Westinghouse

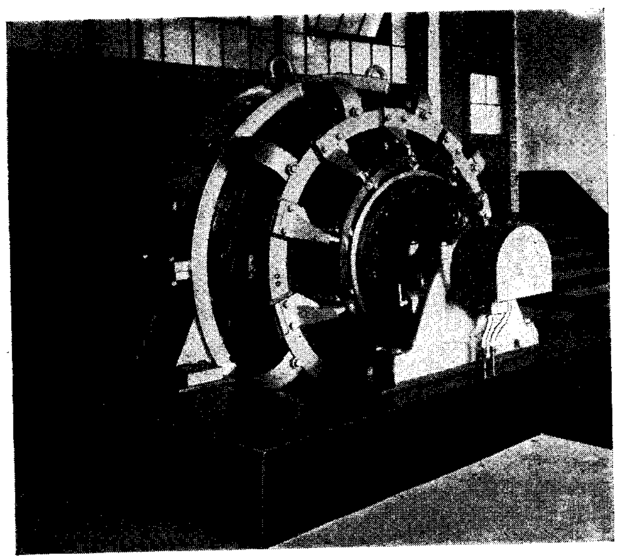
Direct-Current Generators and Motors

Installation

Operation

Maintenance

INSTRUCTION BOOK



Installation of Westinghouse Type QS Motor

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Pa.

I. B. 4000

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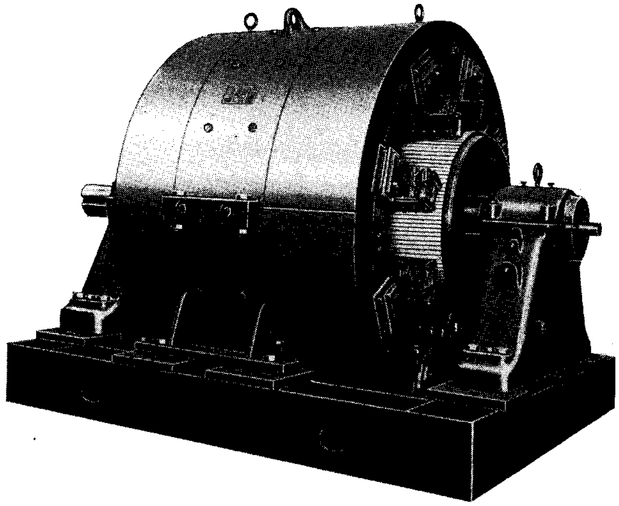


Steel Mill Motor with Special Ventilating Covers

CAUTIONS

Before opening the shipping crates and before installing a machine, read the following instructions carefully, paying particular attention to the section on Installation, Page 8. Adherence to the requirements of foundation, ventilating air, and proper mechanical alignment is essential for continued operation of the machine. Extreme care must be taken when handling parts containing insulated windings as they are easily damaged by careless treatment; see Handling and Unpacking, Page 8.

Keep the generator or motor clean. The finest machines may be shut down by accident if they do not have protection and care. The commutator and winding insulation must be kept clean and dry. Oil and dirt on the insulation are as much out of place as grit or sand in a bearing. On a direct-connected unit, oil may work along the shaft or splash into the machine and cause an insulation failure unless the necessary protection is provided.

COMMUNICATIONS

When communicating regarding a Product covered by this Instruction Book, replies will be greatly facilitated by citing COMPLETE NAME PLATE READINGS of the involved Products. Also, should particular information be desired, please be very careful to clearly and fully STATE THE PROBLEMS AND ATTENDANT CONDITIONS.

Westinghouse

Direct-Current Generators and Motors

GENERAL INFORMATION

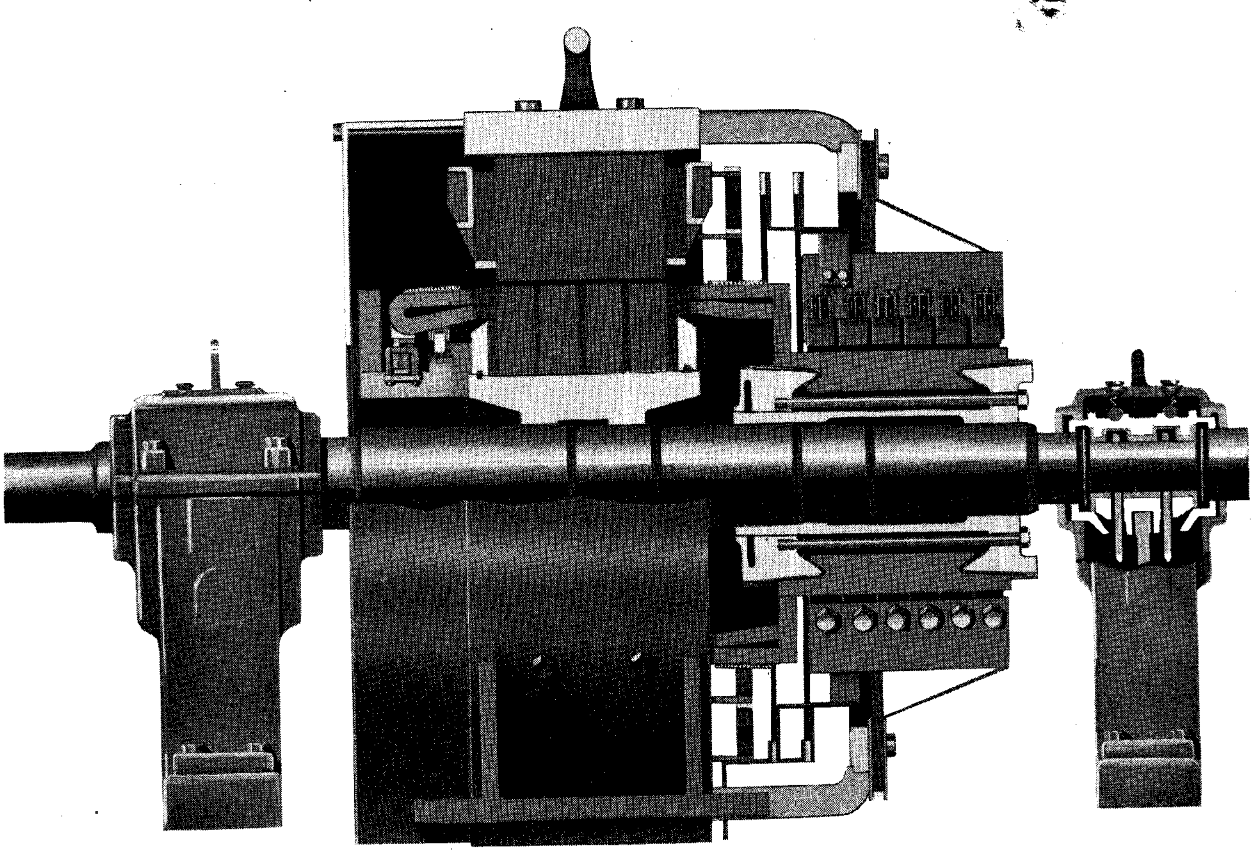


Fig. 1—Sectional View of Direct Current Generators

PURPOSE

These instructions have been especially prepared to provide guidance for the proper installation, operation, and maintenance of Westinghouse direct-current generators and motors. Recommendations for the care of the machines, based on years of experience, are offered as the best assurance of long life and dependable operation. There may be some points about which the operator is not familiar; therefore, before installing or operating the equipment, read the following instructions thoroughly.

