINES. To clean installed bearings of standard machines operating at an angle not exceeding 15° from the horizontal (except totally inclosed, fan-cooled motors), proceed as follows:

(1) Wipe clean the housing, pressure gun, and relief fittings, and then remove both fittings. Keep dirt out of bearings when greasing and cleaning. If a bit of abrasive gets into a bearing, it might not be removed even with the most thorough cleaning.

(2) With a clean screw driver or a similar tool, free the pressure-fitting hole (in the top of the bearing housing) of hardened grease. (See fig. 31①.)

(3) During the cleaning process, free the relief-plug hole in the bottom of the housing. This permits expulsion of the old grease. (See fig. 31②.)

(4) Fill a syringe with grease solvent and inject some into the bearing housing through the pressure-fitting hole while the machine is running or being rotated by hand. This solvent may be a light mineral oil heated to a temperature of 165° F. (60° C.), or carbon tetrachloride. (Kerosene or safety-naphtha may be used in emergencies.) Carbon tetrachloride is



①
Figure 31. Cleaning a ball bearing motor.

noninflammable, does not require heating, and dissolves grease more quickly than hot oil. When using it however, be careful to remove all traces from the bearing housing. Do not allow it to remain in contact with insulated windings. The room should be well-ventilated. (See fig. 31③.)

(5) As the grease becomes thinned by the solvent, it will drain out through the relief hole. Continue to add the solvent until it drains out fairly clear. (See fig. 31④.)

(6) Replace relief plug and inject solvent until it splashes in filling hole. Allow solvent to churn for a few minutes. Remove plug and drain, shielding the ventilating openings to keep solvent out of windings. Repeat operation until solvent runs clean. (See fig. 31⑤.)

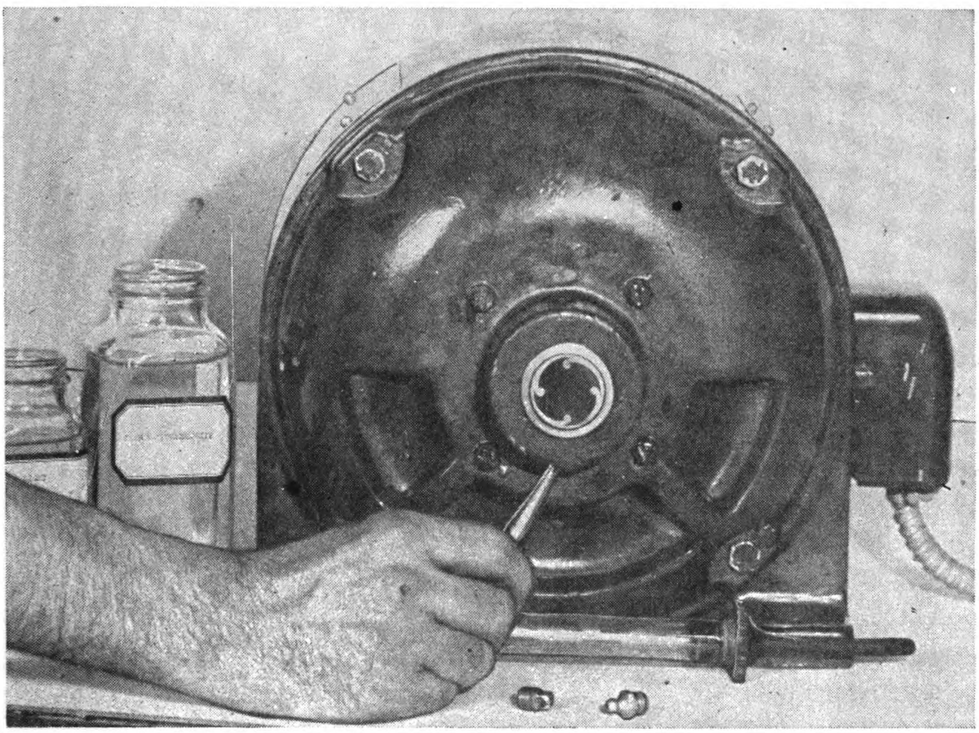
(7) Replace fittings.

b. Totally Inclosed Fan-cooled Motors. The bearing at the pulley end may be flushed as described above. To clean the fan-end bearing, first remove the fan cover and fan; then remove the drain plug at the bottom of the housing.

c. Vertical Motors. The bearings and housing of vertical motors cannot be cleaned except by disassembly.

46. Cleaning Dismounted Ball Bearings

In cleaning dismounted bearings, use plenty of clean rags for wiping and handling. Do not use cotton waste as the short threads may get into the bearings. After bearings have been cleaned, they should immediately



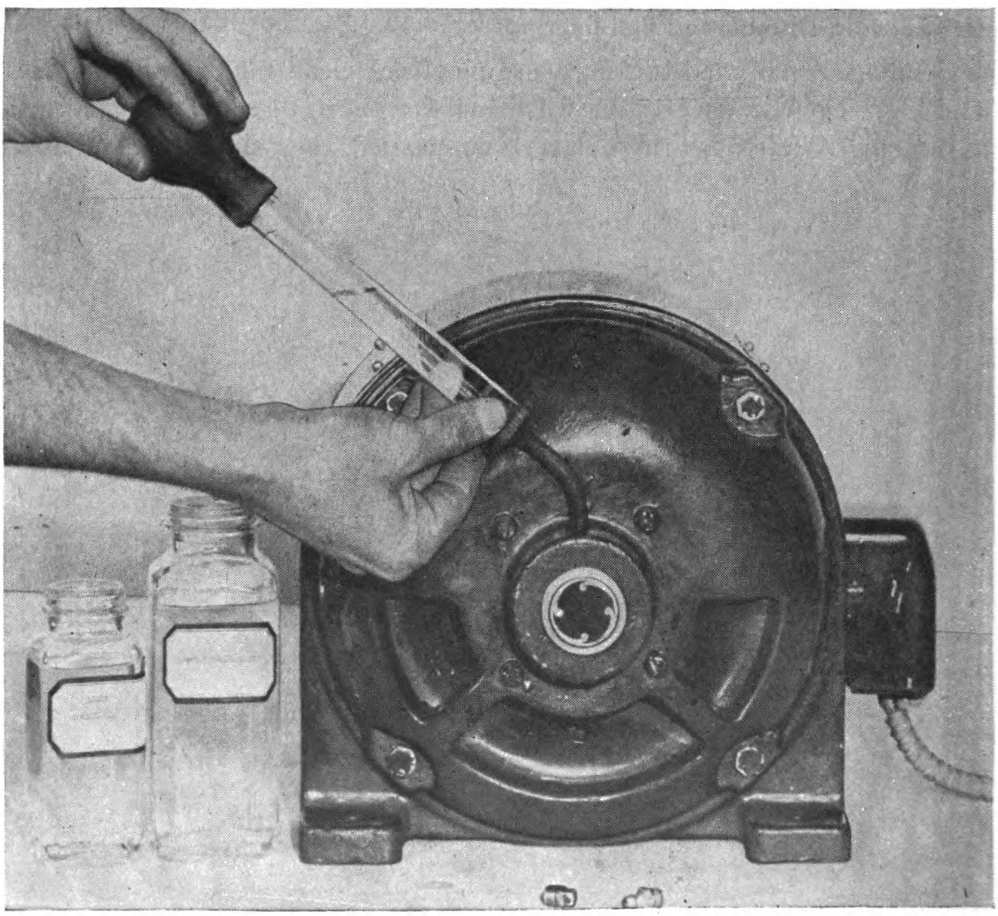
②

Figure 31. Cleaning a ball bearing motor—Continued.

be protected from corrosion and dirt by coating them with oil or light-bodied grease, and wrapping them in oilproof paper. Where possible, dismounted bearings should be placed in a metal basket and suspended in a container of some clean, cold petroleum product. There they should soak for several hours. If no metal basket is available, the bearings may be suspended in the solution by a length of wire. Do not let the bearings rest on the bottom of the container. If the lubricant is badly oxidized, the bearings should be soaked in a light oil heated at 180° to 200° F. (68° to 79° V.), and the basket or wire sloshed through the oil slowly as often as possible. In cases of extreme sludging, the bearings may be soaked in a mixture of alcohol and kerosene or safety-naphtha.

47. Cleaning Sleeve Bearings

Old oil should be drained from the housing at least every year. Remove the drain plug from the bottom of the frame, where available, and flush out any foreign materials that may have accumulated. From motors not equipped with drain plugs, remove the end-shield bolts, rotate the end shield, and clean the bearing before reassembling the end shield and adding new oil.



③

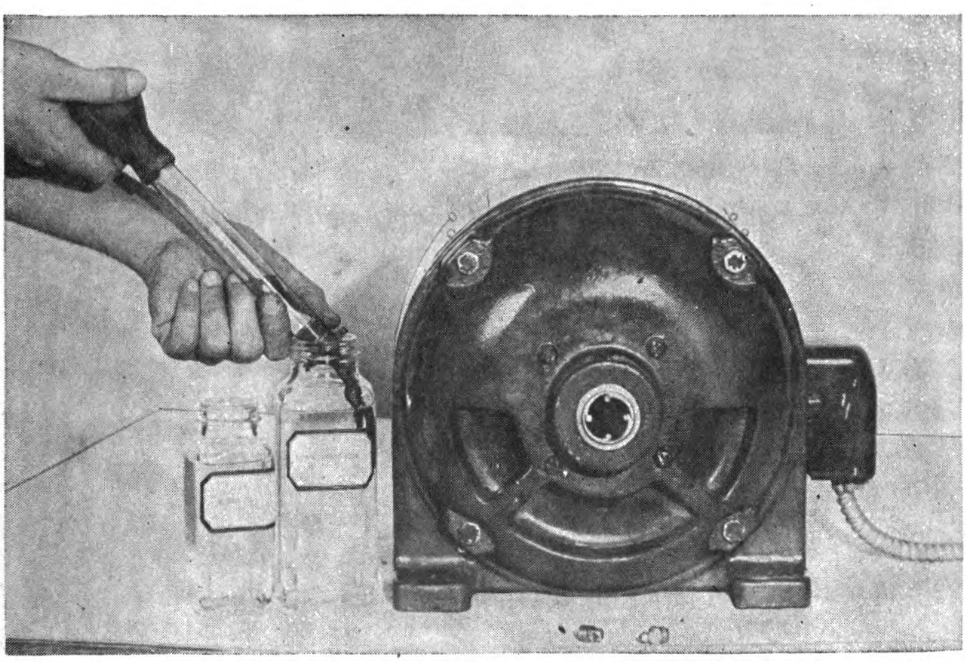
Figure 31. Cleaning a ball bearing motor—Continued.

48. Storing Bearings

a. Cleaning Before Storing. Bearings should be cleaned thoroughly before storing, even when storage is to be of short duration. This will prevent corrosion underneath the protective coating or rust preventive applied on bearings prior to storage.

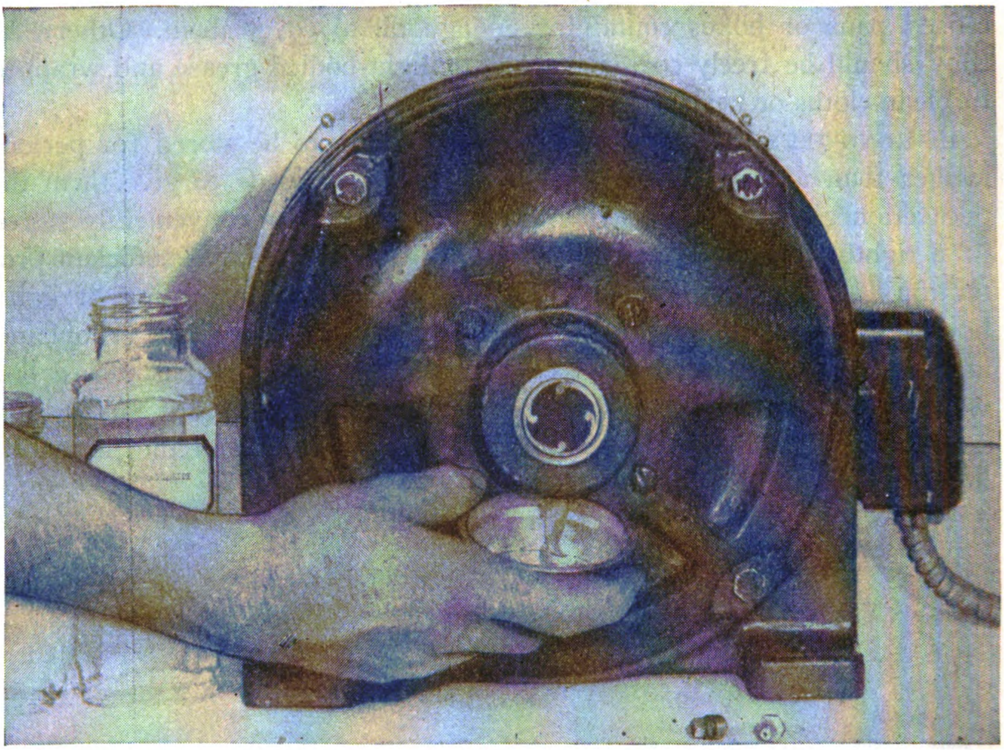
b. Storage Overnight. Bearings may be removed from applications one day, and the opportunity to reinstall them not occur until the day following. Overnight protection is necessary because in humid climate severe rusting can take place in that short time. If bearings are free from shafts or housings and are not too large, they can best be stored in closed pans or boxes containing enough oil to cover them. Otherwise, they should be freely coated with oil or light-bodied grease and wrapped in clean cloths or newspapers.

c. Long-term Storage. When bearings are to be stored for periods longer than a few days, every effort should be made to give them the protection given a new bearing. If a bearing can be conveniently stored in a tightly covered pan of oil, as described above, that is sufficient protection. If not, the bearing should be covered with a coating of light-bodied grease or petrolatum, wrapped in an oilproof paper or cellophane, and placed in a pasteboard box or carton. Storing in a pasteboard box without oilproof paper or wrapping in newspaper is unsatisfactory. In such cases the oil is quickly absorbed by the paper, and the protection against corrosion is soon lost.



(4)

Figure 31. Cleaning a ball bearing motor—Continued.



(5)
Figure 31. Cleaning a ball bearing motor—Continued.

SECTION X

DRIVING DEVICES

---

49. Drive Belt

a. Inspection. The drive belt should be examined regularly for wear, breaks, and adjustment. A worn belt becomes bright and smooth, tending to ride the bottom of the pulley or to slip when under load. Continuous rubbing of the side of a belt wears down the edges and decreases the efficiency of its drive. Excessive friction from contact with abrasive dust causes melting and internal break-down of a rubber belt. The presence of stray lubricant near a rubber belt should be checked; oil and grease soften and deteriorate rubber. A belt which runs loose may snap in two. Low tension causes reduced and unsteady output. Unusual tautness brings on rapid wear of both belt and bearing.

b. Replacement and Adjustment. If a belt shows indications of wear and breaking, or if it is separating at points previously vulcanized, it should be replaced. To check the adjustment of a short drive belt, deflect the belt at a point halfway between the drive pulley and the driven pulley. Deflection occurring at this point should be between three-quarters of an inch and 1 inch. Adjust the length of the belt as required or replace with the correct size. Avoid use of a heavy screw driver in prying a belt into position; the adjustment may loosen too much or the internal cords of the belt may break as a result of the strain. When oiling the bearings, wipe off excess oil so that there is no possibility of slipping or damage to the belt. Leather belts should be dressed occasionally with a suitable polish, such as Dubbing.

50. Pulleys

If a pulley is cracked or loose, it should be replaced or tightened.

51. Coupling Drive

On coupling-drive machines, inspection should be made at intervals to insure that the coupling bolts are tight and securely locked with lock washers in good condition. Worn couplings should be replaced. To check alignment, insert feelers at four places in the coupling joint before pulling up the coupling bolts.

52. Chain Drive

On chain-drive machines, chains should be inspected for stretch in the same manner as prescribed above for drive belts. To adjust the chain properly, one or more links may be removed. Worn links or chain should be replaced. If there is evidence of excess lubricant, examine the chain housing. The housing should be cleaned at regular intervals.

SECTION XI

SPECIAL CONSIDERATIONS FOR SPECIFIC TYPES OF MOTORS

53. Squirrel-Cage Induction Motors (fig. 32)

a. LOOSE AND BROKEN BARS. Overheating and violent jarring ruin squirrel-cage rotor windings by breaking bars and separating them from the end rings to a point where the motor will not operate satisfactorily. A broken bar or joint may be located by a "growler." (See par. 36*b* and app. IV.) Where excessive vibration or repeated shocks have loosened bars in large motor rotors, the condition should be reported so that the bars may be firmly rewedged.

b. IMPEDANCE TEST. To test for open-rotor bars, apply 25 percent voltage or less to one stator phase (only sufficient voltage to give a suitable ammeter reading is required). Turn the rotor very slowly by hand or mechanical means, and observe variation in stator current. Any current variation in excess of 3 percent usually indicates a defective rotor winding with open bars. If a doubt exists, an additional check can be made by turning the rotor one revolution and counting the number of ammeter pulsations. If caused by open bars, the number of pulsations will be equal to the number of poles in the stator winding.

54. Wound-Rotor Motors (fig. 33)

a. VOLTAGE TESTS. If a wound-rotor motor is not operating satisfactorily, a voltage-ratio test may indicate the trouble. With collector rings open-circulated, apply a reduced voltage to the stator and raise it gradually until conditions of normal voltage and normal frequency are obtained. Never raise the brushes to open-circuit the collector rings. Record the current in each stator line, and the voltage between each combination of the collector rings (1-2, 2-3, 3-1, etc.). If stator currents or rotor voltages are unbalanced, turn the rotor to other positions and observe whether the unbalance shifts from one phase to another. This procedure will indicate whether the unbalanced condition is due to an irregularity in the stator or in the rotor. Unbalanced stator currents sometimes occur under normal conditions, but unbalanced rotor voltages usually indicate a defect.

b. CAUTION. On some high-flux-density machines, sufficient core-loss

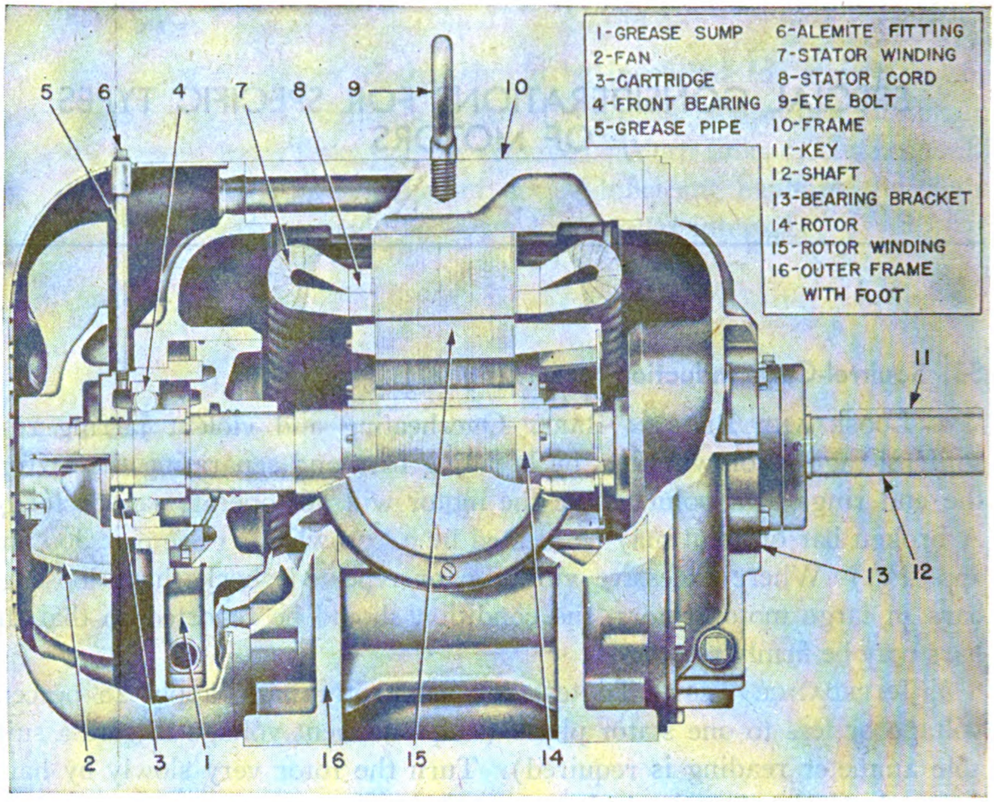


Figure 32. A fan-cooled, squirrel-cage motor.

torque is developed to cause the rotor to turn. It is not safe to hold the rotor stationary with the hands, because a short circuit may occur in the rotor windings and cause the rotor to attain full speed quickly.