GENERAL DESCRIPTION

Types of Construction

Westinghouse standard direct-current generators and motors are divided into the following types:

(1) **Belt Driven, self-contained type,** having two or three bearings, shaft and pulley.

(2) **Coupled, self-contained type,** having two bearings and shaft arranged for direct connection to the prime mover, whether steam, internal-combustion, or hydraulic, if a generator, or to the

element to be driven, if a motor. The frames may or may not be provided with a bedplate.

(3) **Coupled, Marine-type,** having pedestal type bearings and a flanged shaft suitable for direct connection to the prime mover, if a generator, or to the propulsion shafting, if a motor. The frames and pedestals are not furnished with a bedplate, proper support and alignment being provided on the vessel's structure by the shipbuilding contractor.

(4) **Engine type,** consisting of a complete field and armature without bearings or shaft, the armature to be mounted on the extended shaft of the prime mover, if a generator, or on the extended shaft of the machine to be driven, if a motor. Engine-type machines of the larger sizes are not as a rule provided with bedplates. In place of one large bedplate, two smaller supporting pieces, known as sole-plates are supplied. These plates are grouted into the foundation on each side and provide a finished seat for the supporting feet of the field frame.

(5) **Turbo-Generators**—These machines are built for steam turbine drive. They differ from the ordinary engine-type machines mainly in the mechanical features required for the higher rotative speeds at which they operate.

(6) **Turbine Reduction Gear Generators**—These machines are essentially of the coupled type with a forged, flanged shaft which couples directly to the reduction gear shaft. The bedplate is usually supplied by the turbine builder. Generally, only one bearing is supplied, the coupling being attached to and supported by the reduction gear shaft.

(7) **Turbo Generator Exciters** are usually of the flexibly coupled, self contained type with special features to make them suitable for high-speed service and long periods of uninterrupted operation. All sizes are provided with maximum brush accessibility and those with ratings of above 50 kw. are provided with special brush holders which permit the removal of brushes by a workman using only one hand and without the need of tools.

Due to the large volumes of high velocity air which passes through these exciters, special care is taken to provide maximum creepage distances on all electrical parts and to provide for ease of cleaning. This is true in both 3600 rpm. and 1800 rpm. exciters as the brush wear is essentially the same in equivalent exciters at either speed. This is due to the larger diameter commutators required on the 1800 rpm. exciters.

(8) **Water Wheel Generator Exciters**—These exciters have their rotors mounted above the A.C. generator and bolted to the spider or shaft of the A.C. generator. The stator is supported by the upper bracket of the A. C. generator and the pilot exciter (if any) is mounted above the main exciter.

Output

The output of a generator in kilowatts may be obtained by multiplying the current in amperes by the e.m.f. in volts and dividing by 1000. To obtain the horsepower output of a motor, multiply the current in amperes by the applied e.m.f. in volts and multiply this product by the efficiency and divide by 746.

$$\text{Kilowatts} = \frac{\text{Volts x Amperes}}{1000}$$

$$\text{Horsepower} = \frac{\text{Volts x Amperes}}{746} \text{ x Efficiency}$$

Windings

Depending upon the character of field winding employed, a direct-current machine is classified under one of the following three general groups:

1. Shunt wound.
2. Series wound.
3. Compound wound.

Shunt-Wound Generator

The field winding of a shunt-wound generator is composed of a large number of turns of wire or strap of comparatively high resistance, which, in series with a rheostat, is connected directly to the armature terminals, forming, in parallel with the main circuit, a shunt circuit through which only a small percentage of the total current flows. This is a self excited shunt wound generator. A separately excited machine would differ only in having both shunt field leads brought out. This allows the shunt field to be excited from another source of voltage than the generator itself.

The regulation characteristics of a shunt-wound machine are such that the voltage is a maximum at no load, and drops as the load increases unless regulated by the manipulation of a rheostat in the field circuit. This voltage droop is much greater in the case of the self excited generator than on a separately excited generator.

Series-Wound Generator

The field winding of a series-wound generator is composed of a few turns of heavy wire or strap which is connected in series with the armature and external circuit. With this type of machine the total current delivered flows through the field winding and the voltage varies directly with the load. The greater the load the higher the voltage. Generally, a slight load is required to make these machines pick up voltage, therefore series generators are very infrequently used.

Compound-Wound Generator

A compound-wound machine has both shunt and series windings. The shunt field is generally so designed that on open circuit, the series field being idle, the machine will generate the desired line voltage. The result of applying load would, as noted under "Shunt Generator," tend to lower the

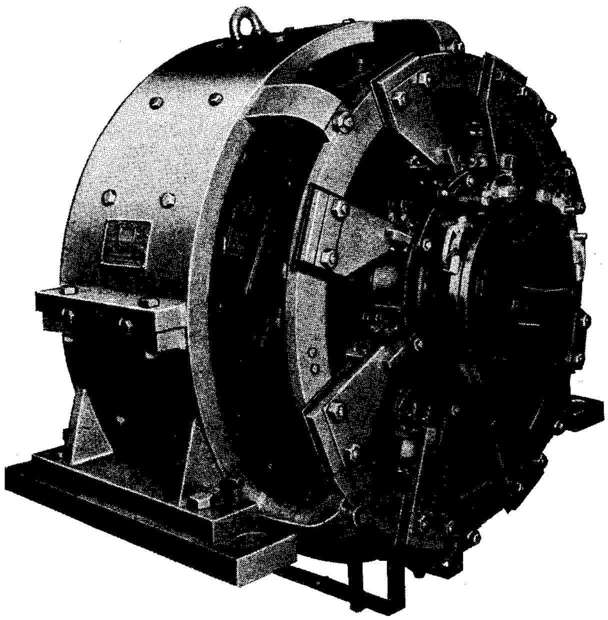


Fig. 2—Commutator End View of Engine Type QS Generator, Showing Collector Rings for 3-Wire Service

terminal voltage; but it is here that the utility of the compound winding becomes apparent. The series coils reinforce the shunt field in direct proportion to the increase of load and thus hold the terminal voltage approximately constant, balancing the drop due to increased copper loss and armature reaction at the heavier loads.

In order to allow some variation and permit adjustments to suit operating conditions, additional hand regulation is provided in the form of a rheostat in the shunt-field circuit.