55. Synchronous Motors

a. Leads. Leads from collector rings to fields, and from field to field, are subjected to centrifugal force. They should be fastened securely with all the clips that come with the machine. Any broken or missing clips or leads should be replaced.

b. Separate Stators. In many applications, the shaft and bearings are part of the driven machine, while the stator is on a separate foundation or support. Settlement or gradual misalignment may occur, and can be discovered early by the air-gap measurement.

56. Direct-Current Motors (fig. 34)

a. Location of Neutral on Reversing Motors. Before brushes are sanded, they are set on mechanical neutral, as described in paragraph 20. Reversing motors, however, require further adjustment to neutral, or to the brush position at which the motor will run in either direction of rotation at the same speed and load with the same shunt-field current. Before attempting to set electrical neutral, it is necessary to have a good brush

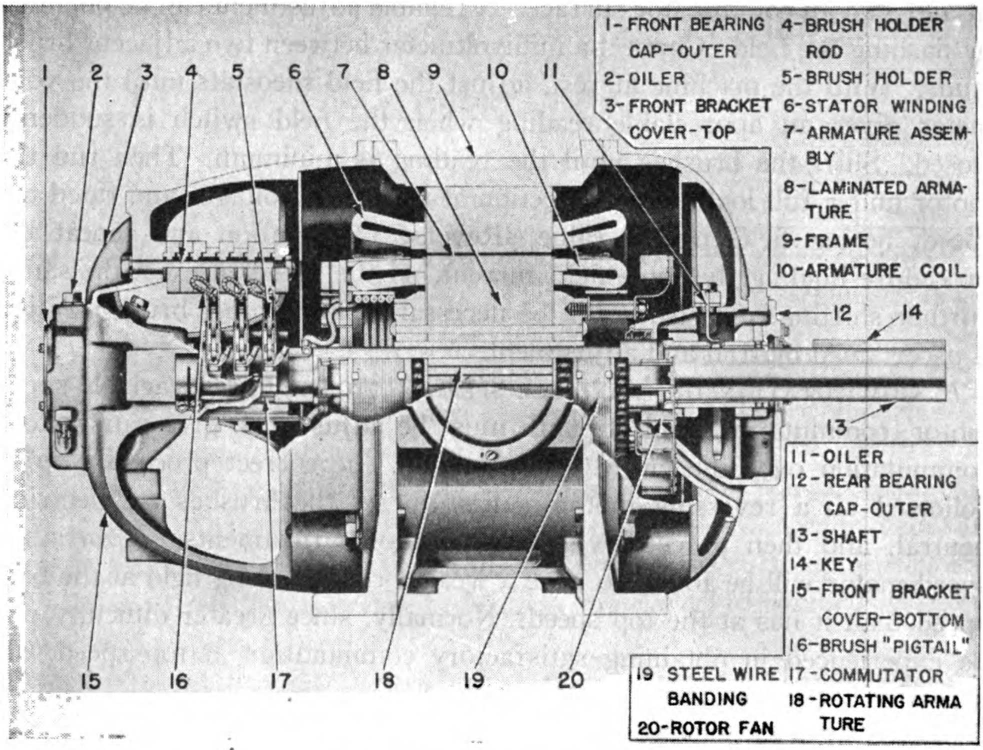


Figure 33. Open-construction, wound-rotor motor.

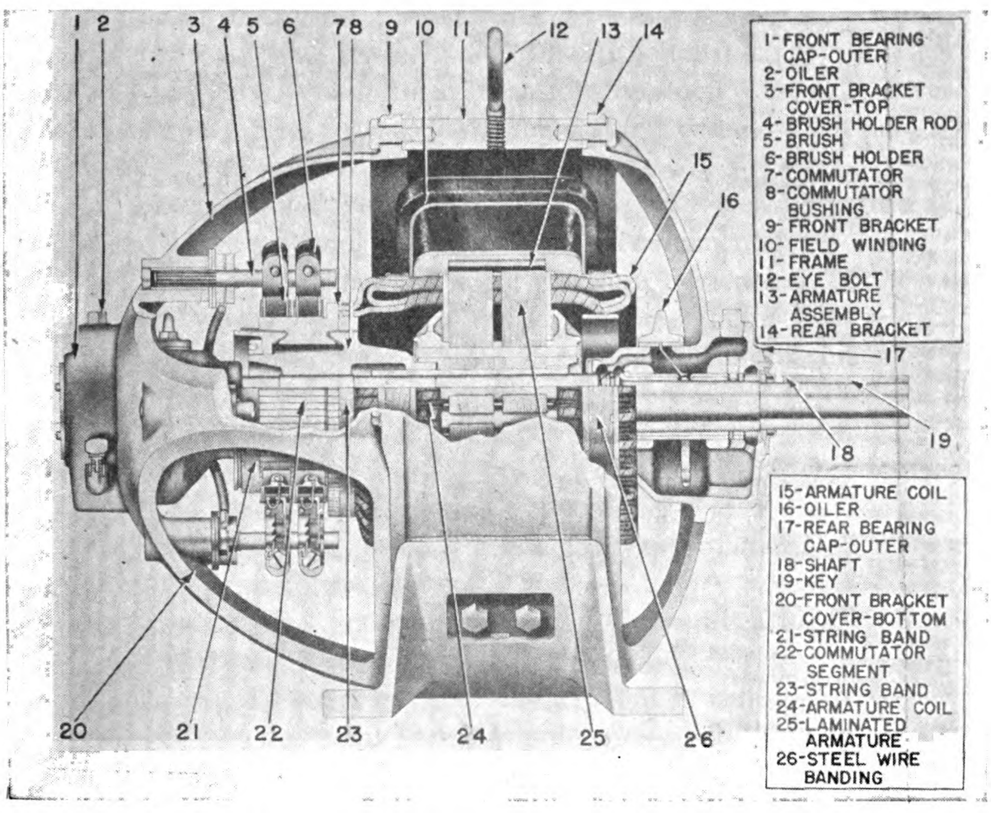


Figure 34. Open-construction D-C motor.

fit and smooth commutator surface. A reliable adjustment can be obtained by flashing the field. Connect a millivoltmeter between two adjacent brush studs. With the machine at rest, adjust the field-rheostats until the voltmeter gives an appreciable reading when the field switch is suddenly closed. Shift the brushes until the reading is minimum. Then run the motor under full load in one direction at rated line voltages and rated top speed, noting field-current value. Reverse the rotation and repeat the procedure holding the same field current. If the speeds are not the same, further shifting of brushes will be necessary. The proper brush position is ascertained by trial and adjustment.

b. Commutation on Variable-speed Motors. For a variable-speed motor, commutating field strength must be adjusted to give satisfactory commutation over the entire speed range. The correct procedure to be followed on a reversing motor is first to set the brushes on electrical neutral, and then proceed with commutation adjustments. A variable-speed motor will be found to have a weaker commutating field at the base speed than it has at the top speed. Normally, since greater difficulty will be experienced in obtaining satisfactory commutation at top speed, observation should be started at that speed.

SECTION XII

LUBRICATION

57. General

Proper lubrication of motors and generators is of primary importance to their continuous operation. *The instructions contained in the War Department Lubrication Order applying to a particular piece of equipment should be followed literally. In the absence of such an order, and pending its publication and distribution, the general instructions presented in this section will be observed, subject to such specific manufacturer's instructions as may be available.*

58. Sleeve-Bearing Machines

a. One of the most important considerations in sleeve-bearing lubrication is the use of a good grade of oil. The oil should have a viscosity of about 200 seconds Saybolt at 100° F. (24° C.). This viscosity is suitable for ordinary operating temperatures and corresponds to U. S. Army Specification 2-104 B, Symbol OE 10. Although turbine oil rather than automotive oil is recommended, occasionally where unusually severe service conditions exist, such as high temperatures or heavy belt pull, a somewhat heavier oil may be preferable.

b. Lubricating Procedure. Procedure will vary with the type of machine. The following instructions are fundamental:

(1) Whenever the need is apparent from evidence of dirt or sludge, clean out the bearing housing (par. 47) before refilling with lubricant.

(2) Where an oil gauge is used on ring-lubricated machines, check the oil level and, if necessary, stop the machine and fill to the line on the gauge. (See fig. 35.) Oil-filler gauges should generally be filled to within one-eighth of an inch from the top. Do not fill to overflow. Make sure no oil is leaking around the filler pipe.

(3) When the journal size is less than approximately 2 inches, stop the machine to check the level.

(4) If motors are equipped with waste-packed bearings, reoil at regular inspection intervals.

(5) Do not oil bearings while the machine is running. Otherwise the oil will get into and damage the windings and will "slop over" the floor, creating a fire hazard, as well as an accident hazard.

(6) If oil is observed creeping along the shaft toward the windings, report the condition.

(7) Special lubricating systems, such as forced lubrication, flood and disk lubrication, are described in Technical Manuals on the specific equipment.

59. Ball-Bearing Machines

a. Type of Lubricant. Ball bearings are generally grease-lubricated; some, however, are oil-lubricated. The choice between a grease and an oil is dependent entirely upon the bearing housing.

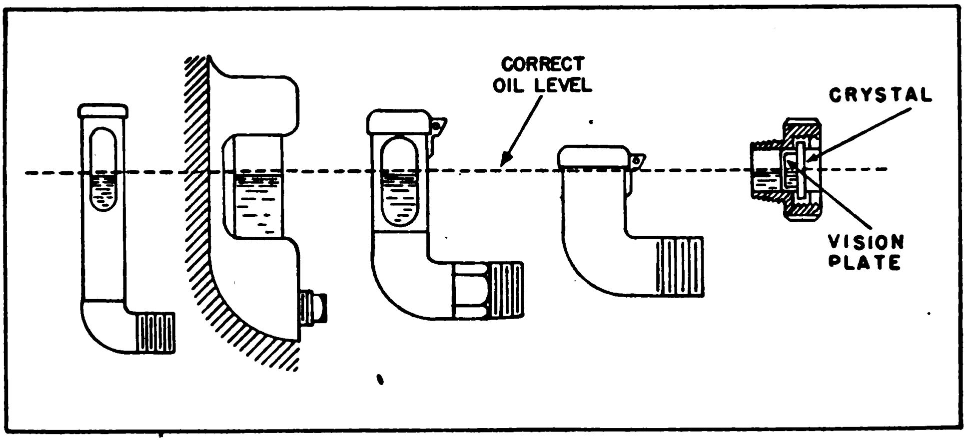


Figure 35. Correct level for various types of oil gauge.

Table of lubricants.

Standard product nomenclature	Specification	Product symbol
Lubricating oil		
Oil, engine	U. S. Army	
	2-104 B	OE 10
	2-104 B	OE 30
	2-104 B	OE 50
Grease		
Grease, general purpose	U. S. Army	
	2-106	CGO
	2-107	CG1
	2-108 A	WB

In general, a lubricant of higher viscosity should be used for higher operating temperatures and one of lower viscosity for high-speed operation. Greases used for high-speed operation should be selected for their ability to cling to rapidly rotating parts. The danger in operation at great speed is that the lubricant will churn or foam, thus raising the operating temperature as well as reducing the value of the lubricant. In general, greases are more suitable than oils where reversing or intermittent operations are encountered.

b. Lubricating Procedure. One of the most important jobs in the maintenance of ball-bearing motors and generators is to determine the correct amount of lubricant in the bearing housing. Too much lubricant, just as too little, will cause overheating and other bad effects. (See par. 41.) Where machines have ball bearings arranged for greasing with a pressure gun, proceed as follows:

(1) When necessary, clean out the bearings in accordance with the instructions in paragraph 45. The pressure-relief method of greasing machines tends to purge the bearing housing of used grease. Complete cleaning of bearings therefore is required at infrequent intervals only.

(2) Wipe the pressure-gun fitting, the bearing housing, and the relief plug to make sure that no dirt gets into the bearing with the grease. (See fig. 36①.)

(3) Always remove the relief plug from the bottom of the bearing before using the grease gun. This prevents putting excessive pressure inside the bearing housing where it might rupture the bearing seals. (See fig. 36②.)

(4) With a clean screw driver or similar tool, free the relief hole of any hardened grease, so that any excess grease will run freely from the bearing. (See fig. 36③.)

(5) While the machine is running, add grease with a hand-operated pressure gun until the grease begins to flow from the relief hole. This tends to purge the housing of old grease. If it should prove dangerous to lubricate the machine while running, follow this procedure with the machine at a standstill. (See fig. 36④.)

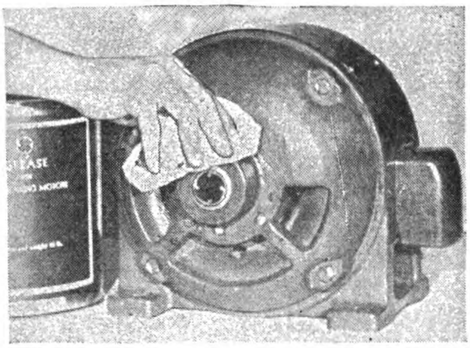
(6) Allow the machine to run long enough after adding the grease for the rotating parts of the bearing to expel all excess grease. (See fig. 36⑤.)

(7) Replace the relief plug and wipe the outside housing clean. (See fig. 36⑥.)

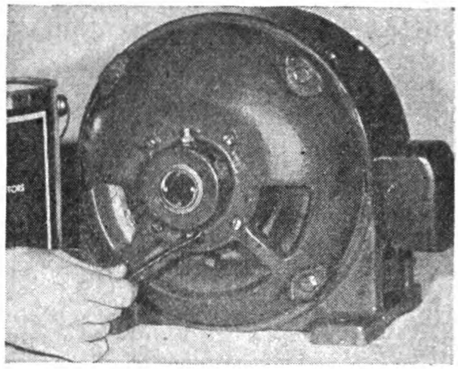
60. Special Types of Motors

a. Standard Fractional-horsepower Motors. Such motors often have sealed ball bearings without pressure fittings. Manufacturer's sealed-for-life bearings should never be relubricated, but should be replaced when they fail.

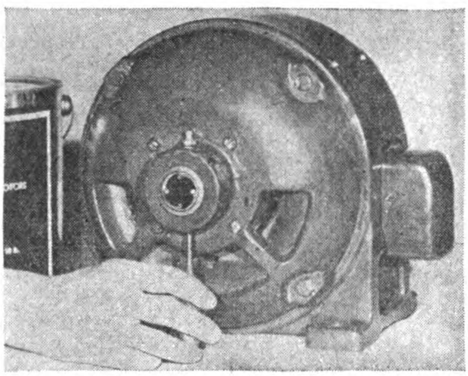
b. Face Type Motors. Motors having face type end shields to permit end-shield connection to the driven machine are provided with a pressure-relief greasing system, but such motors require a procedure slightly different from that prescribed for open motors. Grease is added through a grease fitting screwed into the upper end of a vertical passage in the end shield. For pressure relief, a second vertical passage is provided from the bottom of the housing to the bottom of the end shield where a pipe plug is inserted. This pipe plug must be removed before greasing. While new grease is being added with the pressure gun, determine when the grease begins to discharge from the housing proper; do not wait for grease to appear at the lower end of this passage. No more grease should be added. Replacement of the relief plug completes the greasing operation. It is preferable to run the motor during the greasing process.



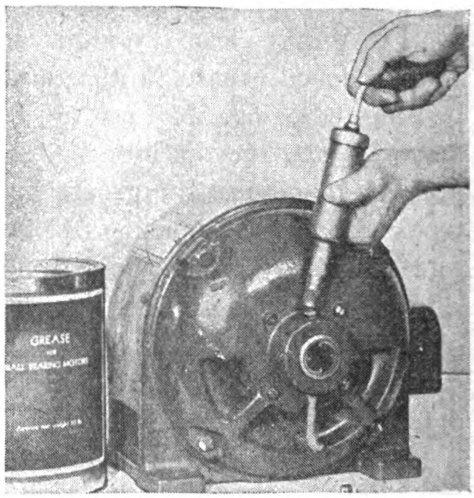
①



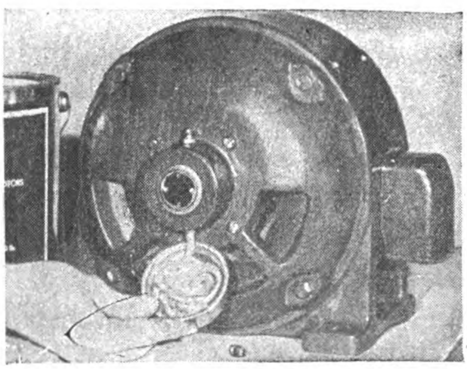
②



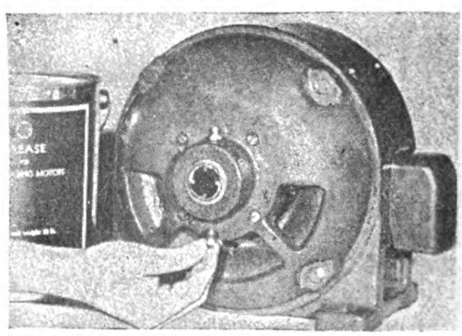
③



④



⑤



⑥

Figure 36. Greasing ball bearings with a pressure gun.

c. Flange Type Motors. Motors having flange type end shields may, in general, be greased like a standard open motor, provided care has been taken to leave the grease fittings accessible. It is preferable that the motor be greased while running. However, if the driven machine presents obstructions, or renders the operation unsafe, the procedure given in paragraph 59 for greasing motors not in operation should be followed. If mounting renders inaccessible the relief plug on the housing, the use of a pressure gun is not recommended, and the procedure given in *f* below for motors not equipped with pressure-relief lubrication systems should be followed.

d. Vertical Motors. Vertical motors which have grease-lubricated ball bearings are provided with pressure-gun fittings and pressure-relief plugs. It is important to note, however, that the design of many vertical motors precludes the location of the relief plug at a point where it can be effective. For this reason, it is recommended that grease be added very sparingly when using a pressure gun; and it is preferable that the motor be disassambled and the housing repacked with the proper amount of grease to insure effective lubrication. Since flushing liquids cannot be drained from the housing while the motor is in the vertical position, it is necessary to disconnect the motor from the load and disassmble it in order to cleanse the bearings thoroughly.

e. Totally Inclosed Fan-cooled Motors. Lubricate as follows:

(1) Remove the horizontal excess-grease pipe. Clean out any old hardened grease that is in the pipe. (See fig. 37①.)

(2) Replace this pipe, and with a pressure gun, add grease to the housing through the vertical pipe. (See fig. 37②.)

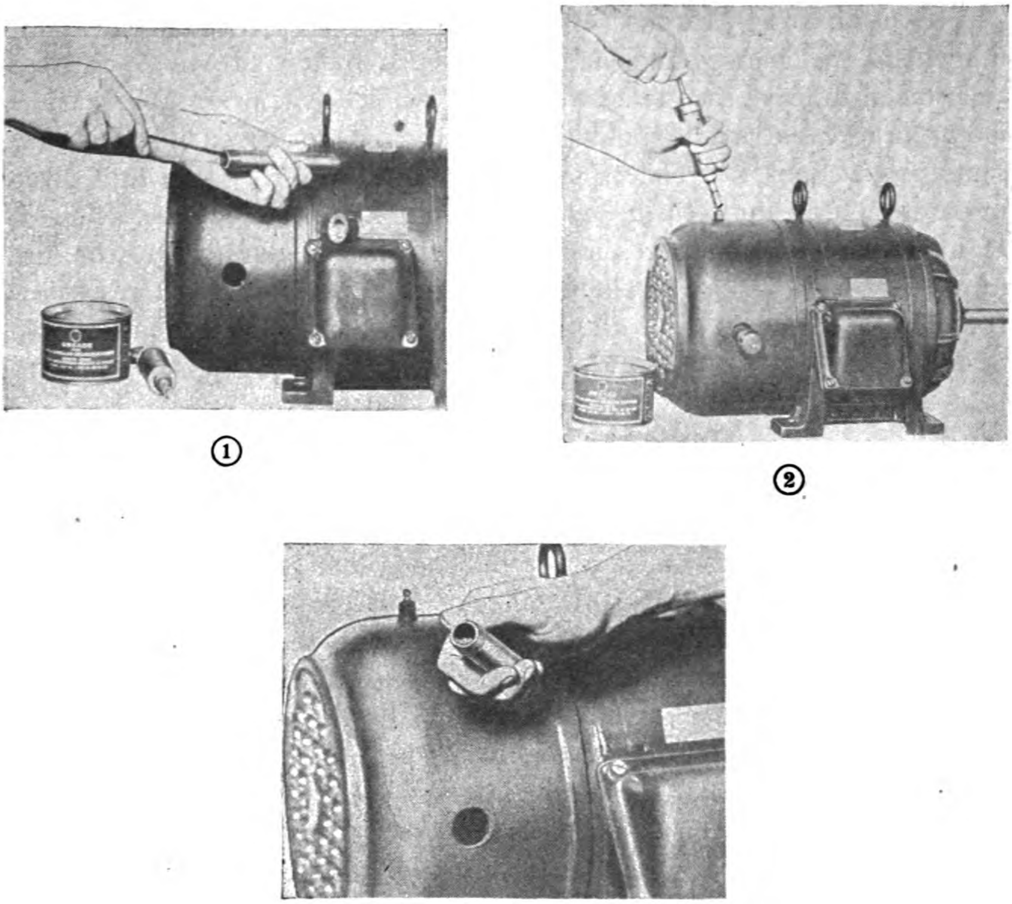
(3) When grease appears at the inner end of the horizontal pipe, no more grease should be added. The pipe should then be cleaned and replaced. (See fig. 37③.)

f. Motors Without Pressure-relief Systems. Under ordinary operating conditions the grease with which the bearing housing of these motors is packed before leaving the factory is sufficient to last about a year. When the first year of service has elapsed, the old grease should be removed and the bearings supplied with new grease each year, or oftener if conditions warrant. To do this:

(1) Disassemble the bearing housings and clean the bearings and the inside of the housings and housing plates, or caps, with carbon tetrachloride.

(2) When thoroughly cleansed of old grease, reassemble all parts except the outer caps, or plates. Apply new grease over and between the balls, either by hand or from a tube. The grease should fill approximately one-half of the free space in the housing.

(3) When reassembling the motor, any V-grooves that are found in the housing lip should be refilled with grease, preferably a fibrous, high-



(1) (2) (3)

Figure 37. Lubrication of a totally inclosed fan-cooled motor.

temperature sealing grease, which will act as an additional protective seal against the entrance of dirt or foreign particles.

The bearing housings of these motors were not designed with a view to making them adaptable for pressure-relief lubrication. However a fair degree of success can be obtained by adding grease fittings to a horizontal motor, provided it has an accessible plug in the bearing housing itself that can be removed during the greasing operation. (Outlet pipes will generally not provide pressure relief.) The housing must be properly relieved of internal grease pressure in order that it may be safely greased with a pressure gun.

61. Gear Portion of Gear Motors (fig. 38)

A pure oil, U. S. Army Specification 2-104 B, Symbol OI 50, should be used for normal ambient temperatures around 25° C. No greases, extreme-pressure lubricants, or other compounds should be added unless the unit is grease-lubricated, in which case detailed information regarding the grease specfications will be given on a tag attached to the unit. Observe the following precautions when lubricating:

a. Change the oil frequently during the run-in period. After 2 weeks the oil should be drained, and the case flushed with a light mineral oil (such as U. S. Army Specification 2-104 B) and refilled. This should be repeated a month later. Thereafter it should be repeated at periods varying from 3 to 6 months, depending upon amount and severity of service.

b. With unit at rest, fill the chamber and check oil level. If checked while running, an incorrect level will be recorded. Be careful not to overfill.

c. Keep water out of the gear case. Any water present will be mixed with the oil and corrosion will result. If the unit is installed in a wet atmosphere, the oil-drain hole in the gear case should be opened frequently during the run-in period; the oil should be drained out, and a check made for the presence of water. From these initial inspections, it can be determined how long an interval the unit can operate before water is noted, and a definite periodic oil-change program can be set up.

d. If a new type of oil is being used, drain a small sample of the oil from the case at least once a month and examine it for water and sediment. If the oil is very dark, the presence of sediment may be detected by diluting with gasoline. If any appreciable sediment is found, the oil should be drained, the casing flushed, and new oil supplied.

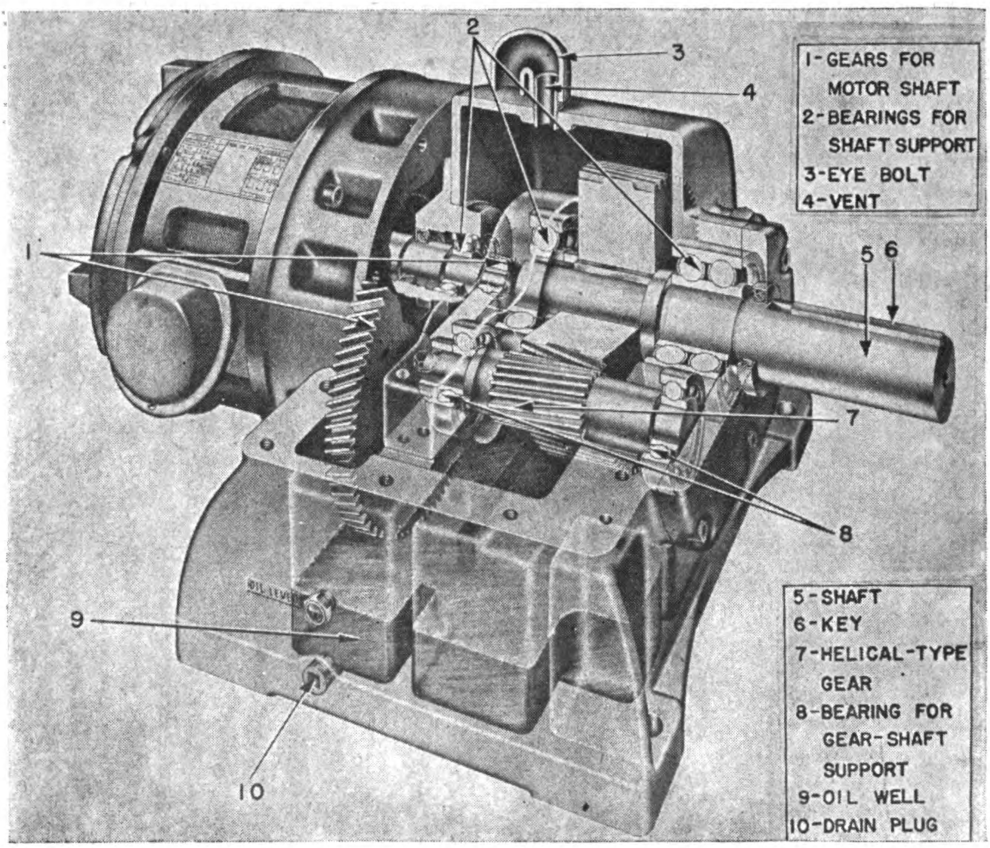


Figure 38. A gear motor.

62. Idle Machinery

Bearings in idle machinery are likely to corrode unless protective measures are taken. They should be thoroughly coated with a light-bodied grease; ordinary lubricating oil will drain off in time, exposing the finished surfaces to corrosion. In some cases, it may be possible periodically to run the machinery for short intervals, and in that manner redistribute the lubricant throughout the bearings. The frequency with which this should be done depends upon local conditions, as some atmospheres may be more corrosive than others.

63. Warning

Keep oil or grease from brushes and commutators.

SECTION XIII

REMOVAL-INSTALLATION AND DISASSEMBLY-ASSEMBLY

64. General

The first and second echelons may be required to remove and install smaller generators and motors, and partially to disassemble and reassemble such machines in order to inspect, adjust, service, or replace component parts. Specific procedures will vary with the widely varying types and usages of motors and generators. Consequently, only general observations and precautions can be presented in this section.

65. Removal of Generators

a. Before removing a generator, locate and identify the wires attached to it. Mark these wires so that they may be connected with the proper terminals when reinstalling the generator or replacing it with a new one. (This is important because incorrect connection of the wires on the generator will cause the generator regulator to overheat and result in serious damage to the generator, regulator or both.) The wires may then be disconnected.

b. Procedure from this point on will depend upon the drive details. In the case of a belt-drive generator, the belt should be removed next; in the case of gear- or coupling-drive generators, the setscrew or other similar device should be removed.

c. Next remove the bolts which secure the generator to the mounting bracket and lift or slide the generator from the mounting.

66. Installation of Generators

a. Make certain that the new generator is of the same make, type, style and voltage as the one replaced.

b. The following procedure is typical for many small belt-drive generators:

(1) Set the unit in position on the generator-mounting bracket, and install the mounting bolts. Do not tighten these bolts at this time.

(2) Move the generator as required to place the drive belt on the pulley.

(3) Install the strap adjustment bolt.

(4) Move the generator as required to adjust the belt properly.

(5) Tighten the strap adjustment bolt.

(6) Tighten the mounting bolts.

(7) Connect the wires to their proper terminals in relation to the marks placed on them before removal.

(8) Before starting, polarize the generator (par. 67); otherwise, both the generator and the regulator may become overheated and be ruined.

c. The following procedure is typical for many small gear- or coupling-drive generators:

(1) Slide the generator into position, so that it is tight against the timing-gear case; then install the setscrew.

(2) Tighten the setscrew and the lock nut.

(3) Connect the wires to their proper terminals in relation to the marks placed on them before removal. Make certain all wire terminals are tight.

(4) Before starting, polarize the generator (par. 67); otherwise, both the generator and the regulator may become overheated and ruined.

67. Polarization of Generators

When a generator is installed or a regulator changed, the field poles in the generator must be polarized in correct relation with the positive and negative terminals of the battery. A generator that is not correctly polarized will, if allowed to run even for a short time, cause serious damage to the regulator and generator. Polarizing procedure may vary according to design and voltage of the unit. The following procedure is typical of a 12-volt generator (fig. 39):

a. Remove the field-coil wire from the regulator field terminal.

b. Start the driving unit and let it warm up.

c. With the unit running at idle speed, attach the field-coil wire to the regulator field terminal.

d. Select a jumper wire and hold one end of it on the armature terminal.

e. Momentarily strike (flash) the other end of the jumper wire on the battery terminal. This action automatically corrects the polarity by a momentary surge of current to the generator.

68. Removal and Installation of Motors

Procedure in removal and installation of motors will also vary with the type of motor and its usage. In general, control linkage, cables, and drive gear must be disconnected before the mounting bolts are removed and the assembly taken out of place. (If the starter switch is mounted on the motor, this switch has to be removed from the motor.) When replacing a motor, the above procedure may be followed in reverse order, with operator making certain that the unit is properly positioned with respect to the drive gear and control linkage before securing the mounting bolts and connections. If the original motor is not being replaced, it is important to make sure that the new motor is of the same make, type, and

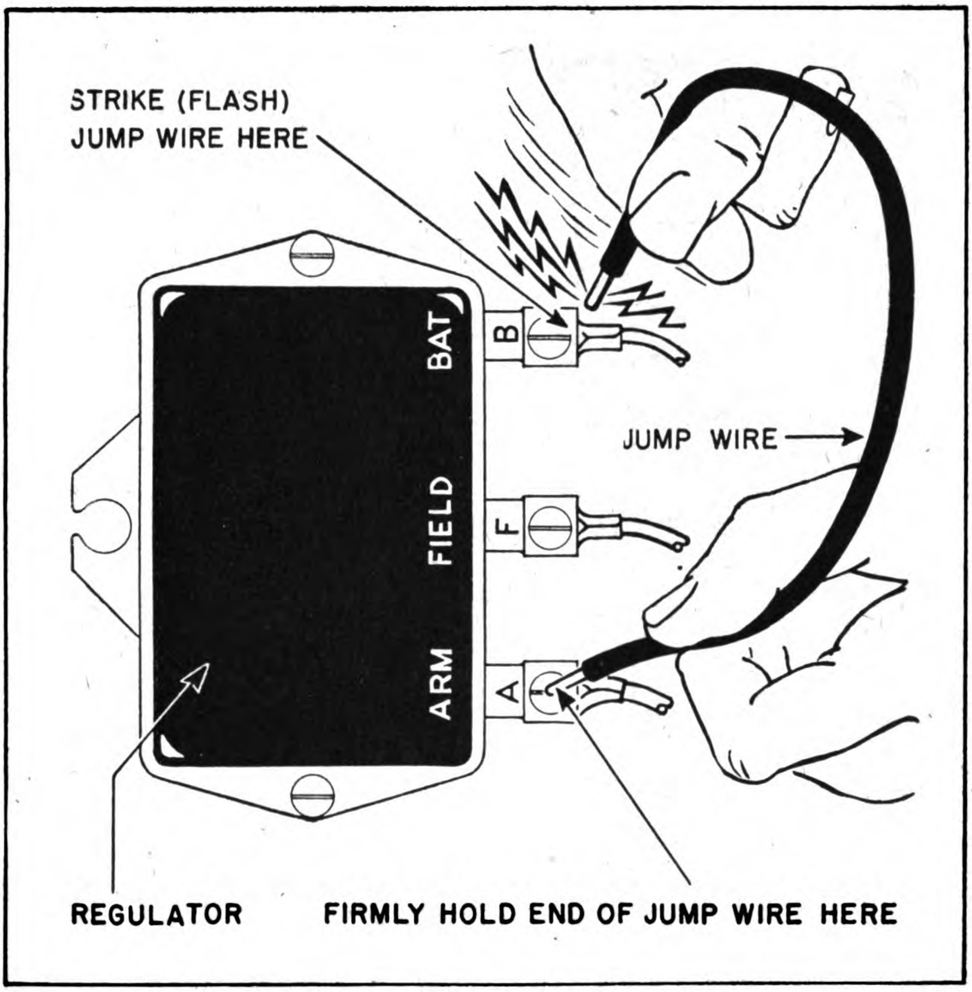


Figure 39. Polarizing a small generator.

voltage as the original motor and has the same type of drive gears and controls. If the starter switch is to be mounted on the motor, mount it before installing the motor.

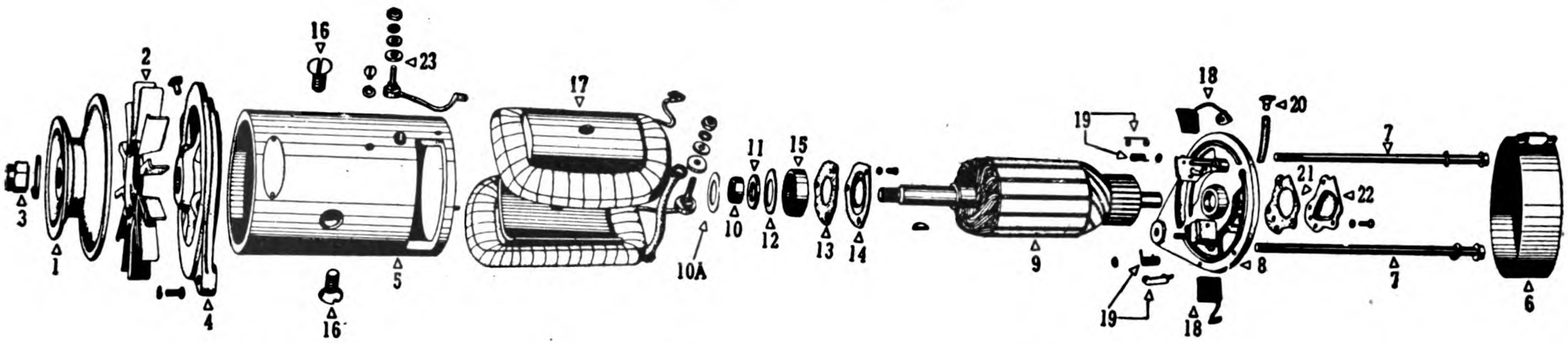
69. Partial Disassembly and Assembly

General disassembly and assembly of motors and generators is properly a function of a well-equipped repair shop staffed with technically-qualified personnel. Such partial disassembly and assembly as may be required of the first and second echelons in order to inspect, adjust, service, or replace a component part of the unit, must be carried out with great care. (See figs. 40 and 41.)

a. Disassembly. The following general precautions must be observed in partial disassembly:

(1) Remove coupling halves, pulleys, pinions, and fans with a puller. Severe hammering or wedging is likely to injure other parts, as well as those being removed.

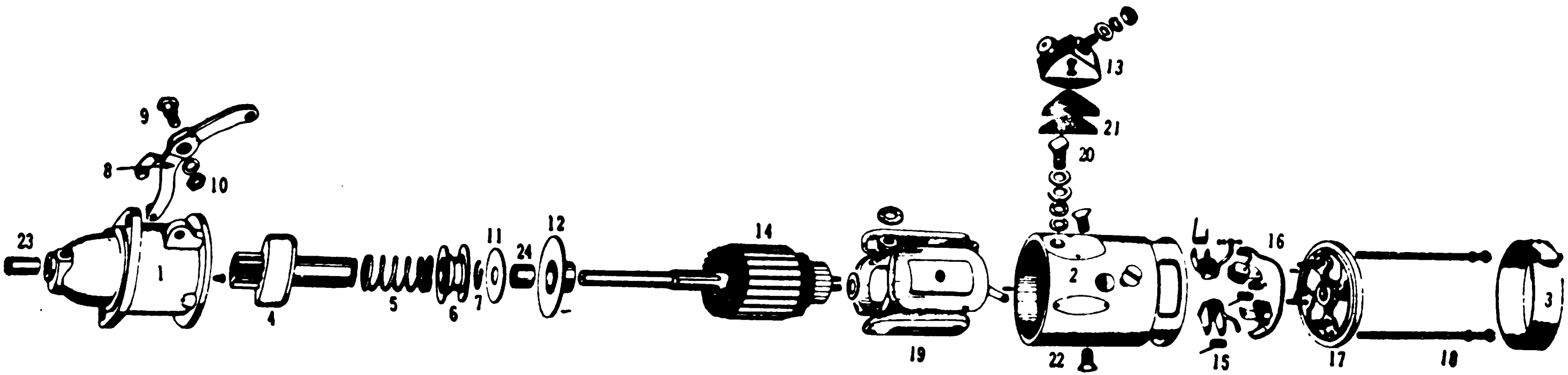
(2) Remove bearings as instructed in paragraphs 42 and 43.



1. Pulley	9. Armature
2. Fan	10. Space collar
3. Pulley nut and washer	10A. Washer
4. Drive end frame	11. Felt washer
5. Frame	12. Felt retainer
6. Cover band	13. Bearing retainer plate
7. Through bolts	14. Plate gasket
8. Commutator end frame	15. Bearing

16. Pole shoe screw
17. Field coils
18. Brush
19. Brush arms and springs
20. Oiler
21. Plate gasket
22. End cover plate
23. Terminal stud and lead

Figure 40. Component parts of a generator.



1. Drive housing
2. Frame
3. Cover band
4. Drive assembly
5. Drive spring
6. Drive sheeve
7. Drive lock ring
8. Shift lever
9. Shift lever stud
10. Stud nut
11. Brake washer
12. Center bearing plate
13. Starter switch
14. Armature
15. Brush springs
16. Brushes and holders
17. Commutator end frame
18. Through bolts
19. Brush arms and springs
20. Terminal stud
21. Switch insulation
22. Shoe screw
23. Housing bushing
24. Center bushing

Figure 41. Component parts of a starting motor.