It is desirable that compound wound generators be supplied with flat compounding, that is, with the same voltage at no load and at full load current, as better division of load between generators in parallel is thus secured.

In some cases the compound winding is connected in reverse, so as to buck the shunt field action. In this case, the machine is called a differentially-compound generator and the voltage droops considerably more than that of a shunt-wound generator.

Long and Short Shunt

When the shunt field winding of a compound-wound generator is connected across the outside terminals of the machine, shunting both the series field and armature windings, it is known as long shunt.

When the shunt field is connected inside the series field it is known as short shunt. This is the more common practice, the voltage applied to the shunt being higher than it would otherwise be by the amount of the drop through the series winding.

Three-Wire Generators

Any of the above types can be made into a three-wire generator. In this modification, equidistant taps are made in the armature winding and carried to collector rings at the end of the armature. The rings are connected through sliding brushes to a choke or balance coil. The middle point of the coil constitutes the neutral point to which the third or neutral wire of the system is connected. A practically constant voltage is maintained between the neutral and outside wires which is one-half the generator voltage. See Figure 9. Two collector rings and one balance coil are used. Three-wire operation requires that one-half the commutating field and series field windings, if any, be connected on each side of the line in order to maintain approximately the same total field strengths under unbalanced load.

Series Motors

Series motors are variable speed machines particularly adapted to a few special uses, such as railway and crane service, but are not extensively employed in the field of work to which this book is devoted. The characteristic features of a series motor are its great torque at starting and low running speeds under heavy loads. A series motor should always be positively connected to a load, as it has a very high run-away speed at no-load.

Compound-Wound Motors

For some special classes of service, in which it is necessary to start under heavy load and later operate at approximately constant speed, a series winding is added to assist the shunt field at the heavy load points.

As in the case of the compound generator, a compound motor combines the characteristics of both shunt and series motors. The series winding gives a drooping speed regulation to the motor and increases the starting torque.

Shunt Motors

This is by far the most common type of winding, and is generally applied to motors designed for operation at constant speed under constant or varying loads. Nearly all commercial applications, particularly those of large capacity, require this type of motor. When necessary, considerable speed variation can usually be secured by means of a rheostat in the field circuit, increased resistance resulting in an increased speed. Practically all so-called "shunt" motors have a slight series field winding, usually known as a stabilizing winding, to maintain stability under load.

INSTALLATION

GENERAL

Storage

Where the equipment is received ahead of the time of actual installation, consideration should be given to proper storage so that exposure to weather, dirt, and moisture will be avoided. It is particularly important to keep the windings and commutator dry since moisture lowers the insulation resistance and increases the likelihood of a breakdown in service. Store the cases containing the machine or its parts in a cool, dry and sheltered location until ready to be put into operation. Do not open the cases and disturb them as little as possible until ready to proceed with the assembly.

Unpacking

The cases containing the machine or any of its parts should be left unopened until the time of assembly. If a machine is brought from cold surroundings into a warm room, it should be kept covered until its temperature has risen to room temperature so as to prevent condensation on the windings and other parts. The safe rule is to open all cases during the cool part of the day.

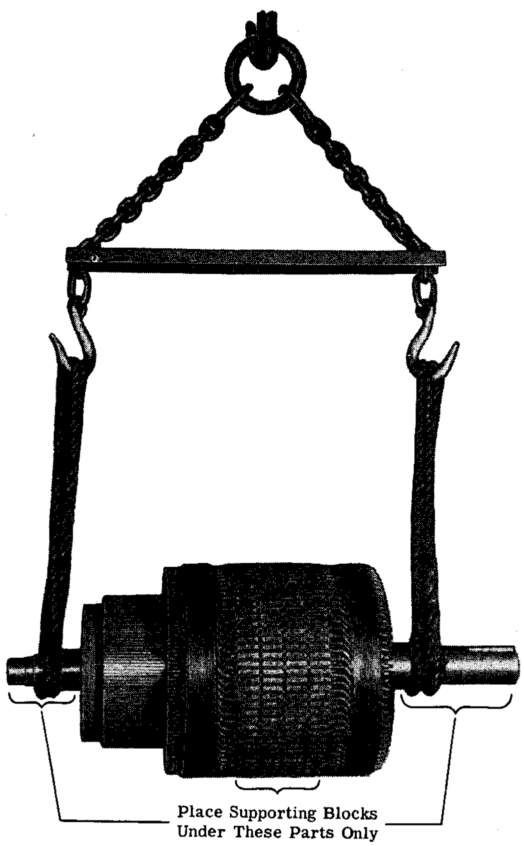


Fig. 4—Lifting Armature with Spreader-Bar

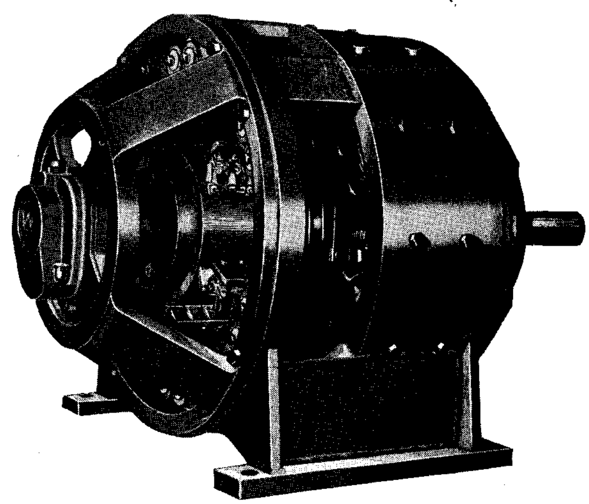


Fig. 3—Standard Large Size Type SK Fabricated Motor

Handling

It is easily possible, by rough handling or careless use of bars or hooks, to do more damage to a machine before or during erection than it would receive in years of regular service.

Care should be taken in transporting and handling the equipment to see that the windings are not damaged. A blow upon any part of the windings is liable to injure the insulation and result in failure of the coil.

Lifting of machines should be done with the greatest of care. The stators are provided with lifting rings on the top of the frame, into which crane hooks may be inserted. Remember that the field coils and wiring-around-frame connections are exposed during assembly and can be very easily damaged; therefore, careful handling of the stator sections is very essential.

The armature is especially liable to damage since its own weight is sufficient to crush the winding if it is lowered on or swung against a projection. The armature should be lifted, preferably, with rope slings looped around the shaft, taking great care that the rope does not touch the commutator or the windings at the back of the armature. Use a spreader-bar to hold the ropes away from the armature as shown in Figure 4. Chains or wires should not be used unless the shaft journals are adequately protected.

Caution—Never support the armature wholly or in part by the commutator either when raised by blocking or when held in a rope sling. Do not allow workmen to stand on the commutator.