(3) Remove brushes as instructed in paragraph 18.

(4) Clean each part immediately and place it on a clean surface under paper or cloth cover.

(5) Tag leads to save time and errors. Clean, scrape, file, or polish contact surfaces so as to insure good contact.

(6) Clean and tag disconnected smaller parts such as field connections, yokes, brush holders, and collector rings, and put them aside in order that they will not be confused with other parts.

(7) Carefully handle field coils, armatures, and wound rotors, and place them on a suitable support to avoid bruising or cracking the exposed insulation. Handle as little as possible. (See par. 34.)

b. Assembly. The following general precautions must be observed in partial assembly:

(1) Start with clean parts and keep them so during assembly.

(2) Bring parts into position without marring or distortion. Do not force parts together.

(3) Line up the machine carefully if the alignment may have been affected by any disassembly operations. If a coupling is used, check to make sure that the faces are parallel and that the shafts are in line before setting up the coupling.

(4) Remove all dirt and rubbish around the machine.

(5) Before putting the machine into service again, make sure that adequate lubrication is provided.

(6) Turn the machine by hand, if possible, and note any noises, binding, or uneven torque.

(7) If wiring connections may have been affected by the partial disassembly, check them carefully.

(8) Operate motor or generator long enough to note general performance. Pay particular attention to the parts which have been replaced.

(9) If a scheduled inspection is not due soon, make a special inspection within a few days after putting the machine into service, paying particular attention to the parts which have been replaced.

SECTION XIV

TROUBLE SHOOTING

70. General

The information contained in this section includes a compilation of difficulties which may be encountered in the operation of motors and generators, together with a listing of possible causes and remedies. In general, when a machine shows sign of improper operation, check *all* possible causes of the difficulty, beginning with the most probable, until the actual cause is discovered. Experience has shown that many difficulties may be corrected by checking first for loose connections or shorts. In any event, do not disassemble parts of a machine unnecessarily. Be sure to use dependable instruments. The compilation below, intended to be more or less complete, includes functions that are beyond the corrective scope of the second echelon. Data given in such cases are for information only and are not to be construed as a basis for remedial action by the second echelon other than reporting of these conditions.

71. Induction Motors

Trouble	*Cause*	*Remedy*
General.		
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.	Connect power to control, and control to motor. Check clip contacts.
	Faulty (open) fuses.	Test fuses.
	Low voltage.	Check motor-nameplate values with power supply. Also check voltage at motor terminals with motor under load to be sure wire size is adequate.
	Wrong control connections.	Check connections with control-wiring diagram.
	Loose terminal-lead connection.	Tighten connections.
	Driven machine locked.	Disconnect motor from load. If motor starts satisfactorily, check driven machine.
	Open circuit in stator or rotor winding.	Check for open circuits. (See par. 36.)
	Short circuit in stator winding.	Check for shorted coil. (See par. 36.)
	Winding grounded.	Tested for grounded winding.
	Bearings stiff.	Free or replace bearings.
	Grease too stiff.	Use special lubricant for special conditions.
	Faulty control.	Check and correct or replace faulty device.
	Overload.	Reduce load.
Motor noisy.	Motor running single phase.	Stop motor, then try to start. It will not start on single phase. Check for "open" in one of the lines or circuits.

Trouble	*Cause*	*Remedy*
	Electrical load unbalanced.	Check current balance. (See app. III.)
	Shaft bumping (sleeve-bearing motors).	Check alignment and condition of belt. On pedestal-mounted bearing, check cord play and axial centering of rotor.
	Vibration.	Remove motor from load. If motor is still noisy, rebalance rotor. Driven machine may be unbalanced.
	Air gap not uniform.	Center the rotor and if necessary replace bearings.
	Noisy ball bearings.	Check lubrication. Replace bearings if noise is persistent and excessive.
	Loose punchings or loose rotor on shaft.	Tighten all holding bolts.
	Rotor rubbing on stator.	Center the rotor and replace bearings if necessary.
	Objects caught between fan and end shields.	Disassemble motor and clean it. Any foreign matter around motor should be removed.
	Motor loose on foundation.	Tighten holding-down bolts. Motor may possibly have to be realigned.
	Coupling loose.	Insert feelers at four places in coupling joint before pulling up bolts to check alignment. Tighten coupling bolts securely.
Motor at higher than normal temperature or motor smoking.	Overload.	Measure motor loading with ammeter. Reduce load.
	Electrical load unbalance.	Check for voltage unbalance or single phasing.
	(Fuse blown, faulty control, etc.).	Check for "open" in one of the lines or circuits.
	Restricted ventilation.	Clean air passages and windings.
	Incorrect voltage and frequency.	Check motor-nameplate values with power supply.

Trouble	*Cause*	*Remedy*
		Also check voltages 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 shorted.	(See par. 36.)
	Stator winding grounded.	(See par. 36.)
	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 properly replaced.	Make sure end shields fit squarely and are properly tightened.
	Excessive belt tension or excessive gear side thrust.	Reduce belt tension, or gear pressure, and realign shafts. See that thrust is not being transferred to motor bearings.
	Bent shaft.	Straighten shaft.
Sleeeve bearings.	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.
	Oil rings rotating slowly or not rotating at all.	Oil too heavy; drain and replace. Oil ring has worn spot; replace with new ring.
	Motor tilted too far.	Level motor or reduce tilt and realign, if necessary.
	Rings bent or otherwise damaged in reassembling.	Replace rings.

Trouble	*Cause*	*Remedy*
	Ring out of slot (oil-ring retaining clip out of place).	Adjust or replace retaining clip.
	Motor tilted, causing end thrust.	Relevel motor, reduce thrust, or use motor designed for thrust.
	Defective bearings or rough shaft.	Replace bearings. Resurface shaft.
Ball bearings.	Too much grease.	Remove relief plug, and let motor run. If excess grease is not drawn off, flush and relubricate. (See pars. 45 and 59.)
	Wrong grade of grease.	Add proper grease. (See par. 59.)
	Insufficient grease.	Remove relief plug and regrease bearing.
	Foreign material in grease.	Flush bearings, relubricate; make sure grease supply is clean (keep grease can covered when not in use).
	Bearings misaligned.	Align motor and check bearing-housing assembly. See that races are exactly 90° with shaft.
Wound-rotor motor troubles.	Bearings damaged (corrosion, etc.).	Replace bearings.
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 by ringing-out circuit; repair.
	Brushes sparking.	(See pars. 14 and 16.)
	Dirt between brush and ring.	Clean rings and insulation assembly.
	Brushes stuck in holders.	Use right-size brush.
	Incorrect brush tension.	Check brush tension; correct. (See par. 16.)
	Rough collector rings.	File, sand and polish.

Trouble	Cause	Remedy
	Eccentric rings.	Turn in lathe or use portable tool to true-up rings without disassembling motor.
	Excessive vibration.	Balance motor.
	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.)

72. Direct Current Motors and Generators

Trouble	Cause	Remedy
Motor will not start.	Open circuit in control.	Check control for open starting-resistor-switch or burned fuse.
	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 lubrication in bearings to make sure that oil has been replaced after installing motor. Disconnect motor from driven machine, and turn motor 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 sprung shaft (machines under five hp.).
Motor stops after running short time.	Motor is not getting power.	Check voltage at the motor terminals; also check fuses, clips, and overload relay.

Trouble	*Cause*	*Remedy*
Motor attempts to start but overload relays operate.	Motor is started with weak or no field.	If adjustable-speed motor, check rheostat for correct setting. If correct, check condition of rheostat. Check field coils for open windings. Check wiring for loose or broken connections.
	Motor torque insufficient to drive load.	Check line voltage with nameplate rating. Use larger motor or one with suitable characteristic to match load.
Motor runs too slow under load.	Line voltage too low.	Check and remove any excess resistance in supply line, connections or control.
	Brushes ahead of neutral.	Set brushes on neutral. (See par. 20.)
	Overload.	Check to see that load does not exceed allowable load on motor.
Motor runs too fast under load.	Weak field.	Check for resistance in shunt-field circuits. Check for grounds. (See par. 36.)
	Line voltage too high.	Correct high-voltage condition.
	Brushes behind neutral.	Set brushes on neutral. (See par. 20.)
Brush troubles.		
Sparking at brushes.	Commutator in bad condition.	Clean and reset brushes. (See pars. 17 and 18.)
	Eccentric or rough commutator.	Grind and true commutator; also undercut mica.
	Excessive vibration.	Balance armature. Check brushes to make sure they ride freely in the holders.
	Broken or sluggish acting brush-holder spring.	Replace spring, and adjust pressure to manufacturer's recommendations.
	Brushes too short.	Replace brushes.

Trouble	*Cause*	*Remedy*
	Machine overloaded.	Reduce load or install larger motor.
	Short circuit in armature.	Check commutator, and remove any metallic particles between segments.
		Check for short between adjacent commutator risers. Test for internal shorts in armature; repair.
Brush chatter or hissing noise.	Excessive clearance of brush holders.	Adjust holders. (See par. 13.)
	Incorrect angle of brushes.	Adjust to the correct angle. (See par. 14.)
	Incorrect brushes for the service.	Refer to manufacturer's recommendations.
	High mica.	Undercut mica.
	Incorrect brush-spring pressure.	Adjust to correct value. (See par. 16.)
Selective commutation. (One brush takes more load than it should.)	Insufficient brush-spring pressure.	Adjust to correct pressure, making sure brushes ride free in holders.
	Unbalanced circuits in armature.	Eliminate high resistance in defective joints by inserting armature or equalizer circuit or commutator risers.
		Check for poor contacts between bus and bus rings.
Excessive sparking.	Poor brush fit on commutator.	Sand in brushes and polish commutator surface.
	Brushes binding in the brush holder.	Remove holders and brushes and clean with carbon tetrachloride.
		Remove any irregularities on surface of brush holders or rough spots on the brushes.
	Insufficient or excessive pressure on brushes.	(See par. 16.)
	Brushes off neutral	Set brushes on neutral. (See par. 20.)

Trouble	Cause	Remedy
Sparking at light loads.	Paint spray, chemical, oil or grease, or other foreign material on commutator.	Use motor designed for application.
		Clean commutator, and provide protection against foreign matter. Install an inclosed motor designed for the application.
Commutator overheats.	Brushes off neutral.	Adjust brushes.
	Excess spring pressure on brushes.	Decrease brush-spring pressure but not to the point where sparking is introduced.
Grooving of commutator.	Brushes not properly staggered.	Stagger brushes.
Brushes wear rapidly.	Rough commutator.	Resurface commutator and undercut mica.
	Excessive sparking.	Make sure brushes are in line with commutating fields.
Field coils overheat.	Short circuit between turns or layers.	Replace defective coil.
Armature overheats.	Motor installed in location where ventilating is restricted.	Arrange for free circulation of air around motor.
	Armature winding shorted.	Check commutator and remove any metallic particles between segments. Test for internal shorts in armature and repair.
	Motor overloaded.	Reduce load to correspond to allowable load.

73. Synchronous Motors

Trouble	Cause	Remedy
Motor will not start.	Faulty connection.	Inspect for open or poor connection.
	Open circuit one phase.	Test, locate, and repair.
	Short circuit one phase.	Open and repair.
	Voltage falls too low.	Reduce the impedence of the external circuit.

Trouble	*Cause*	*Remedy*
	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 and connections.
	Wrong direction of rotation.	Reverse any two main 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.
Motor 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.

Trouble	*Cause*	*Remedy*
		Set rheostat to give rated field current when field is applied. Check contact of switches.
	Load excessive.	Reduce load.
		Check operation of unloading device (if any) on driven machine.
	Inertia of load excessive.	May be a misapplication.
Motor pulls out of step or trips breaker.	Exciter voltage low.	Increase excitation.
		Examine exciter as shown in D-C motor.
		Check field ammeter and its shunt to be sure reading is not higher than actual current.
	Open circuit in field and exciter circuit.	Test with magneto and repair break.
	Short circuit in field.	Check with low voltage and polarity indicator and repair field. (See par. 36.)
	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.
	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.
		If driven machine is a compressor, check valve operations.
		Increase or decrease flywheel size.
		Try decreasing or increasing motor field current.

Trouble	*Cause*	*Remedy*
Stator overheats in spots.	Rotor not centered.	Realign and shim stator or bearings.
	Open phase.	Check connections and correct.
	Unbalanced currents.	Check for and correct improper internal connections.
One or more coils overheat.	Short circuit.	Cut out coil as expedient (in motors up to five hp.); replace coil when the opportunity arises.
Field overheats.	Short circuit in a field coil.	Replace or repair.
	Excessive field current.	Reduce excitation until stator current is at nameplate value.
All parts overheat.	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.
	Reverse field coil.	Check polarity and, if wrong, change leads.
	Improper voltage.	See that nameplate voltage is applied.
	Improper ventilation.	Remove any obstruction and clean out dirt.
	Excessive room temperature.	Supply cooler air.

APPENDIX I
APPROXIMATE FULL-LOAD CURRENTS OF MOTORS

(The table below gives values that are approximate, and typical only of motors of usual speeds and frequencies. For low-speed and special motors the full-load currents are somewhat higher than shown here.)

FULL-LOAD-CURRENT-AMPERES

HP of Motor	Alternating-Current Induction Motors													
	Three-Phase (Full load currents for two-phase motors are 0.87 times the three-phase values)													
	Direct-Current Motors		Single-Phase Motors		Squirrel-Cage				Wound-Rotor					
	115-Volt	230-Volt	110-Volt	220-Volt	220-Volt	440-Volt	550-Volt	2200-Volt	220-Volt	440-Volt	500-Volt	2200-Volt		
1/6	2.0	1.0	3.34	1.67	0.90	0.45	0.36	....	....	....	....	....		
1/4	2.6	1.3	4.8	2.4	1.16	0.58	0.48	....	....	....	....	....		
1/3	3.2	1.6	....	....	1.4	0.70	0.56	....	....	....	....	....		
1/2	4.6	2.3	8.0	4.0	1.9	0.95	0.76	....	....	....	....	....		
3/4	6.4	3.2	10.6	5.3	2.6	1.3	1.04	....	....	....	....	....		
1	8.2	4.1	12.8	6.4	3.4	1.7	1.36	....	5.4	2.7	2.2	....		
1 1/2	12.4	6.2	17.6	8.8	5.0	2.5	2.0	....	6.8	3.4	2.7	....		
2	16.2	8.1	22	11	6.2	3.1	2.5	....	8.0	4.0	3.2	....		
3	24	12	31	15.5	9.0	4.5	3.6	....	10.5	5.3	4.2	....		
5	40	20	48	24	14.5	7.2	5.7	....	16	8.0	6.4	....		
7 1/2	60	30	68	34	21	10.5	7.3	....	23	11.5	9.2	....		
10	78	39	90	45	26	13.5	11	....	29	14.5	10.5	....		
15	114	57	....	....	40	20	16	....	42	21	17	....		

FULL-LOAD-CURRENT-AMPERES												
HP of Motor	. Alternating-Current Induction Motors											
	Three-Phase (Full load currents for two-phase motors are 0.87 times the three-phase values)											
	Direct-Current Motors		Single-Phase Motors		Squirrel-Cage				Wound-Rotor			
	115-Volt	230-Volt	110-Volt	220-Volt	220-Volt	440-Volt	550-Volt	2200-Volt	220-Volt	440-Volt	550-Volt	2200-Volt
20	150	75	....	....	52	26	21	....	54	27	23	....
25	186	93	....	....	65	32	26	7.0	68	34	27	7.7
30	225	112	....	....	78	39	31	8.1	80	40	32	8.8
40	295	147	....	....	102	51	41	10.5	104	52	42	11
50	365	182	....	....	126	63	51	12.5	128	64	51	13.5
60	....	218	....	....	152	76	60	15	154	77	62	15.5
75	....	270	....	....	188	94	75	18.5	188	94	75	19
100	....	355	....	....	250	125	100	24.5	250	125	100	25
125	....	445	....	....	310	155	125	30	310	155	125	31
150	....	530	....	....	370	185	145	36	370	185	145	37
200	....	700	....	....	490	245	195	49	490	245	195	49

APPENDIX II

FRACTIONAL HORSEPOWER MOTORS — APPLICATION DATA

Type of Motor				HP. Range	Approx. Torque (% full load torque)* Starting	Approx. Torque (% full load torque)* Break-down	Reversibility At rest	Reversibility In motion	Application Data
Alternating-Current	Single-Phase	Split-Phase	General Purpose	1/20 to ⅓	110 to 225	200 to 280	Yes—change connections.	No—except with special design and relay.	Suitable for frequent starting, as on oil burners, fans, blowers.
Alternating-Current	Single-Phase	Capacitor	High Torque	⅙ to ⅓	230 to 300	260 to 350	Yes—change connections.	No—except with special design and relay.	Suitable for continuous and intermittent duty where operation is infrequent, as on sump pumps.
Alternating-Current	Single-Phase	Capacitor	General Purpose	⅙ to ¾	300 to 450	225 to 300	Yes—change connections.	No—except with special design and relay.	Used for heavy-duty drives such as compressors, pumps, stokers, refrigerators, air conditioning.
Alternating-Current	Polyphase	2 or 3 Phase	Squirrel-Cage	¼ to ¾	225 to 350	200 to 270	Yes—change connections.	Yes—change connections.	Suitable for across-the-line starting.
Direct-Current			Shunt Wound and Compound Wound	1/12 to ¾	375 to 1000	250 to 360 (At 80% rated speed)	Yes—change connections.	No—except with special design	Suitable for all D-C applications and for across-the-line starting below ½ hp. Rheostats recommended for ½ hp. and up.

* Torque variations for A-C motors are due to (1) LOCKED ROTOR CURRENT limitations which reduce torques on higher horsepower ratings, and (2) SPEED (maximum for 1725 and 1425 rpm.). Torque variations for D-C motors are due to TYPE OF WINDING and HORSEPOWER RATING (maximum for compound wound of smaller sizes).

APPENDIX III

A-C AND D-C FORMULAS AND MEASUREMENTS

---

1. Basic Formulas:

a.

D C	*A C*
Current $= \frac{\text{Voltage}}{\text{Resistance}}$	Current $= \frac{\text{Voltage}}{\text{Impedance}}$
or, Amperes $= \frac{\text{Volts}}{\text{Ohms}}$	or, Amperes $= \frac{\text{Volts}}{\text{Ohms (Impedance)}}$
or, $I = \frac{E}{R}$	or, $I = \frac{E}{Z}$

b.

D C	*A C*
Power = Voltage × Current	Power = Voltage × Current × Phase Angle
or, Watts = Volts × Amperes	or, Watts = Volts × Amperes × Power Factor
or, $P = E \times I$	or, $P = E \times I \times Pf$ (See par. 2, below)

c. 1 watt = .001341 horsepower (hp.)
= .73756 ft. = lb. per second

d. 1 kilowatt (kw.) = 1,000 watts
= 1.3410 horsepower
= 2,655,200 ft. = lb. per hour

e. 1 kw. hour = 1,000 watt-hours
= 1.341 horsepower-hours
= 2,655,200 ft.-lb.

f. 1 hp. = 745.7 watts
= 0.7457 kw.
= 33,000 ft.-lb. per minute

g. To find the synchronous speed (rpm.) of an A-C motor: Motor rpm (revolutions per minute) $= \frac{120 \times \text{frequency}}{\text{no. of poles}}$

Note. The number of pulsations which occur in alternating current per second is the frequency of the current. It is the number of complete cycles per second. The frequency of the current and the number of poles in the stator of a motor determine the synchronous or maximum speed of the motor. An induction motor "attempts" to run at synchronous speed, but there is usually a slip which causes it to run under this speed on full load. Thus, a four-pole motor at 60 cycles will operate at a maximum of 1800 $\frac{(120 \times 60)}{4}$ rpm. usually about three percent below this (or 1750 rpm.) due to slip. (An odd number of poles cannot be used in the above formula.)