LOCATION OF MACHINES

It is very important that the location be wisely chosen, due regard being paid to the rules of the National Board of Fire Underwriters and to local regulations. The following considerations should also be carefully observed:

1. The machine should be located in a cool, dry place, well ventilated and not exposed to moisture. Remember that the room temperature is added to that developed in the machine, and therefore, the total temperature, and consequently the capacity of the machine depends upon the temperature of the surrounding air.

2. The machine should not be exposed to moisture from leaky pipes, escaping steam, or condensation of atmospheric moisture on an overhead glass or metal roof. Drip-proof covers should be provided if such conditions exist.

3. It should not be exposed to the corrosive action of acid fumes or other injurious gases.

4. The machine should not be exposed to dirt from coal handling or similar operations.

5. A direct-current machine must never be placed in a room where any hazardous process is carried on, or in a place where it will be exposed to inflammable gases or flying chips, sawdust or other combustible material.

6. The machine should be located so as to receive proper ventilation. This is important and means that the air circulation in the room must be such as to carry away the heated air and supply cool air to the machine. To provide this it may be advisable in some cases to put in ducts that will bring air from outside of the building.

7. The machine should be so located that it will be easily accessible for observation, inspection, oiling and cleaning.

8. Belt-driven machines should have proper distance between belt centers.

FOUNDATIONS

Machines not exceeding 50 kilowatts and 1000 amperes capacity may be supported by timber bases, but larger units require solid masonry or concrete foundations, to which they should be secured by foundation bolts. These bolts must be accurately spaced, the approved method of location being to construct a light wood template or frame with the bolt holes carefully bored to dimensions given on the blue print of the generator base. It is advisable to have these bolts, surrounded by iron pipes of proper length and with inside diameter somewhat larger than bolts, set in the foundation with the openings in the masonry to allow access to the nuts at their lower ends in case renewals become necessary. The slight flexibility of position permitted by this pipe construction is often of great convenience on the final lining up of the bedplate.

Be sure that the foundation is carried down to a solid bottom, or is made of sufficient area to prevent sinking or displacement under the full load it is expected to support.

A competent engineer who is familiar with local conditions should lay out this part of the work.

Care should be taken that all pits in the concrete are properly drained and that passages remaining for piping and wiring are easily accessible and so laid out that the work of installing and connecting up will be simplified in every possible way.

Insulation of Frames

The desirability of insulating the frame from the ground is an open question and must be decided upon by the merits of the case. As a matter of fact, frames of machines up to 700 volts are seldom insulated; it is well, however, to keep in mind the following points.

Broadly speaking, the strain on the insulation of the windings is decreased and the danger to the attendant increased by insulating the frame of the machine from the ground. There is also likelihood of flashing to ground with high-voltage machines.

If the frame is to be insulated from the ground, the foundation can be capped with a stout wooden frame bolted to the masonry, care being taken that the bolts are so placed that they do not make electrical contact with the bolts which secure the machine base to the wooden cap. This wooden cap may be covered with some waterproof insulating paint or compound. Porcelain insulators set in the concrete of the foundation have also been used. In any case an insulating platform should extend around the machine of sufficient width so that the attendant must mount it before he can touch part of the frame.

Direct-connected units necessarily have their rotating parts grounded through the driving machine and piping. The stationary parts might be insulated, but it is difficult to accomplish this and at the same time secure the machine firmly to the foundation.

ERECTION

Some of the smaller machines are shipped completely assembled and need only to be set upon their foundations, leveled, and lined up before making connections.

The armatures for larger generators and motors are shipped separately. Whenever possible, the stator frames are shipped assembled and with all internal wiring connected. Preparatory to assembling the machine, the upper half of the rocker ring must be removed, the wiring-around-frame connections at the frame split must be opened, and the top half of the frame must be lifted off.

In all cases where the frame is split to remove the top half, care must be taken in reassembling to tighten the commutating pole bolts at the frame split before the frame lug bolts are tightened.

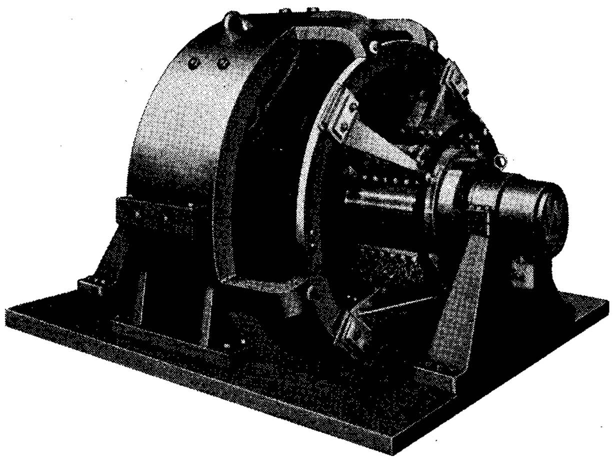


FIG. 5—TYPE QS GENERATOR WITH ANTI-FRICTION BEARINGS

This will spring the two halves of the frame into the proper position and thus avoid incorrect effective commutating pole air gaps for those poles at the split.

The erection of Westinghouse generators and motors is considered as divided into four general classes, namely:

1. Belt-driven, self-contained machines
2. Coupled, self-contained machines
3. Coupled, marine-type machines
4. Engine-type machines

Erection of Belt-Driven, Self-Contained Generators and Motors

1. Set the lower half of the frame and rocker rings in position. Level and insert the bearings, if they are separately shipped. Inspect the bearings and oil reservoirs carefully to be sure they are clean and free from dirt.

2. After covering the journals with a film of oil, lower the rotating part into the bearings. Fill the bearings with oil to the proper level, place the bearing caps in position and screw down the cap bolts lightly.

3. Clean the contact surfaces of both halves of the frame. Set the upper half in position and secure to the lower half by the bolts and feather keys. Swing the upper half of the rocker ring into place and, after bolting the halves together, see that it moves easily in its seat.

4. Re-connect the armature leads and the field wiring connections inside of the machine. Insert the brushes in the brushholders and check to see that the brush alignment is correct; that is, that the edges of the brushes are parallel to the commutator bars, that the brushes are accurately spaced around the commutator, and that the brushholders are within $\frac{1}{16}$ to $\frac{1}{8}$ inch of the commutator surface. Check that the brushes are set on the "factory brush position" by following out the instructions in regard to "Mechanical Redetermination of Brush Position" as given on Page 16. Grind in the brushes to a perfect seat on the commutator, using sandpaper only; see Figure 19. See that the brushes move freely in the holders and are held under an equal and moderate pressure; 2 to 2½ pounds per square inch of cross-sectional area is a normal pressure.

5. Accurately align the shaft with the driving or driven shaft, with the center lines of pulleys directly opposite. Tighten up the foundation bolts. Place the belt in position and run slowly. If the shafts are parallel, but the pulleys not directly opposite, the belt will run to one side of the larger pulley. If the pulleys are opposite but the shafts not parallel, it will run to one side of the smaller pulley.

6. After final adjustment, set the foundation bolts up hard.

7. Connect the machine to the switchboard. (For further information, see diagrams on Pages 34 and 35.)

Erection of Coupled, Self-Contained Generators and Motors

Proceed as in sections 1, 2, 3 and 4 of the preceding instructions.

5. Align the generator shaft with the driving shaft and mount the coupling.

6. Connect the machine to the switchboard. (For further information, see diagrams on Pages 34 and 35.)

7. Connect the couplings and run slowly; then secure the machine permanently to its foundation.

Erection of Coupled, Single-Bearing Generators and Motors

1. Place the lower half of the field frame and rocker ring in position on the supporting structure which should be of such a height as will allow room for approximately one-half of the liners furnished for adjustment under the frame when the air gap is correct.

2. Locate the bearing pedestals so that the centers of the bearings are on the horizontal axis through the connecting shaft.

3. Lift the armature using rope slings around the shaft, taking care that the ropes do not touch the windings at the back end of the armature. (See Figure 4, Page 7.)

Caution: Never support the armature wholly or in part by the commutator. Do not allow workmen to stand on the commutator.

Inspect the shaft journals for any rough spots or scratches as these may cut the bearings and cause them to run hot. Cover the shaft journals and bearing surfaces with a film of oil and lower the armature carefully into its bearings.

4. Adjust the bearing pedestals to obtain correct coupling alignment, as checked by "breaking" the coupling so that a thickness (feeler) gauge may be inserted between the half coupling faces. With the coupling connected, check for longitudinal clearance at the bearings with the shaft end-play all out in both directions. Bolt the pedestals to the mounting plates, fill with oil to the proper level, and replace the bearing caps.

5. Adjust the frame in position, shifting it in a direction parallel with the shaft until its center line (halfway between the faces of the laminated main pole iron) is directly opposite the center of the rotating part (half-way between the endplates which hold the laminations of the core.)

6. Clean the contact surfaces of both halves of the frame. Place the top half of the frame and the upper part of the rocker ring in position and bolt together.

7. Adjustment of the air-gap—In setting up any machine in which the bearings are independent of the frame, great care must be exercised in the adjustment of the air-gaps between the armature core and the pole faces, as any inequality in the gaps may cause serious electrical unbalance and unequal heating of the armature iron. Adjust the airgap horizontally by shifting the frame, and vertically by means of steel liners placed under the frame feet until equal feeler gauge measurements are obtained between the main poles and the armature at both the front and back of the machine.

8. Re-connect the armature leads and the field wiring connections inside of the machine. Insert the brushes in the brushholders and check to see that the brush alignment is correct; that is, that the edges of the brushes are parallel to the commutator bars, that the brushes are accurately spaced around the commutator, and that the brushholders are within $\frac{1}{16}$ to $\frac{1}{8}$ inch of the commutator surface. Check that the brushes are set on the "factory brush position" by following out the instructions in regard to "Mechanical Re-determination of Brush Position" as given on Page 16. Grind in the brushes to a perfect seat on the commutator, using sandpaper only; see Figure 19. See that the brushes move freely in the holders and are held under an equal and moderate pressure; 2 to $2\frac{1}{2}$ pounds per square inch of cross-sectional area is a normal pressure.

9. Connect the machine to the switchboard. (For further information, see diagrams on Pages 34 and 35.)

Erection of Engine-Type Machines

1. Set the soleplates, if any, in place and level up to proper position; i.e., to such a height as will allow room for approximately one-half of the liners provided for adjustment under the frame when the air-gap is correct.

2. Place the lower half of the field frame and rocker ring in position.

3. With machines of large size, the armature must be pressed upon the shaft at point of installation, if this has not been done at factory.

The shaft is turned accurately to a certain gauge and the hub is bored out to a similar gauge several thousandths of an inch smaller in order to secure a press fit. Before attempting to force the armature on its shaft, inspect the surfaces to be fitted as they may have received injury during transportation. File down any roughness of this sort and smooth with emery cloth.

See that the key has a good bearing on its sides and clears on top about $\frac{1}{32}$ of an inch.

Before proceeding further with the operation, the surfaces on the shaft and the interior of hub finished for the fit should be painted with a mixture of white lead and engine oil to prevent cutting the shaft.

The force required to press the armature on, varies with the temperature, condition of surface, and quality of the metal to such an extent as to make it practically impossible to estimate its value with any degree of accuracy. It is generally safe to assume that from 100 to 200 tons force will be required.

For forcing a large armature on its shaft, a hydraulic press is preferable. When this cannot be secured, make two yokes out of I-beams. Place one of these across the rear of the armature so as to press on the end of the armature spider, and one at the end of the shaft, and draw the armature in place by means of two bolts which pass through the yokes and spider close to the shaft. Care

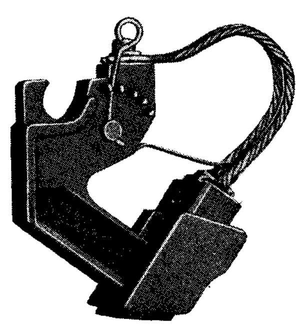


Fig. 6—D-C. Brushholder for QS Generators and Motors

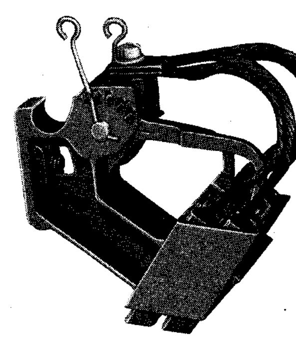


Fig. 7—D-C. Double Brushholder for QS Generators and Motors

should be taken to tighten up evenly on the bolts, otherwise, the spider will twist and bind on the shaft. Once started, this operation should be carried to completion as quickly as possible, as, if the armature is allowed to set several hours when only part way on the shaft, it may require from 25 to 50 per cent more force than was previously used to start it again.

Do not mar or scratch the shaft, as any roughness may cut the bearings and cause them to run hot. A large armature which must be pressed on the shaft in the station should be supported when possible on the spokes of the spider by passing heavy timbers through the spider and blocking up to them at each end. When this is impossible, it should be set in a cradle cut out of heavy timber to fit, and lined with excelsior or waste, so that the weight will be evenly distributed over a large area of the core. This cradle should be made narrower than the core in order not to injure the winding. An armature so supported should be braced on both sides.

4. After the armature has been pressed upon the shaft, it should be carefully lifted in a sling and lowered into its bearings.

Caution: Never support the armature wholly or in part by the commutator, either when raised by blocking or when held by a rope sling. Lift it by a rope sling about the shaft, taking great care that the ropes do not touch the windings at the back end of the armature. Do not allow workmen to stand on the commutator.

5. Adjust the frame in position, shifting it in a direction parallel with the shaft until its center line (half-way between the faces of the laminated main pole iron) is directly opposite the center of the rotating part (half-way between the endplates which hold the laminations of the core).