2. Measurements

a. Power Factor. In taking A-C and D-C measurements, it is important to remember that D-C current and voltage work together (in phase) because of the steady movement, whereas A-C current and voltage work together only when a certain kind of load is connected to the line. Thus, if the load is made up of resistance only, like lights or heater elements, the voltage and current are in phase; if volts are multiplied by amperes, the true watts of the A-C circuit are obtained just as in a D-C circuit. But if an inductive load like a motor is connected to the line there is an upset to the balance between the surge of voltage and current. A voltmeter and ammeter inserted in the line give a product which is still watts (called apparent power) but the total is not the same as that which would be indicated by a wattmeter installed in the line (true power). It is comparable to inserting a gas pump in a gas line. Before the gas can enter the cylinder of the pump, the pressure must first open the inlet valve. After the inlet valve opens, then the flow of fluid starts. But since the pressure surge must act first, there is an appreciable lag before the flow starts. Thus for an inductive load like a motor, the current lags behind the action of the voltage. The two actions are out of phase and therefore the product of the two does not give the true value of power. The ratio of the power shown by a wattmeter to the power found from the product of volts by amperes as indicated by a separate voltmeter and ammeter is called the power factor (pf.). It is an indication of the out-of-phase relationship of voltage and current. For lights and resistance loads, the power factor is unity. For induction motors it is a lagging power factor, meaning current lags behind voltage. For example, a single-phase motor drawing five amperes at 220 volts, as shown by instruments, but having a power factor of 80 percent at that load (80 percent pf.), has a true power of 880 watts ($5 \times 220 \times .80$).

b. Use of Instruments. The use of instruments in taking A-C and D-C measurements should be guided by the following information and figures:

A-C MEASUREMENTS

Electrical Quantity	*Instrument to Use*	*Special Tips*
Current.	Ammeter*.	Always connect an ammeter in series with the load—never across it. Ground the current-transformer secondary. (See figs. 42 and 43.)****

Electrical Quantity	*Instrument to Use*	*Special Tips*
Voltage.	Voltmeter**.	Always connect a voltmeter across the load—never in series. To extend the range of a voltmeter, a multiplier may be used. If a higher-rated voltmeter is not available, use a potential transformer. Ground the potential-transformer secondary. (See figs. 44 through 46.)
Current and Voltage.	Voltmeter and Ammeter.	In Fig. 47, the voltmeter measures line voltage, not load voltage. The ammeter measures load current only. In figure 48, the voltmeter measures load voltage, not line voltage. The ammeter measures load current plus voltmeter current.

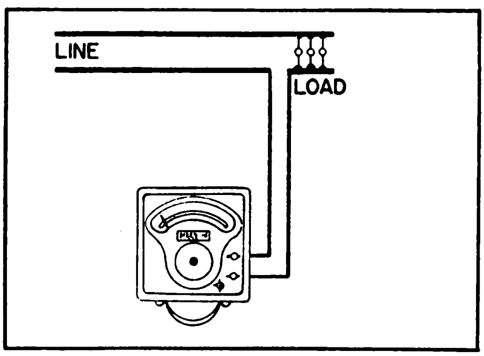


Figure 42. Ammeter.

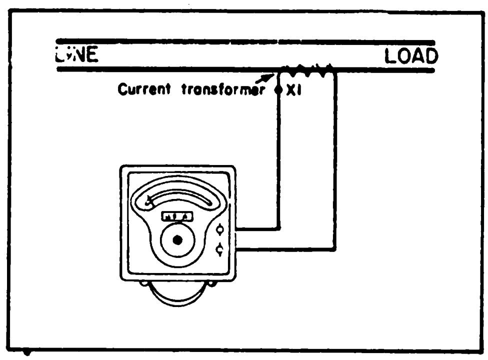


Figure 43. Ammeter with current transformer.

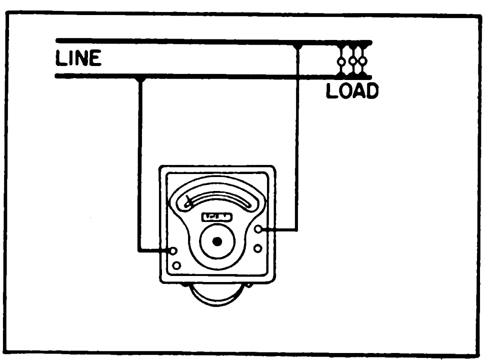


Figure 44. Voltmeter.

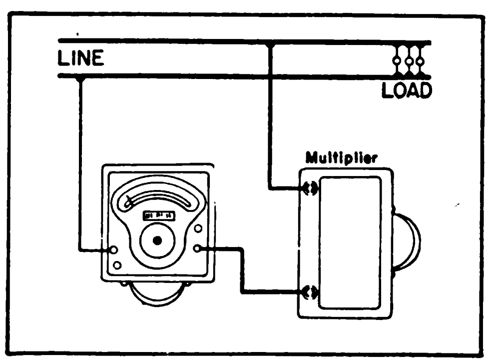


Figure 45. Voltmeter and multiplier.

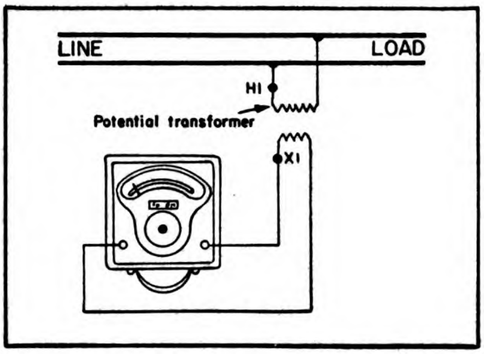


Figure 46. Voltmeter with Potential Transformer.

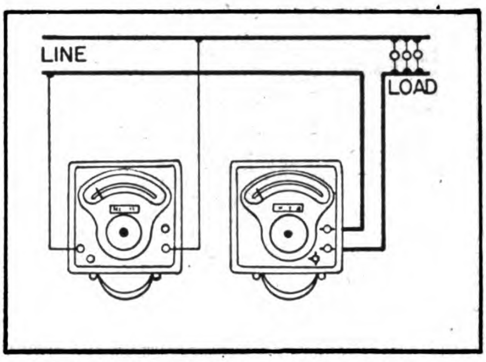


Figure 47. Voltmeter and ammeter.

Electrical Quantity	*Instrument to Use*	*Special Tips*
Watts (Single-Phase).	Wattmeter***.	In figure 49, the instrument is measuring power load plus loss in its own current-coil circuit. If the instrument reads backwards, reverse the current leads. In figure 50, the instrument is measuring power load plus loss in its own potential-coil circuit. Potential transformers are recommended on circuits above 300 volts. On circuits of 750 volts and above potential and current transformers should be used. Always ground the secondary of the potential-transformer circuit. (See figs. 51 and 52.)
Watts (Single-Phase).	Voltmeter and Wattmeter.	In figure 53, the wattmeter measures power load plus losses in the voltmeter and wattmeter potential circuits. In figure 54, the wattmeter measures power load plus loss in its own current-coil circuit.

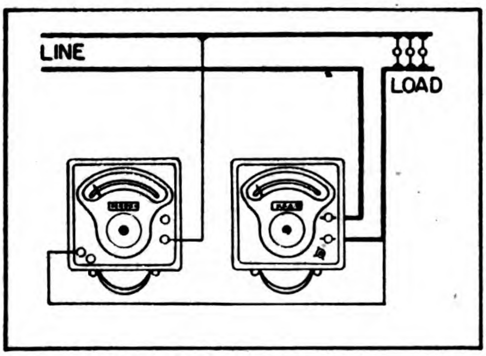


Figure 48. Voltmeter and ammeter.

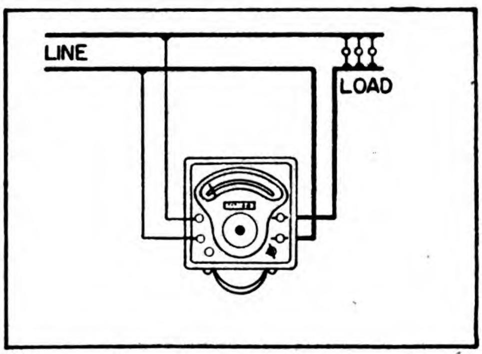


Figure 49. Wattmeter in single-phase circuit.

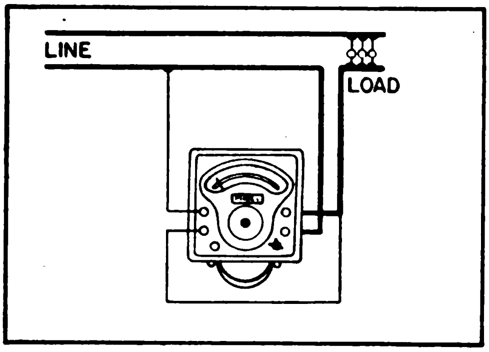


Figure 50. Wattmeter in single-phase circuit.

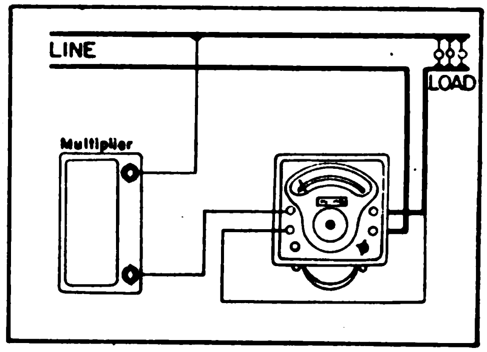


Figure 51. Multiplier and wattmeter.

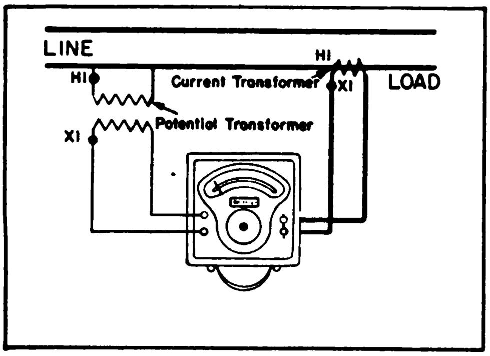


Figure 52. Wattmeter with current and potential transformer.

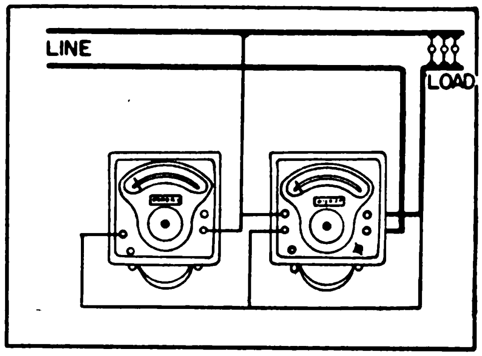


Figure 53. Voltmeter and wattmeter.

Electrical Quantity	*Instrument to Use*	*Special Tips*
Watts (Single-Phase).	Voltmeter, Wattmeter, and Ammeter.	Power factor is determined by dividing the wattmeter reading by the product of the ammeter and voltmeter readings. In figure 56, the wattmeter measures power load plus losses in the ammeter and wattmeter current-coil circuits. In figure 57, the wattmeter measures the sum of the power losses of the load, the potential circuit of the wattmeter, and the voltmeter.
Watts (Polyphase).	Wattmeter.	In figure 55, the power of the system is three times the indications of the wattmeter. The wattmeter indicates its own potential losses plus the power in one phase of the load. In figure 58, the two wattmeters will not indicate alike, even if the load is balanced. Above 50 percent power factor, the three-phase

Electrical Quantity	Instrument to Use	Special Tips
		power is the sum of the two readings; below 50 percent power factor, it is necessary to reverse the reading of one wattmeter (by reversing its current leads) and then take the difference between the readings of the two instruments. The accuracy of tests made with single-phase wattmeters will be somewhat higher than those made with polyphase wattmeters. (See figures 59 through 61.) Voltage ranges can be extended by the use of multipliers or transformers. For high accuracy, use the instruments at 40 percent of rated current or above.

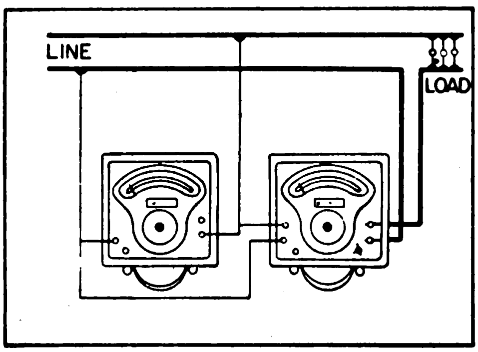


Figure 54. Voltmeter and wattmeter.

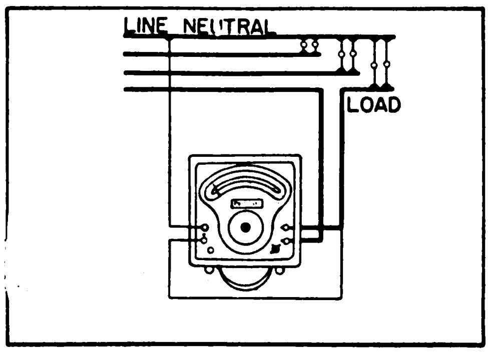


Figure 55. Single-phase wattmeter in balanced three-phase four-wire circuit.

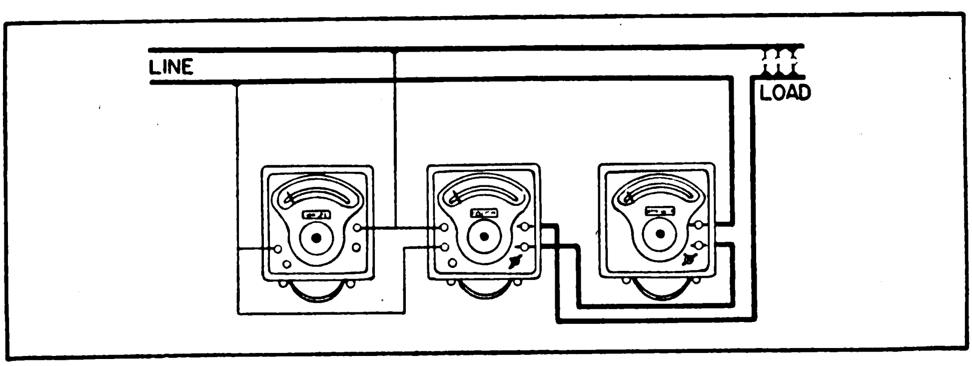


Figure 56. Voltmeter, wattmeter, and ammeter.

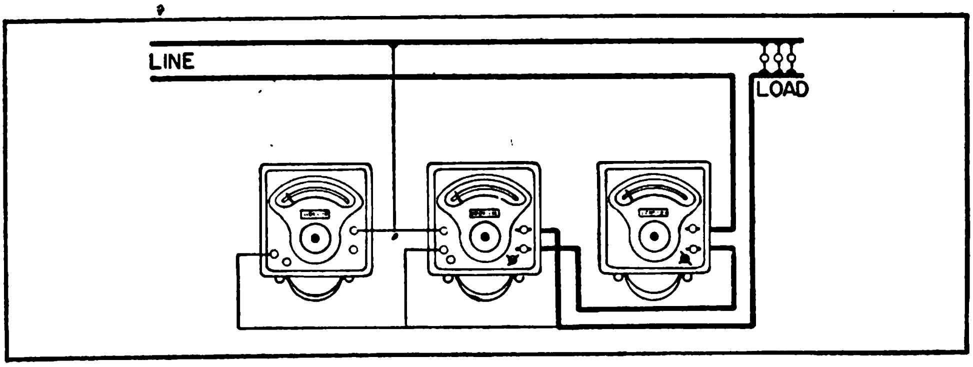


Figure 57. Voltmeter, wattmeter, and ammeter.

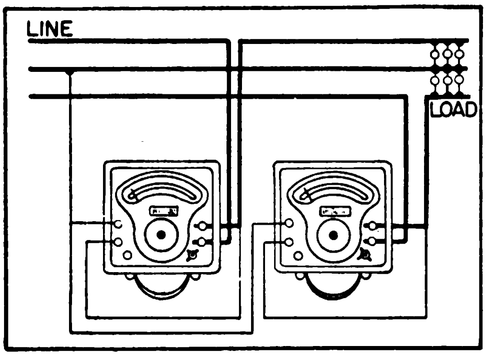


Figure 58. Two wattmeters connected for three-phase balanced or unbalanced voltages or load.

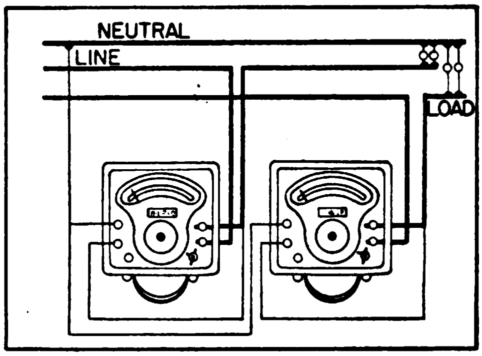


Figure 59. Two wattmeters connected for two-phase, three-wire balanced or unbalanced load.

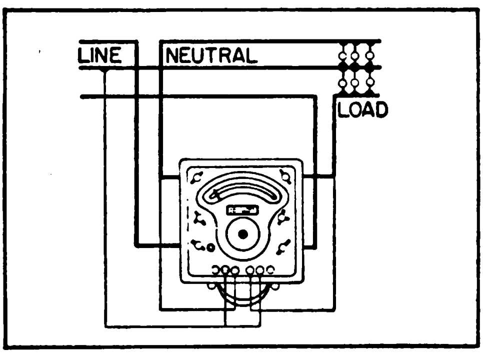


Figure 60. Polyphase wattmeter in two-phase, three-wire circuit, balanced or unbalanced load.

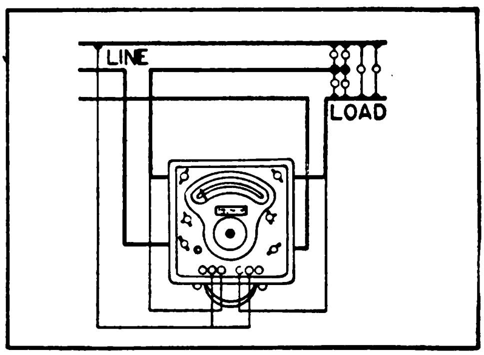


Figure 61. Polyphase wattmeter in three-phase, three-wire circuit.

Electrical Quantity	*Instrument to Use*	*Special Tips*
Power Factor.	Power-Factor Meter.	Connections made as shown in figures 62 through 64 are correct at all power factors. Polyphase power-factor meters are intended for use in balanced circuits only. Single-phase power-factor meters should be used only at the calibrated frequency.

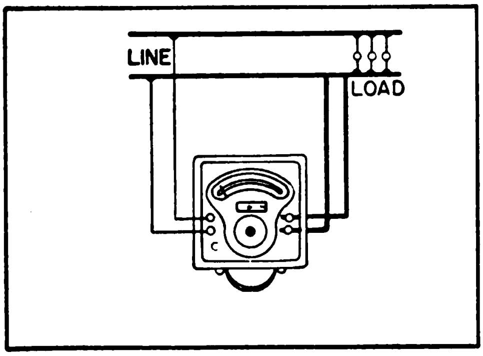


Figure 62. Single-phase power-factor meter.

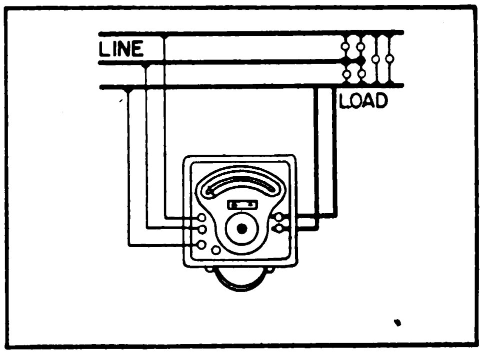


Figure 63. Three-wire, three-phase power-factor meter.

Electrical Quantity	*Instrument to Use*	*Special Tips*
Frequency.	Frequency Meter.	Frequency meters are connected as are voltmeters. (See figures 44 and 46.) Built for use on 110/120 circuits, they should not be used on voltages greater than 150 volts. Above 150 volts a variable-voltage autotransformer or a potential transformer should be used. Resistance multipliers must not be used.