6. Clean the contact surfaces of both halves of the frame. Place the top half of the frame in position, mount the upper part of the rocker ring and check adjustments to see if they are still correct.

7. If mounted on soleplates, tighten the soleplate bolts and cement the soleplates to the foundation, using a mixture of one part of Portland cement and two parts of sand, or half cement and half sand; either will give good results. First mix the cement and sand dry and then add water until a very thin solution is obtained. Construct a dam around the bedplate and pour this solution under it continuing the process until the cement stands about half an inch above the bottom of the soleplates. The entire operation of mixing and pouring the cement should be carried on without interruption and as rapidly as possible until completed, otherwise, the cement first poured under the bedplate may partially set and prevent that poured later from flowing freely to all parts. When the cement has sufficiently hardened, remove the surplus from the outside and smooth up the joint under the soleplates.

8. Adjustment of the air-gap—In setting up any machine in which the bearings are independent of the frame, great care must be exercised in the adjustment of the air-gap between the armature core and pole faces, as any inequality in this gap map cause serious electrical unbalance and unequal heating of the armature iron. Adjust the air-gap horizontally by shifting the frame, and vertically by means of thin sheet steel liners placed between the bedplate and the frame feet. During this operation gauge the gaps at different points on the front and back of the machine by inserting thin feelers in the air-gap and measuring the thickness of the stack of feelers.

9. Re-connect the armature leads and the field wiring connections inside of the machine. Insert the brushes in the brushholders and check to see that the brush alignment is correct; that is, that the edges of the brushes are parallel to the commutator bars, that the brushes are accurately spaced around the commutator, and that the brushholders are within $\frac{1}{16}$ to $\frac{1}{8}$ inch of the commutator surface. Check that the brushes are set on the "factory brush position" by following out the instructions in regard to "Mechanical Redetermination of Brush Position" as given on Page 16. Grind in the brushes to a perfect seat on the commutator, using sandpaper only; see Figure 19. See that the brushes move freely in the holders and are held under an equal and moderate pressure; 2 to $2\frac{1}{2}$ pounds per square inch of cross sectional area is a normal pressure.

10. Connect the machine to the switchboard. (For further information, see diagrams on Pages 34 and 35.)

PREPARING FOR OPERATION

It sometimes happens that the insulation of a machine is mechanically injured or exposed to moisture after the factory test but previous to being placed in service. Since the insulation resistance of the windings is an indication of the condition of the insulation, measurements of insulation resistance should be made before the machine is run. For methods of measuring insulation resistance of windings, see "Insulation Resistance Test" on Page 14. Unusually low values of insulation resistance should be corrected by repairing damaged insulation or by drying out the windings, as the case may be.

If there is reason to believe that the windings have been exposed to moisture during shipment or erection, they should be subjected to a drying process before putting the machine into regular operation. See "Drying Out Windings" on Page 15.

CONNECTIONS

CONNECTIONS FOR PARALLEL OPERATION OF GENERATORS

Diagrams of connections for generators operating in parallel are given on Pages 34 and 35.

Parallel operation of direct-current generators is effected in a comparatively easy manner if machines are of the same make and voltage or are designed with similar electrical characteristics. If they are shunt-wound machines, no connections other than the main leads are required; if they are compound-wound machines, the addition of equalizer connections between the machines is required. If the division of load between generators operating in parallel is not sufficiently balanced, it will be necessary to make adjustments as directed under "Operation," Page 20.

In laying out the wiring of generators that are to operate in parallel, particular attention should be paid to the relative resistance of the connecting leads. If generators are of the same size and make, the only feature requiring special attention in connecting to the switchboard is to see that all the cables which lead from the various machines to the bus-bars are of equal resistance. This means that if the machines are at different distances from the switchboard, different sizes of cables should be used, or resistance inserted in the low resistance leads, to equalize the voltage drops in these circuits.

If generators differ in design or size, the matter requires more attention. In this case the difference in potential or drop in voltage between the terminals of the machine and the bus-bars to which they are connected should be exactly the same for every generator when each is carrying its proper share of the load. To secure the best results, the total drop between generator terminals and switchboard must not only be the same at equal loads, but the drop in corresponding sections of the connecting cables of the different machines should also be equal; i.e., the drop in the positive lead from any one generator at full load should equal the drop in each of the other positive leads when carrying full load, and, similarly, the drop in a negative lead should equal the drop in each of the other negative leads. The same conditions should be secured, for compound wound generators, in the series field windings and leads. It may be necessary in achieving the desired results to alter the length or size of connecting cables, and occasionally additional resistance is required.

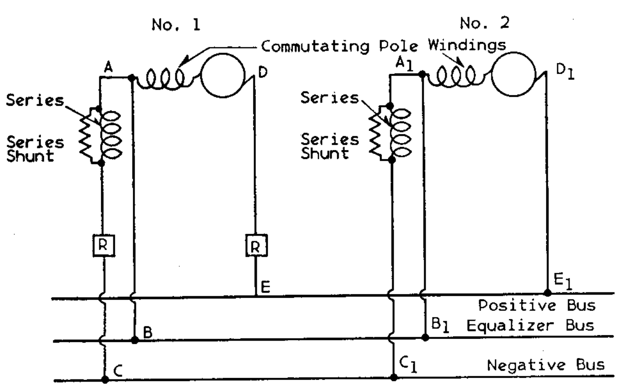


FIG. 8—DIAGRAM SHOWING CONNECTIONS OF GENERATORS FOR PARALLEL OPERATION

The diagram in Figure 8 will indicate how this is to be done.

To meet the conditions for parallel operation the volts drop through the leads D_1 E_1 and DE must be equal, and the drop from A_1 to C_1 including series winding must be equal to that from A to C including series winding. R shows resistance added, if required. While the diagram is made for two machines, it, of course, applies to any number.

EQUALIZER

An equalizer, or equalizer connection, connects two or more compound generators operating in parallel at a point where the armature and series field leads join, thus placing the armatures in multiple and the series windings in multiple, in order that the load may be divided between the generators in proportion to their capacities. The arrangement of connections is shown in the diagram, (Figure 8.)

The object of the equalizer, as the name implies, is to divide the total load between the machines according to their capacity. Consider, for example, two compound-wound machines operating in parallel without an equalizer. If for some reason, there is a slight increase in speed of one machine, it would take more than its share of load; and the increased current flowing through the series field would strengthen the magnetism, raise the voltage, and cause the machine to take a still greater amount until it carried the entire load. When equalizers are used, the current flowing through each series coil is inversely proportional to the resistance and is independent of the load on any machine; consequently an increase of voltage on one machine builds up the voltage of the other at the same time, so that the first machine cannot take all the load, but will continue to share it in proper proportion with the other generators.

The equalizer lead must have as little resistance as is practicable, and for this reason it is the usual practice to make the equalizer leads the same size as the main leads. No additional resistance should ever be put in it, irrespective of the lengths.