D-C MEASUREMENTS

Electrical Quantity	*Instruments to Use*	*Special Tips*
Current.	Ammeter.	If one side of the line is grounded, ammeters should be connected to that side. (See figure 65.)
	Millivoltmeter.	Shunts are used with millivoltmeters (figure 66) to measure large current values. If the instrument reads backward, reverse the instrument leads.
Voltage.	Voltmeter.	Always connect a voltmeter across the load—never in series. (See figures 67 and 68.)

Notes.

* If an ammeter is to be used in circuits of devices having a high starting current (such as motors), short out the ammeter until after the starting period. Or, if the instrument is to be left in the circuit for some time, use a short-circuiting switch to avoid damaging the instrument. The switch can be opened whenever a reading is to be taken.

** An A-C voltmeter connected to an inductive circuit (such as a generator-field circuit) should be disconnected before the circuit is opened. Otherwise, the inductive kick may result in a bent pointer or other injury to the instrument.

*** Special care should be taken not to overload wattmeters. It is possible to burn out a wattmeter without exceeding the full-scale reading. The reason is that a wattmeter reading is dependent on three factors: voltage, current, and power factor. Thus, it is possible to exceed the current or voltage rating without exceeding the full-scale indication.

**** When using current transformers on A-C circuits, make sure that the secondary is always short-circuited either by the ammeter or by a short-circuiting jumper whenever there is current in the primary; dangerous and destructive voltages will be produced if the secondary is open-circuited.

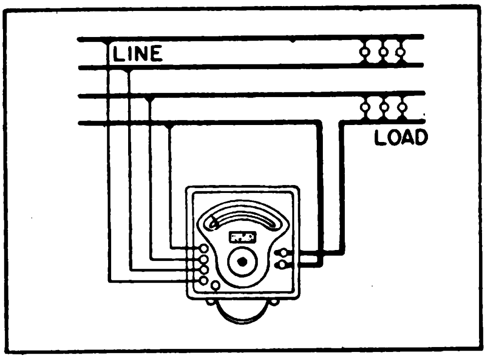


Figure 64. Four-wire, two-phase, power-factor meter.

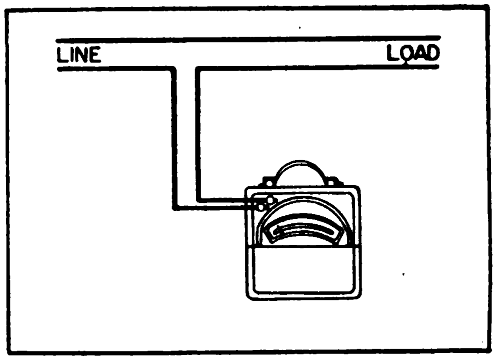


Figure 65. Ammeter.

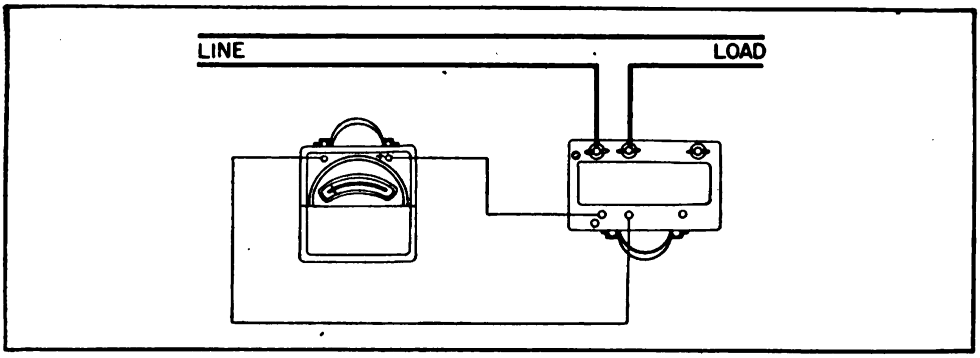


Figure 66. Millivoltmeter and shunt for measuring current.

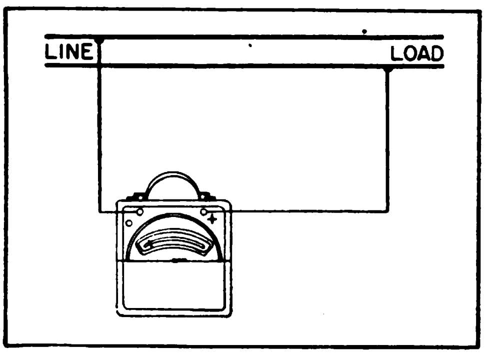


Figure 67. Voltmeter.

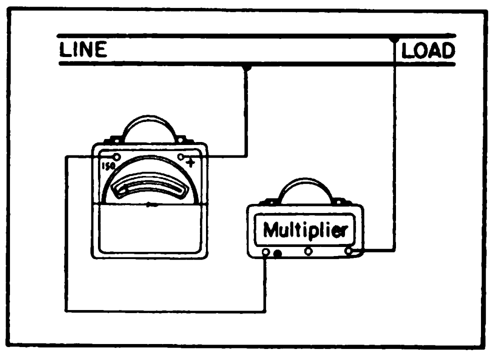


Figure 68. Voltmeter and multiplier.

APPENDIX IV

TESTS FOR SMALL MOTORS AND GENERATORS

Note. See also section VIII. Instruments shown below are typical only and not the sole means of testing.

1. Field-Coil Test for Continuous Circuit

Place prods on field-coil leads. (See fig. 69.) If test lamp does not light, field coils are open-circuited.

2. Field-Coil Test for Grounds

Place one test prod on frame and other on field terminal. (See fig. 70.) If lamp lights, field coils are grounded.

3. Armature Test for Short

Place armature on "growler". (See fig. 71.) Place saw blade over armature core, rotate armature, and test. If saw blade vibrates, armature is short-circuited. To determine whether armature windings or commutator is shorted, clean out between the commutator bars and recheck armature. If saw blade still vibrates, armature is short-circuited.

4. Armature Test for Ground

Place one test prod on armature core, and other to commutator bars. (See fig. 72.) If test lamp lights, armature is grounded and should be replaced.

5. Main-Brush Test for Ground

Place one test prod on negative (insulated) brush and other on end frame. (See fig. 73.) If test lamp lights, negative brush holder (insulated) is grounded.

6. Brush-Lead-To-Negative-Terminal Test for Continuous Circuit

Place one test prod on negative (insulated) terminal (armature) and other on end of wire. (See fig. 74.) If test lamp does not light, wire is open-circuited.

7. Negative-Terminal Test for Ground

Place one test prod on terminal and one on frame. (See fig. 75.) If test lamp lights, terminal insulation is broken down.

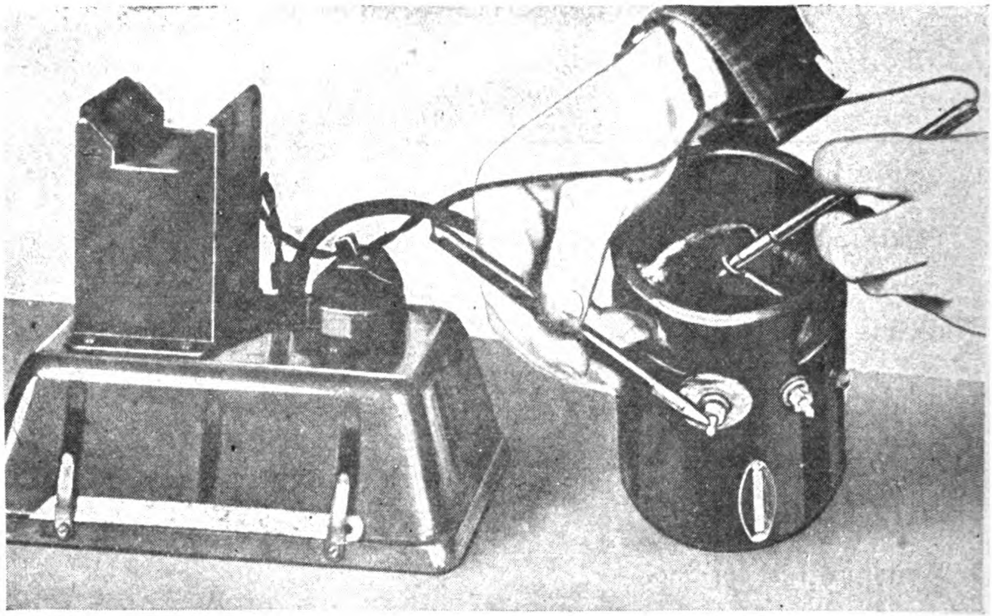


Figure 69. Field-coil test for continuous circuit.

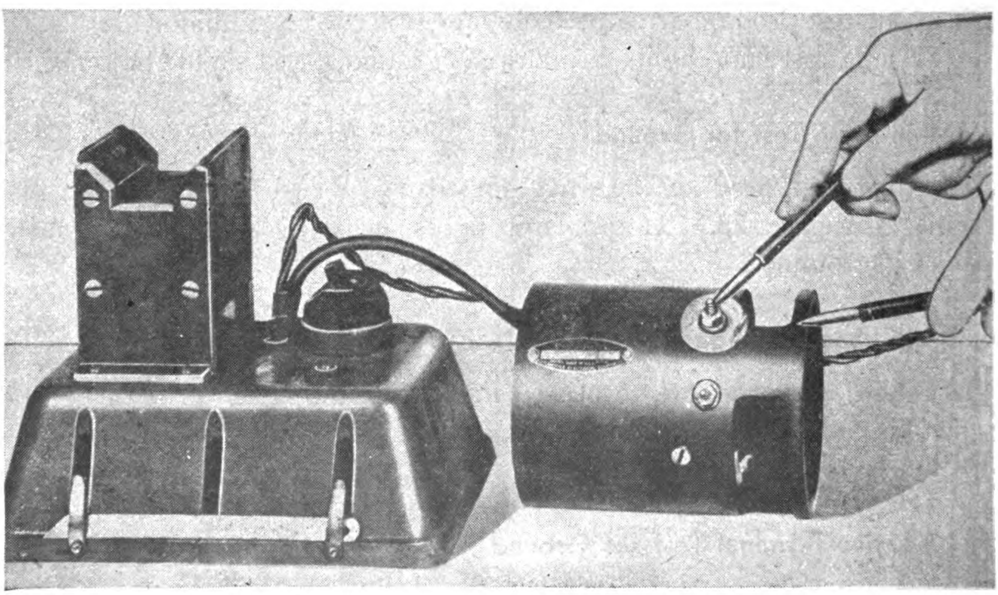


Figure 70. Field test for ground.

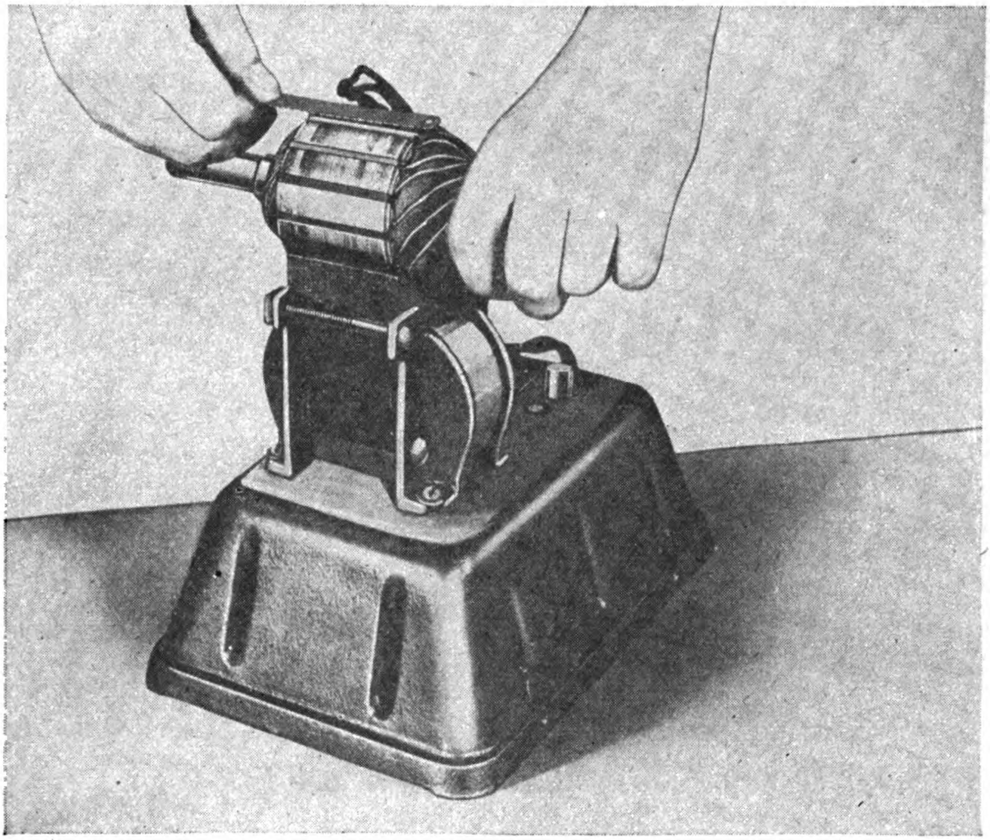


Figure 71. Armature test for short.

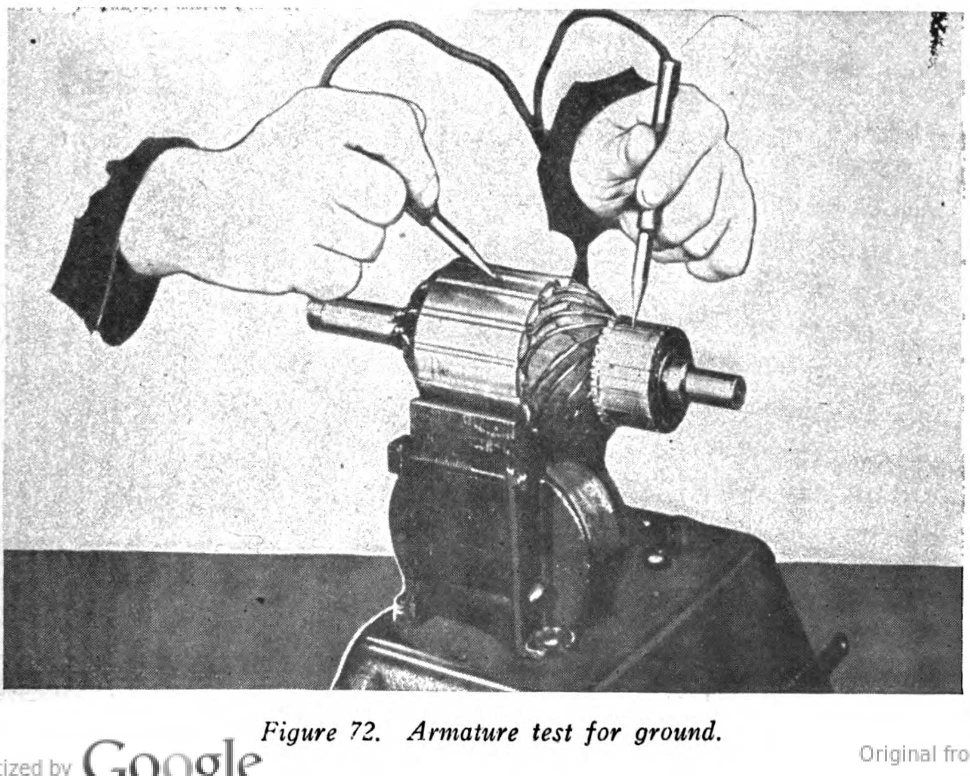


Figure 72. Armature test for ground.

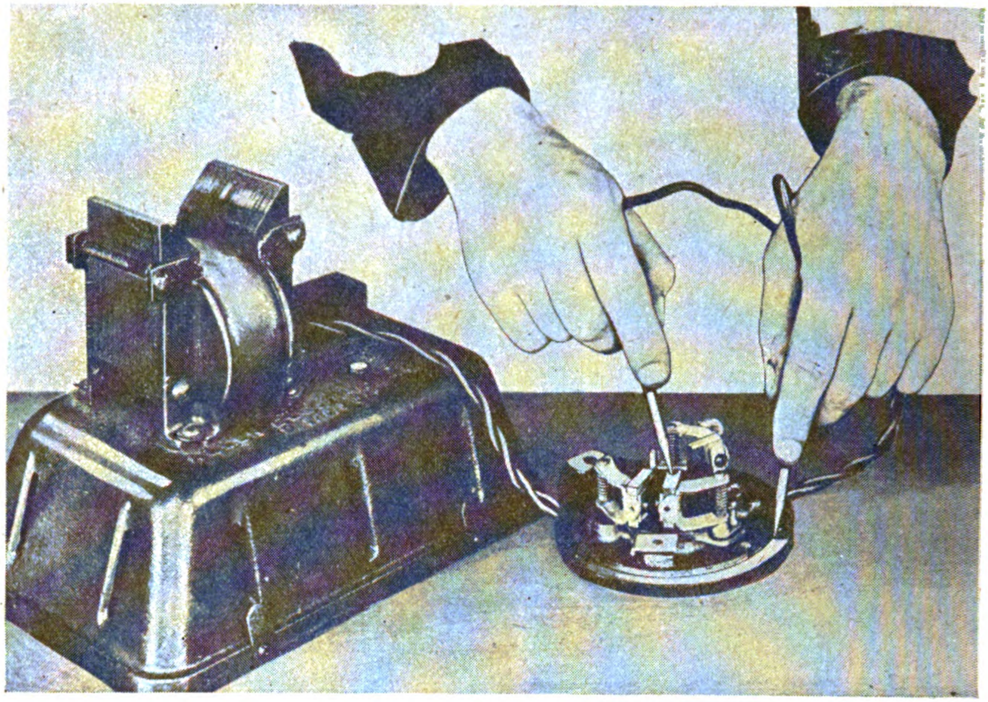


Figure 73. Main-brush test for ground.

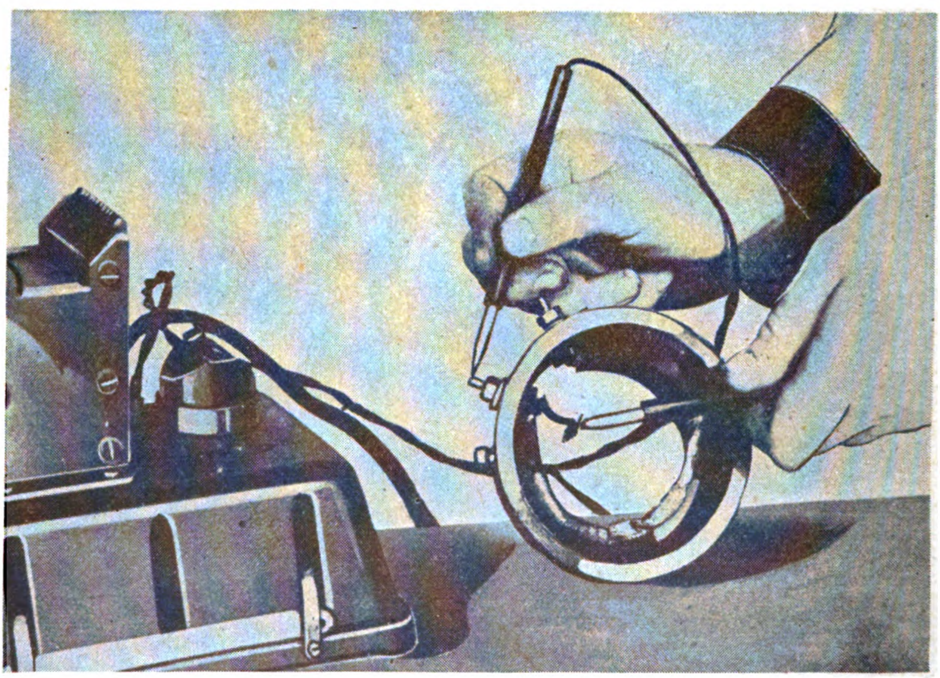


Figure 74. Brush-lead-to-terminal test for continuous circuit.