SERIES SHUNTS

A series shunt consists of a low resistance connection across the terminals of the series field, by means of which the compounding effect of the series winding may be regulated by shunting more or less of the armature current past the series coils. It may be in the form of grids, on large machines, or of ribbon resistors. In the latter case it is usually insulated and folded so as to take up but a small amount of space.

BALANCE COIL CONNECTION FOR THREE-WIRE GENERATORS

A diagram of connections of a Balance Coil to a three-wire d.c. generator is shown in Figure 9.

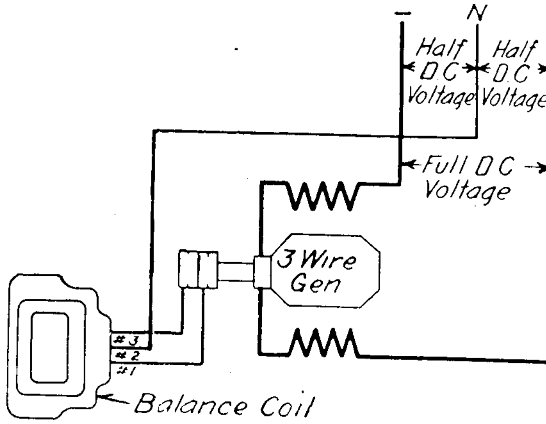


Fig. 9—Diagram Showing Connections of Balance Coil for Three-Wire D-C Generator, 125-250 Volts

Wires connecting the balance coil to the machine must be short and of low resistance. Any considerable resistance in this connection will affect the voltage regulation. The unbalance current flows along these connections, consequently, if they have much resistance, the resulting drop reduces the voltage on the heavily loaded side.

Switches are not ordinarily placed in the circuit connecting the collector rings to the balance coil. When necessary, the coil may be connected from the generator by raising the brushes from the collector rings. Switching arrangements sometimes make it necessary to run the balance coil connections to the switchboard and back, requiring heavy leads to keep the drop low; or if heavy leads are not used, then poor regulation may result. The balance coils are so constructed that there is very little likelihood of anything happening to them which will not be taken care of by the main circuit-breakers.

ADJUSTING AND TESTING

INSULATION RESISTANCE TEST

The insulation resistance of windings is measured, usually, with an instrument called a megger. This measurement gives an indication of the condition of the insulation particularly with regard to moisture and dirt. The actual value of resistance varies greatly in different machines depending on the size and voltage. The chief value of the measurement, therefore, is in the relative values of resistance taken on the same machine at various times. When measurements are made at regular intervals as part of the maintenance routine, it is thus possible to detect an abnormal condition of the insulation and take steps to remedy it before a failure occurs.

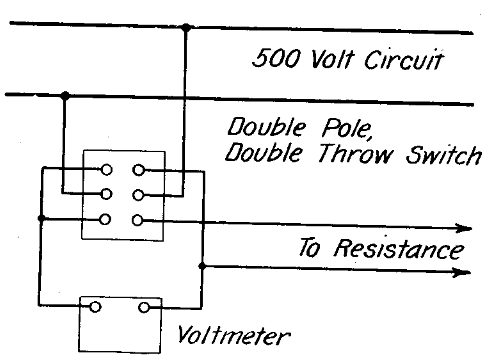


Fig. 10—Connections for Measuring Insulation Resistance

The higher the resistance, the better the general condition of the insulating material. The insulation resistance of the field will be much higher in proportion to its voltage above ground than that of the armature and will in general give little trouble. Since large armatures have much greater areas of insulation, their insulation resistance will be proportionately lower than that of smaller machines even though the material is in exactly the same condition. The insulation resistance of the armature windings of machines in good condition is usually not less than the following:

Insulation Resistance (in megohms) = $\frac{\text{Machine Voltage}}{\text{Rated Kw} + 1000}$. The insulation resistance of any machine will be much lower when hot than when cool, especially when the machine is rapidly heated.

The only feasible way of increasing the insulation resistance when a machine is complete is by "drying out" the windings with heat. Baking in an oven is to be preferred but is often impracticable; the usual method being to circulate current through the windings. See section on "Drying Out Windings," Page 15.

In case a "megger" is not available for making the insulation resistance measurements, a 500-volt direct-current circuit and a 500-volt direct-current voltmeter may be conveniently used. The method of making a measurement is to first read the voltage of the line, then to connect the resistance to be measured in series with the voltmeter and take a second reading.

The measured resistance can be readily calculated by using the following formula and the method of connecting the apparatus shown in the diagram Figure 10.

$$R = \frac{r\,(V-v)}{v}$$

V = voltage of the line.

v = voltage reading with insulation in series with voltmeter.

r = resistance of voltmeter in ohms (generally marked on label inside the instrument cover.)

R = resistance of insulation.

Voltmeters having a resistance of one megohm are now made for this purpose so that, if one of these instruments is used, the calculation is somewhat simplified, since r = 1 and the above formula becomes

$$R = \frac{V-v}{v} = \frac{V}{v} - 1 \text{ megohms.}$$

If a grounded circuit is used in making this measurement care must be taken to connect the grounded side of the line to the frame of the machine to be measured, and the voltmeter between the windings and the other side of the circuit.

DRYING OUT WINDINGS

If the armature and field windings have absorbed moisture, as evidenced by low values of insulation resistance, it is well to dry them out by heat. The windings can be dried by the use of external heat as from space heaters. Baking in an oven is to be preferred but is often impractical. They are usually dried out by circulating current through the windings. The current should be increased so as to raise the temperature to about 70°C. and then adjusted to maintain that temperature until the coils become thoroughly dry. The temperature should not be allowed to drop to that of the surrounding atmosphere, as the moisture would then again be condensed on the coils, and the effect of the previous drying would be largely lost.

In the case of a generator armature, this may be accomplished by short-circuiting the armature leads beyond the ammeter through a fuse with current capacity equal to that of the machine and adjusting the field current until sufficient current is circulated to raise the temperature to about 70° .

There is always danger of overheating the windings of a machine when drying them with current, as the inner parts, which cannot quickly dissipate the heat generated in them may get dangerously hot, while the more exposed and more easily cooled portions are still at a comparatively moderate temperature. The temperature of the hottest part accessible should always be observed while the machine is being dried out in this way and should not be allowed to exceed 80 degrees Centigrade total temperature. Keep in mind that insulation is more easily injured by overheating when damp than when dry. It may require several hours or even days to thoroughly dry out the machine, especially if it is of large capacity. Large field coils dry very slowly.

DIELECTRIC TEST

A high-voltage test is sometimes useful in determining the strength of the insulation of the machine. It is made by subjecting the insulation to an e.m.f. greater than it will have to stand in actual service. As this test is in the nature of an overstrain, it must be applied with great caution. Such tests are always made in the factory and rarely need to be repeated. However, when they must be made, it is well to remember that the insulation is more easily broken down when hot than when cold and that the test should not be made immediately after the machine is started the first time but after is has run hot for some hours and had a chance to dry out. Tests of this character should not be made when the insulation resistance is low.