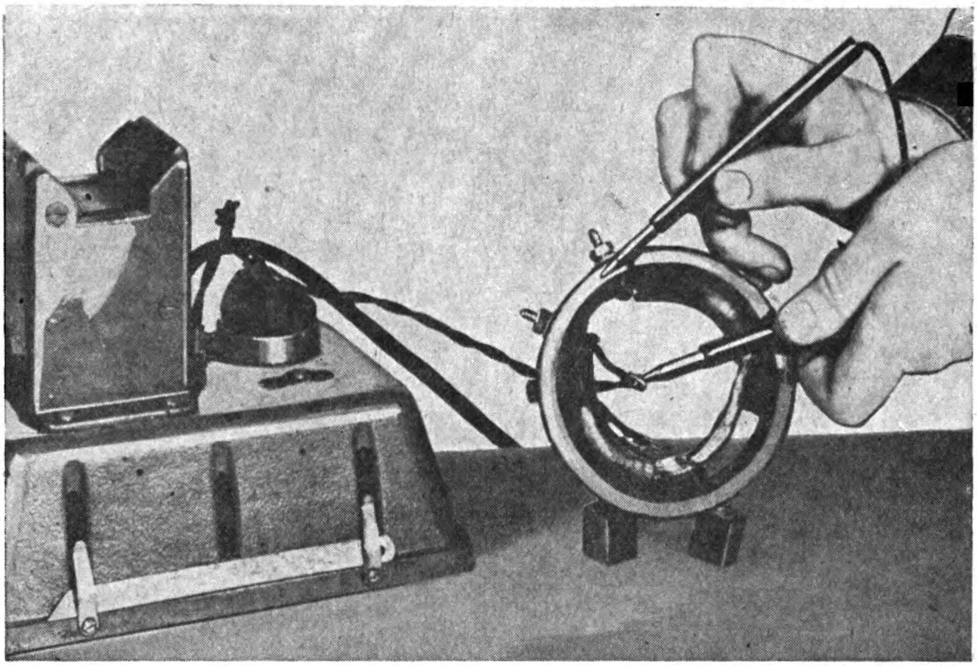
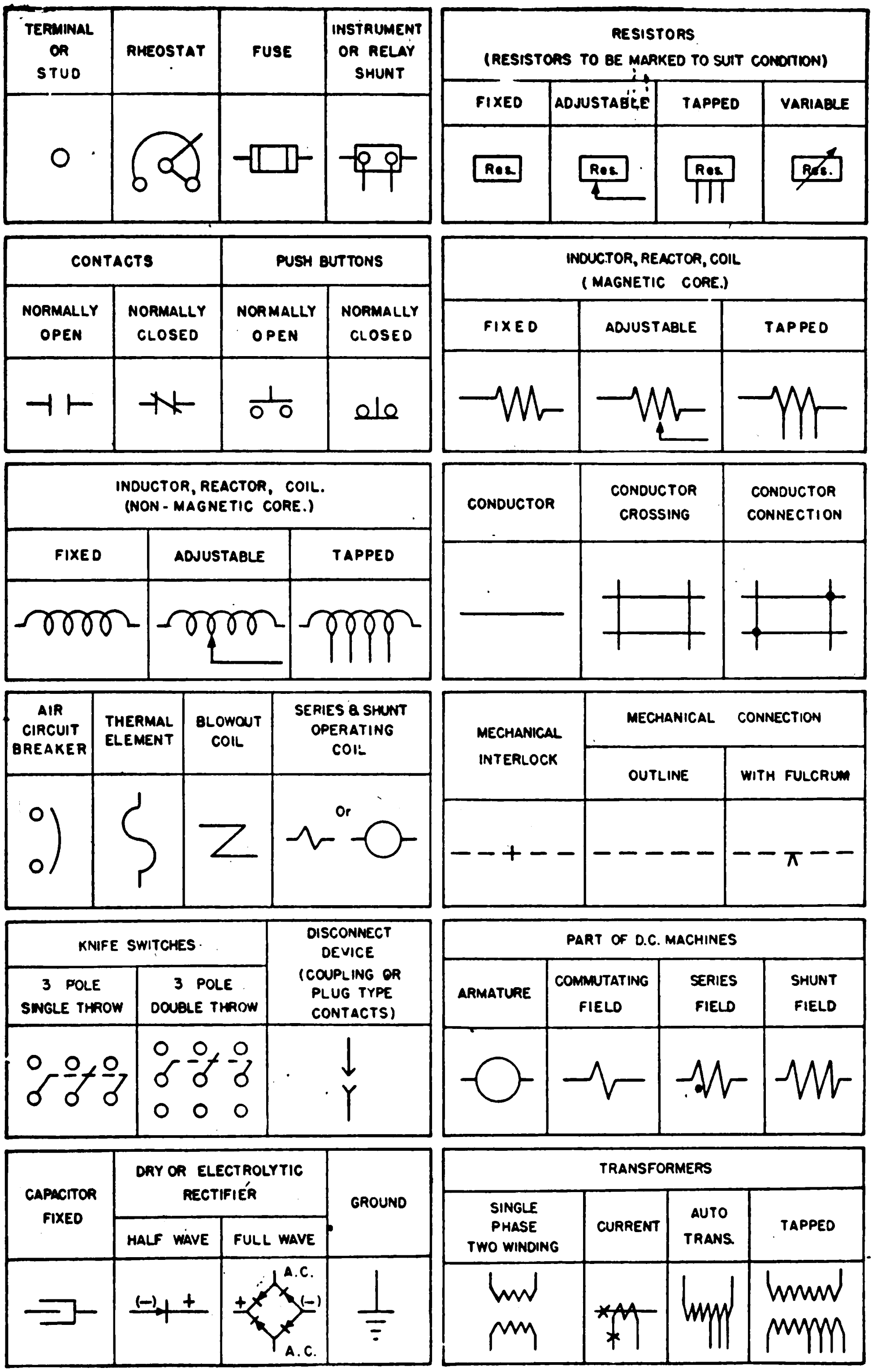


Figure 75. Negative-terminal test for ground.

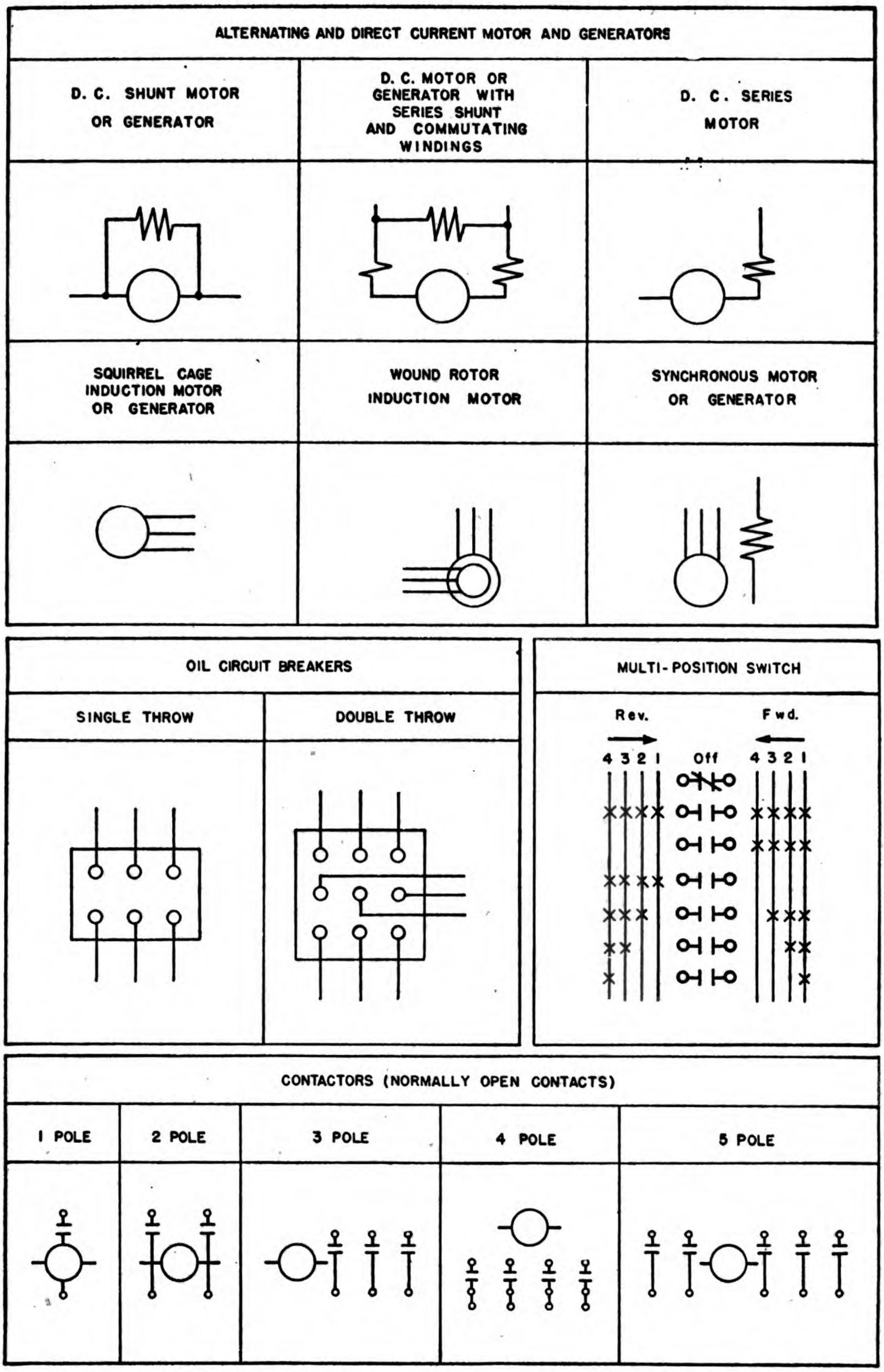
APPENDIX V

COMMON ELECTRICAL SYMBOLS AND DIAGRAMS AND STANDARD DEVICE MARKINGS



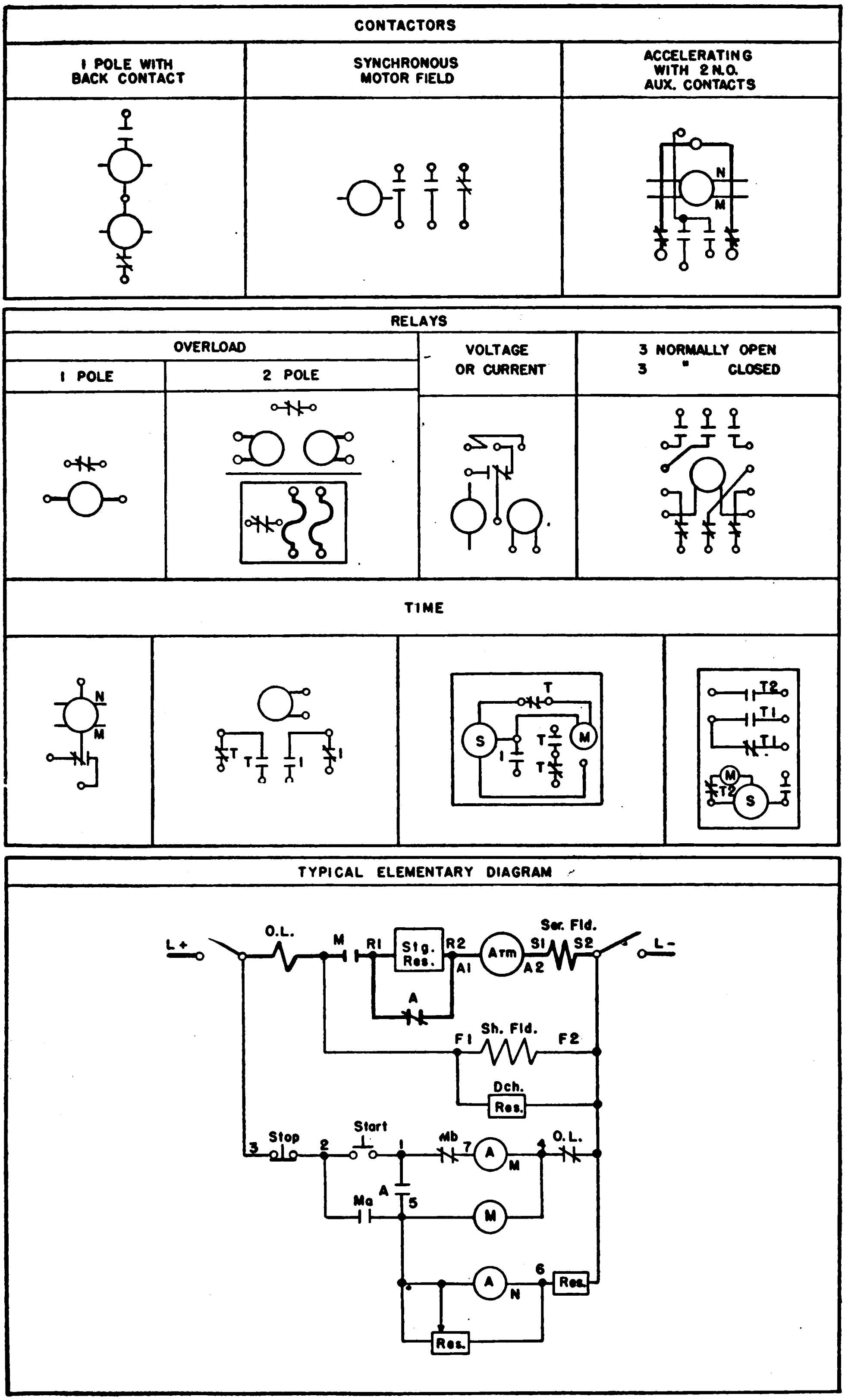
①

Figure 76. Common electrical symbols and diagrams.



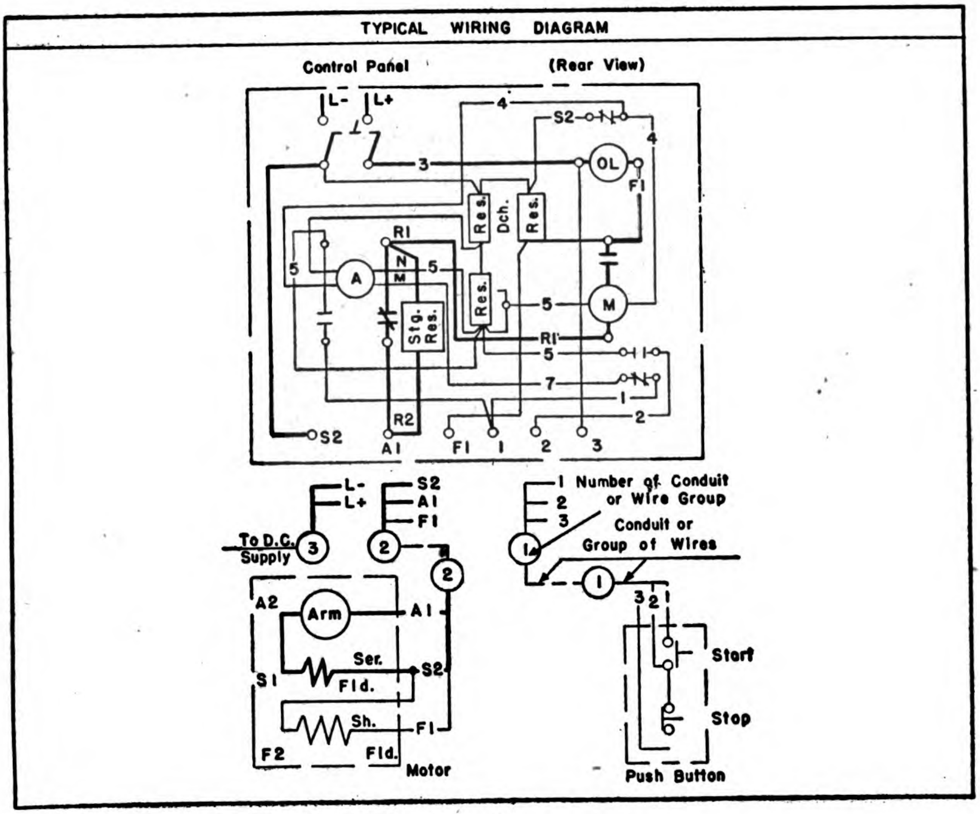
②

Figure 76. Common electrical symbols and diagrams—Continued.



③

Figure 76. Common electrical symbols and diagrams—Continued.



④

Figure 76. Common electrical symbols and diagrams—Continued.

STANDARD DEVICE MARKINGS

Armature acceleration	A
Armature shunt	AS
Auxiliary switch (breaker) normally open.	"a"
Auxiliary switch (breaker) normally closed.	"b"
Balanced voltage	BV
Brake	BR
Compensator—running	MR
Compensator—starting	MS
Control	CR
Door switch	DS
Down	D
Dynamic braking	DB
Field acceleration	FA
Field deceleration	FD
Field discharge	FD
Field dynamic braking	DF
Field failure (loss of field)	FL
Field forcing (decreasing on variable voltage).	DF
Field forcing (increasing on variable voltage).	CF
Field protective (field weakened at standstill).	FP
Field reversing	FR
Field weakening	FW
Final limit—forward	FLF
Reverse	R
Series relay	SR
Slow down	SD
Thermostat	TS
Final limit—reverse	FLR
Final limit—hoist	FLH
Final limit—lower	FLL
Final limit—up	FLU
Final limit—down	FLD
Forward	F
Full field	FF
Generator field	GF
High speed	HS
Hoist	H
Instant	I
Jam	J
Kick-off	KO
Landing	LD
Limit switch	LS
Lowering	L
Low speed	LS
Low torque	LT
Low voltage	LV
Master switch	MS
Maximum torque	MT
Middle Landing	MLD
Main or line	M
Motor field	MF
Overload	OL
Pilot motor	PM
Plug	P
Time	T
Up	U
Undervoltage	UV
Voltage relay	VR

APPENDIX VI

MOISTUREPROOFING AND FUNGIPROOFING

1. General

Failure of motors and generators in tropical areas occurs because of deterioration from rot, mold, mildew, and corrosion. Extreme humidity, abundant rainfall, and high temperatures promote the growth of fungi and accelerate corrosion. Tropicalization and preventive maintenance measures will retard the harmful effects of such conditions.

2. Causes of Deterioration

a. ROT, MOLD, OR MILDEW. Under favorable conditions of temperature and moisture, fungi (microscopic plant life appearing as a mold or slime) will germinate like seeds and grow, secreting a corrosive fluid which attacks wood, metal, and insulation. Thus, as a result of profuse fungi growth, the surface of a rubber belt drive in a motor may be damaged beyond repair.

b. CORROSION. Conditions favoring corrosion are airborne moisture, salt water, coral dust, acid soil, and the electrolytic action of metals. Deterioration of electrical equipment is caused by moisture and salt water settling in insulating parts, windings, and winding spaces. The electrolytic action that results is visible in the form of corrosion. The principal effects include break-down in the resisting quality of insulation and insulated wiring, damage to plastic elements, arcing and leaking of current in the electrical circuit. In addition, the wound sections of the armature, field poles, and commutating poles will suffer from exposure to fungus infection. Allowed to go unchecked, corrosion will eventually impair the strength of the metal and destroy thin metal surfaces. Resultant scaling will clog the lubrication system, and "freeze" the bearings.

3. Preventive Measures and Remedies

a. ROUTINE PREVENTIVE MAINTENANCE. Equipment should be kept clean and dry. Where possible, keep it off the damp ground and provide proper ventilation. Inspection and cleaning should be undertaken regularly. (See secs. II and III.)

b. STORAGE. Good storage practices play a large part in the battle against tropical deterioration. A closed heated building provides the best storage for supplies. Where heated storage cannot be provided, proper ventilation is the next best preventive measure. Equipment should be stored high enough to keep from contact with the damp ground. Desiccating agents may be used to absorb moisture from the air. Silica gel in bags or anhydrous calcium chloride are placed in sealed cases containing the equipment.

c. HEAT-DRYING. Heat-drying retards corrosion and fungus growth. A heated box or closet provides a measure of protection. However, there should be a vent for leakage of air to reduce the humidity within the closed space. Raising the temperature 10° or 15° F. above the surrounding temperature, will reduce the humidity of the container to a safe level. Heat-drying is also used as preparatory treatment before applying moisture-resistant lacquers and varnishes. Infra-red lamps, ovens heated by a gasoline burner, or the field kitchen oven are used for this purpose. (See par. 31.)

4. Use of Water-Proof Lacquers, Varnishes, and Compounds

Specialized treatment of electrical equipment against fungus growth, insects, corrosion, salt spray, and moisture is generally a function of third echelon or higher maintenance. Approved materials and procedures are specified in the following War Department Technical Bulletins:

TB ORD 242, Protection of Electrical Equipment on Ordnance Vehicles Against Corrosion and Rust.

TB ENG 58, Field Tropicalization Measures for Engineer Material.

TB SIG 13, Moistureproofing and Fungiproofing Signal Corps Equipment.

APPENDIX VII

GLOSSARY

---

1. Alternating Current (A-C)

A current that changes its direction of flow in a regular, established sequence.

2. Ambient Temperature

The temperature of the air or water which, coming in contact with the heated parts of a machine, carries off their heat.

3. Ammeter

A device for measuring electrical current.

4. Ampere

A unit of the amount of current in a circuit. (See fig. 77.)

5. Armature

This is an ambiguous term. In the simplest sense, it refers to the movable or rotating part of a generator or motor, and consists essentially of coils of wire around an iron core. In this sense, when the armature of a generator moves through a magnetic field between pole pieces, an electric current is induced; when an electric current is passed through the armature coils of a motor, the coils are caused to move or rotate by electro-magnetic induction. However the term "armature" has come to be applied to both the stator of a synchronous motor and the rotor of a D-C motor (as well as to the moving bar or core, without windings, of a contactor or solenoid). Then again, the rotor of a self-starting synchronous motor acts as an armature in starting (currents being induced in the squirrel cage bars), and as a field in running when the exciting current is turned on. Obviously the distinction between "armature" and "field" cannot be made definitive. Where there is any chance of misunderstanding, the terms "rotor" and "stator" should be used. Where there is no doubt as to function, the terms "armature" and "field" should be used.

6. Branch Circuit

That portion of a wiring system extending beyond the final overcurrent device protecting the circuit.

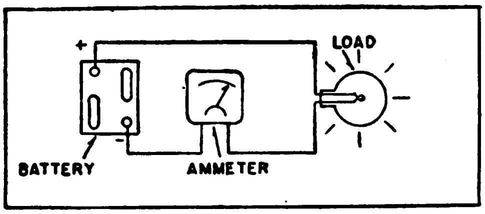


Figure 77. Amperage.

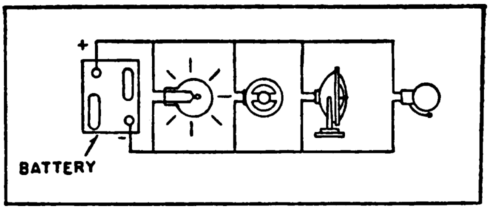


Figure 78. A circuit in parallel.

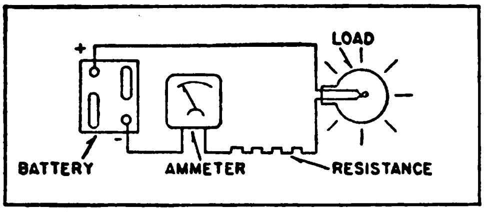


Figure 79. Resistance.

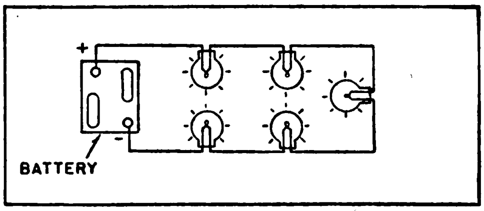


Figure 80. A circuit in series.

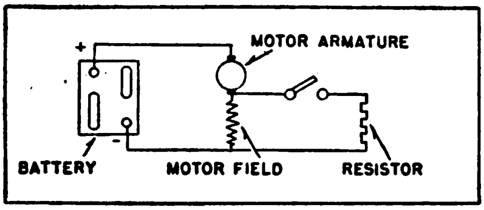


Figure 81. A device in shunt.

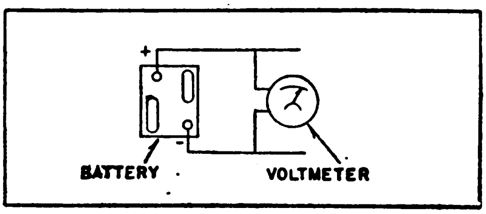


Figure 82. Voltage.

7. Brushes

Conducting material, generally of copper or carbon, bearing against a commutator or collector ring and providing a passage for electric current.

8. Collector Rings

Metal circular rings for collecting induced current from an armature. This current passes through brushes resting on the rings and connects to an external circuit.

9. Commutation

The act of converting the alternating currents in the armature inductors into direct currents by a device called the commutator.

10. Commutator

See "Commutation."

11. Condenser

An instrument for holding or storing an electric charge.

12. Conductor

A material through which electricity will flow.

13. Contact

A conducting part which coacts with another conducting part to complete or interrupt a circuit.

14. Contactor

A device for repeatedly establishing and interrupting an electric power circuit.

15. Continuous Duty

A requirement of service which demands operation at substantially constant load or for an unlimited period.

16. Continuous Rating

The load which can be carried for an unlimited period, without causing any of the limitations to be exceeded.

17. Current Relay

A relay which functions at a predetermined value of current. A current relay may be either an overcurrent relay or an undercurrent relay.

18. Cut-out Relay

A device that closes the circuit between the generator and the battery when the generator is revolving at generating speed, and opens the circuit when the generator falls below generating speed.

19. Cycle

A complete period of change in direction of an alternating current.

20. Direct current (D-C)

An electric current flowing in one direction only and more or less free from pulsation.

21. Dynamo

See "Generator."

22. Electric Controller

A device which serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected.

23. Electromagnet

A magnet formed by passing a current ef electricity through wire wound around a core.

24. Field

A space influenced by magnetic lines of force, as a generator field. (See "Armature.")

25. Field Coil

Coil of insulated wire which magnetizes a field.

26. Field Pole

A structure of magnetic material on which a field coil may be mounted.

27. Foot-Pound

The work done in lifting one pound one foot.

28. Frequency

The number of complete cycles of alternating current per second.

29. Fuse

An overcurrent protective device with a circuit-opening fusible member directly heated and destroyed by the current passing through it.

30. Generator

A machine by which mechanical energy is changed into electrical energy.

31. Ground

An electrical connection with the earth, either intentional or accidental.

32. Growler

A device for testing armatures, particularly for short circuits. A growler consists essentially of a primary coil and the primary portion of the iron of a transformer. The iron of the armature or stator under test completes the magnetic circuit. When an alternating current is passed through the growler it sets up an alternating magnetic flux in the iron core of the growler and in the iron of the armature or stator spanned by the jaws of the growler. As this magnetic flux passes through any coil of the device it induces a potential in the coil and if the coil is short-circuited a current will be set up in the coil. This current produces a load on the growler which sometimes changes the tone of the hum of the growler. It also sets up a magnetic field around the coil which shows up strongly across the opening of the two slots carrying the short-circuited coil. Growlers are made with or without meters for measurement of current in the primary circuit.

33. Horsepower

A unit for measuring power. It is the rate of doing work at 33,000 foot-pounds per minute.

34. Impedance

Quantity which represents the combined resisting effects of: (a) Actual (ohmic) resistance, and (b) the apparent resistance (reactance) or the opposition due to counter electromotive forces of self-induction and permittance.

35. Induction Generator

An electric generator similar in construction and operation to an induction motor; in order to generate, it must be driven above synchronous speed and must be excited from the A-C supply into which it is delivering power.

36. Induction Motor

A motor which runs asynchronously, that is, not in step with the alternations of the A-C. The armature, not being connected to the external circuit, is rotated by currents induced by the varying field set up through the field coils. The operation of a polyphase induction motor depends upon the production of a rotating magnetic field by passing alternating current through the field magnets. This means that the poles produced by the A-C are constantly changing their positions relative to the field winding, the latter being stationary; hence the term "rotating magnetic field." This field "rotating" in space about the axis of the armature induces currents in the latter. The reaction between these currents and the rotating field creates a torque which tends to turn the armature, whether the latter be at rest or in motion. The armature must rotate slower than the rotating magnetic field. The difference in speed is called the slip. There are numerous types of induction motors.

37. Inertia (WR2) of Driven Machine

The inertia or flywheel effect (WR2) of the rotating parts of the driven machine affect the accelerating time and, therefore, the heating of motors and control.

38. Insulation

A protective covering on wires or electrical parts to prevent short circuits.

39. Interlock

A device actuated by the operation of some other device with which it is directly associated, to govern succeeding operations of the same or allied devices. Interlocks may be either electrical or mechanical.

40. Intermittent Duty

A requirement of operation or service consisting of alternate periods of load and rest so apportioned and regulated that the temperature rise at no time exceeds that specified for the particular class of apparatus under consideration.

41. Jogging (or Inching)

The quickly repeated closure of the circuit to start a motor from rest in order to accomplish small movements of the driven machine.

42. Kilo

Prefix denoting 1000; as kilowatt (1000 watts).

43. Kilovolt Ampere

The unit of apparent power in alternating-current circuits (as distinguished from kilowatts, which represent the true power). See "Power Factor."

44. Kva

Kilovolt amperes.

45. Magnetic Field

Space around a magnet through which magnetic lines of force travel.

46. Manual Controller

A controller operated by hand.

47. Master Switch

A switch which serves to govern the operation of other switches.

48. Motor

A machine for converting electric energy into mechanical energy, as an A-C or D-C motor. The use of the word motor for engine is objectionable.

49. Negative Terminal (Pole)

The usual terminal to which the current returns after passing through a circuit.

50. Neutral Plane

Brush position at which the motor will run in either direction of rotation at the same speed and load with the same shunt field current.

51. Ohm

A unit of measurement of electrical resistance. One ohm allows one ampere of current to flow through a conductor at one volt.

52. Ohmic Resistance

True resistance as opposed to impedance.

53. Open Circuit

A circuit through which no current can pass.

54. Overload Protection

The effect of a device operative on excessive current, but not necessarily on short circuit, to cause and maintain the interruption of current flow to the device governed.

55. Overload Relay

An overcurrent relay in the circuit of a motor which functions at a predetermined value of the current to cause the disconnection of the motor from the line.

56. Parallel

When objects are connected across a power line so that the current in each is independent of the other, they are in parallel. (See fig. 78.) The current from the source is the total of the currents flowing through all objects across the line.

57. Periodic Duty

A requirement of service which demands operation for alternate periods of load and rest in which the load conditions are well-defined and recurrent as to magnitude, duration and character.

58. Periodic Rating

The load which can be carried for the alternate periods of load and rest specified in the rating, the apparatus starting cold, and for the total time specified in the rating, without causing any of the limitations to be exceeded.

59. Phase

A stage in a recurring cycle, as in the case of alternating current. See "Alternating Current" and "Single Phase."

60. Pole

A point of maximum intensity of electric or magnetic force. See "Field Pole." In relation to an electric circuit, see "Negative Terminal" and "Positive Terminal."

61. Positive Terminal (Pole)

The usual terminal from which current enters a circuit.

62. Potential

Ability to exert energy; expressed electrically by "voltage."

63. Power Factor

The ratio of the power shown by a wattmeter to the power found from the product of volts by amperes as indicated by a separate voltmeter and ammeter. It is an indication of out-of-phase relationship of voltage and current.

64. Rating

An arbitrary designation of the operating limit of a machine or device. Thus the rating of a controller is based upon the power governed, the duty, and the service required.

65. Rectifier

A device for converting alternating current into uni-directional or direct current.

66. Regulator

An automatic device for maintaining or adjusting the current, speed, etc., of a machine, transformer, or the like.

67. Relay

A device that is operative by a variation in the conditions of one electric circuit to effect the operation of other devices in the same or another electric circuit.

68. Resistance

The "holding back" quality of a circuit. A circuit of low resistance (measured in ohms) will allow a large current to flow, and vice versa. (See fig. 79.)

69. Resistor

A device that possesses the property of electrical resistance. A resistor, as used in electric circuits for purposes of operation, protection, or control, commonly consists of an aggregation of units.

70. Rheostat

A resistor which is provided with means for readily varying its resistance.

71. Rotor

The rotating part of an electrical machine. See "Stator."

72. Rpm

Revolutions per minute.

73. Series

When objects are connected so that the same current flows through one after the other, they are in series. (See fig. 80.) The current is the same anywhere in the circuit. Breaking the circuit of any one object breaks the flow of current to the entire circuit.

74. Short Circuit

A fault in an electric circuit, due usually to imperfect insulation, with the result that the current follows a bypath and inflicts damage or is wasted.

75. Shunt

If a device is connected in parallel with some equipment, thus by-passing a portion of the current which would otherwise flow through that equipment, it is in *shunt*. (See fig. 81.)

76. Single Phase

A term applied to a single alternating current as distinguished from polyphase currents; also known as monophase or uniphase.

77. Slip

The extent to which the speed of an induction motor, operating with a load, is below synchronous speed. Percentage of slip equals synchronous speed minus full load speed divided by synchronous speed.

78. Stator

The stationary part of an electrical machine. (See "Rotor" and "Armature".)

79. Switch

A device for making, breaking, or changing the connections in an electric circuit.

80. Synchronous Converter

A machine which converts from an alternating current to a direct current; usually called rotary convertor.

81. Synchronous Motor

A motor constructed to rotate in step with the alternating current that operates it. Its average speed is exactly proportional to the frequency of the A-C supply. Normally, synchronous motors have direct-current field excitation. Any single or polyphase alternator will operate as a synchronous motor when supplied with current at the same pressure and frequency and wave shape as it produces as an alternator. The essential condition, in the case of a single-phase machine, is that it be speeded up to synchronism before being put in the circuit.

82. Synchronous Speed

For practical purposes, the speed at which an induction motor would run without any load. In rpm., it is equal to $\frac{120 \times \text{frequency}}{\text{number of poles}}$

83. Tachometer

An instrument indicating speed of rotation or revolutions per minute. (See fig. 83.)

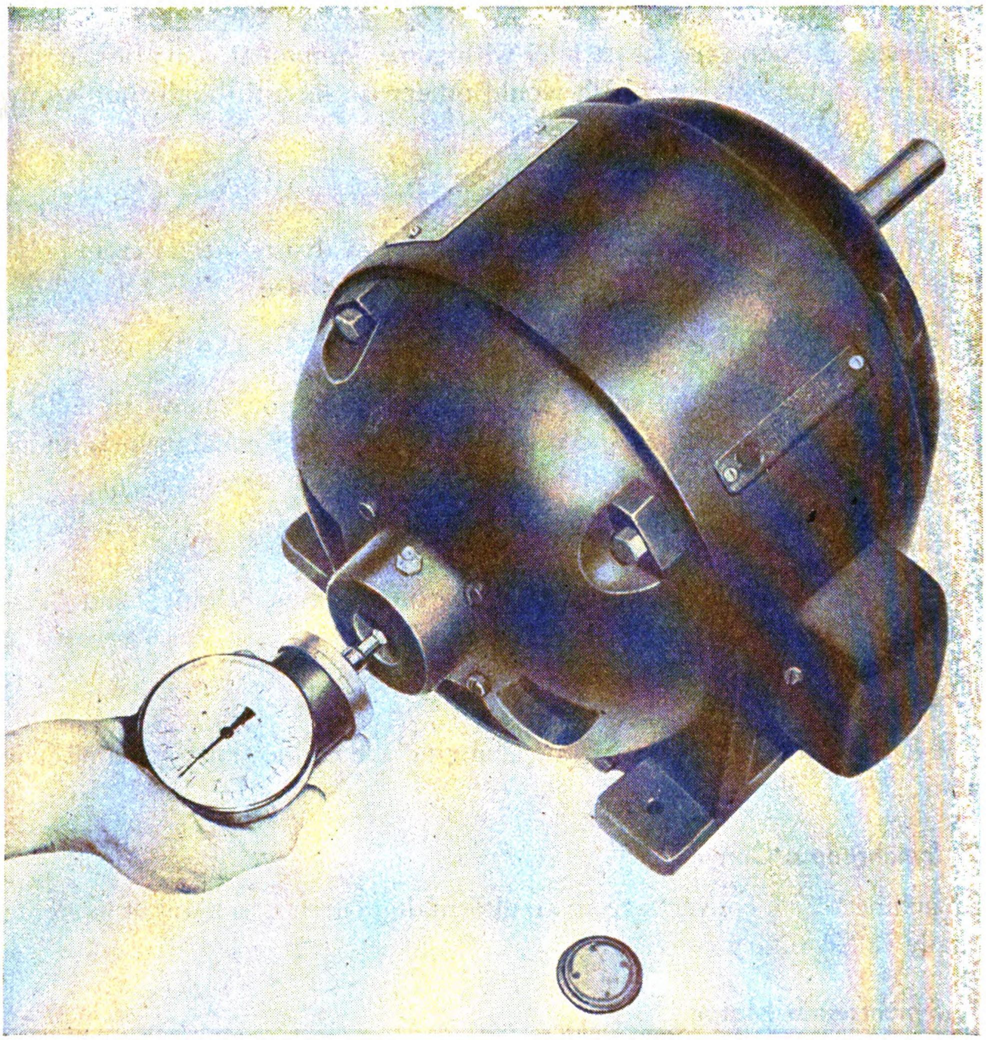


Figure 83. Use of a hand tachometer to determine revolutions per minute.

84. Torque

A twisting effort in the operation of a machine. Torque is the product of force multiplied by the distance from the center of rotation. For example, a force of 40 pounds applied on the end of a 2-foot pipe wrench would be equivalent to 80 foot-pounds of torque. There are two kinds of torque that must be considered in applying a new or replacement motor to a load, the starting torque and the pull-out torque. Excessive starting torque results in low efficiency, low power factor, and poor speed regulation. On the other hand, if the starting torque is too low, in many cases the load cannot be started. Very high pull-out or stalling torque also means low power factor with high starting current. If the pull-out torque is too low, the motor may stall on ordinarily harmless overloads. A stalled motor may result in "roasted" insulation.

85. Transformer

An apparatus for transforming an electric current from a high to a low potential (step-down transformer) or vice versa (step-up transformer) without changing the current; a converter. The term is now commonly applied to an apparatus for transforming alternating currents.

86. Volt

A unit of electrical pressure or electromotive force. The higher the pressure (voltage) of a battery the more current it will force through a wire, coil, lamp, or other device. (See fig. 82.)

87. Voltage Relay

A relay which functions at a predetermined valve of voltage. A voltage relay may be either an over-voltage relay or an under-voltage relay.

88. Voltmeter

A device for measuring voltage.

89. Watt

Unit of electric measurement of power. One watt of power equals one ampere of current times one volt of potential.

90. Wattmeter

An instrument combining voltage and current coils and showing on its dial the product of the two, or watts.

91. Winding

Wire wound or coiled around an object. Field winding connected in parallel with the armature winding is known as a shunt-field winding; if connected in series with the armature winding, it is known as a series-field winding.

APPENDIX VIII

REFERENCES

TM 1-455, Electrical Fundamentals.

TM 9-1825 A, Ordnance Maintenance Electrical Equipment (Delco-Remy).

TM 9-1825 B, Ordnance Maintenance Electrical Equipment (Auto-Lite).

TM 10-580, Automotive Electricity.

TM 37-250, Basic Maintenance Manual.

TM 37-265, Instruction Guide—Care and Maintenance of Ball and Roller Bearings.

TB ENG 58, Field Tropicalization Measures for Engineer Materiel.

TB ORD 242, Protection of Electrical Equipment on Ordnance Vehicles Against Corrosion and Rust.

TB SIG 13, Moistureproofing and Fungiproofing Signal Corps Equipment.

INDEX

U. S. GOVERNMENT PRINTING OFFICE: 1945—657673—TM 264