Large machines, when tested at high voltage, require a considerable output from the charging transformer, as a heavy current is taken by the machine. The transformer capacity required for testing varies with the square of the voltage of the test, with the frequency of the circuit, and with the static capacity of the apparatus under test. A 5-kilowatt transformer has sufficient output for testing machines up to 500 kilowatts at a testing e.m.f. of 6000 volts.

When making a high-voltage test, the low-voltage circuit should always be closed or opened to throw the e.m.f. on or off.

The severity of the test depends to a marked degree upon the time the e.m.f. is applied. All dielectric tests are supposed to be applied for not more than one minute, as long continued test is liable to permanently injure the insulation even if no immediate fault is developed.

Machines which have been in service will have some dirt deposited on the creepage paths regardless of strenuous cleaning. These machines should never be subjected to the high voltage test that would be applied to a new machine. A clean machine that has been in service should not be subjected to more than ⅔ the voltage specified for a new machine. A.I.E.E. rules state that a new machine should be subjected to a voltage of 2 x rated volts plus 1000. Of course old machines not entirely clean must have even the ⅔ figure reduced.

BRUSH POSITION

For commutating-pole machines, accurate adjustment of the brush position is necessary in order to obtain satisfactory commutation and regulation. If the brushes are given a backward lead on a commutating-pole generator, the machine will over-compound and may not commutate properly; with a forward lead of the brushes, a generator will under-compound and will not commutate properly. For a commutating-pole motor, a backward lead of the brushes will increase the speed and a forward lead will decrease the speed, with less satisfactory commutation resulting for both positions.

When the brush position on a commutating-pole machine has once been properly located, no shifting is afterwards required or should be made. The correct brush position is located at the factory during test. This position is known as the "factory brush position" and is clearly marked on the brushholder supporting ring (rocker-ring). However, since the mark on the rocker-ring will not be correct after the position of the brushholder supporting brackets has been moved on the rocker-ring (as, for example, will occur when the brushholders are adjusted in order to compensate for commutator wear), provision is made wherever possible to locate the factory brush position directly from the frame as given under "Mechanical Re-determination of Factory Brush Position."

Two methods for locating the electrical neutral brush position are given, but should not be used unless absolutely necessary or when it is impossible to locate the "Factory Brush Position" by the mechanical method.

MECHANICAL RE-DETERMINATION OF FACTORY BRUSH POSITION

In the event that the brush position has been disturbed, the brushes should be re-located so that they are on the original factory setting. The following is the mechanical method for checking the factory brush position: (See Figure 11).

With a convenient constant radius, using the two center punch marks inside the circle marks on the front edge of the frame as centers, scribe two arcs to intersect on the front end of the commutator bars near the commutator surface. Draw through this intersection a radial line to the commutator surface. The point of intersection of this radial line with the commutator surface is the correct location for the center of the brush fit on the commutator. The center of the brush fit is found by scribing a bisecting line along the outside edge of the end brush to the riding face, or in the case of double-brushholders is midway between the two brushes at the commutator surface. This point is the factory brush position; it may or may not be the electrical neutral position, as machines are shipped with the brushes in a position to give the best operation both in regards to commutation and other operating characteristics.

SPACING OF BRUSHES

The position of one row of brushes having been located, the other brushes should be equally spaced around the commutator with reference to this first row of brushes. The brush spacing between all rows to brushes should be accurate to within $\frac{1}{32}''$. The best way to secure this spacing is to cut a narrow strip of tough paper exactly equal in length to the circumference of the commutator. This strip is then marked off into equal parts, corresponding to the number of brush-arms, after which it is stretched around the commutator and the brushes spaced accordingly. This method gives far more accurate results than those obtained by spacing the brushes an equal number of commutator bars, which is dependent upon the uniform spacing of the bars. The latter method, however, may be used as a rough check.

STAGGERING BRUSHES

The brushes are staggered at the factory to give an even wear to the commutator. The staggering is done in pairs of brush arms (not alternate arms); that is, one positive set of brushes with an adjacent negative set, is offset to the right or left of an initial pair of positive and negative brush arms ⅜ inch or more. The third pair of brush arms trail the first pair; the fourth, the second, and so on. See Figure 12. If the brushholder supports are removed from the rocker ring they should be re-assembled so that correct staggering is obtained.

LOCATING THE ELECTRICAL "KICK-NEUTRAL"

Where it is necessary for any reason to locate the electrical neutral position on commutating-

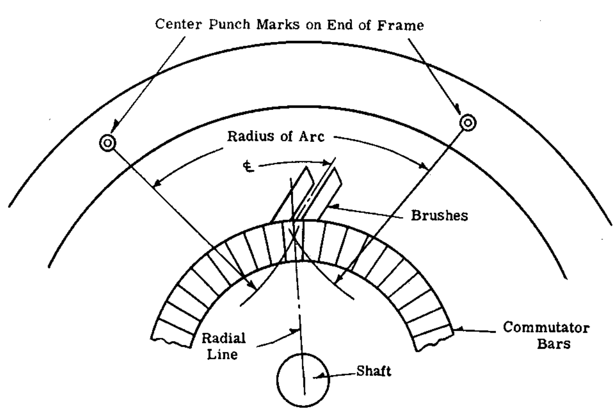


FIG. 11—METHOD FOR LOCATING FACTORY BRUSH POSITION

pole machines in the field, it may be correctly and simply located by the Electrical or "Kick" method, if due care is exercised.

With all the brushes raised from the commutator and the machine standing still, if the shunt field be excited to about one-half of its normal strength and the field current suddenly broken, voltages will be induced in the armature conductors by a transformer action. Consideration of these voltages in conjunction with the diagram in Figure 13, will show that the maximum voltages are produced in those conductors located in the interpolar space (between the main poles) and that the maximum voltages are produced in those conductors located nearest to the centers of the main poles. It will also be found that the induced voltages in conductors located at equal distance to the right and left of the main pole centers are equal in magnitude and opposite in direction.

Hence, if the terminals of a low-reading voltmeter (say five volts) be connected to two commutator bars on opposite sides of the center line of a main pole Figure 14, and exactly half-way between the center lines of two main poles, it will show no deflection when the field current is broken, because there will be equal fluxes in opposite directions through equal numbers of turns. The spacing of these commutator bars is evidently the correct distance between brushes on adjacent brush arms.

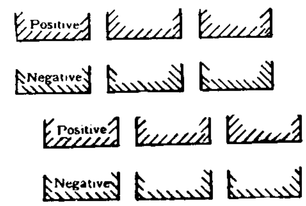


Fig. 12—Correct Method of Staggering Brushes

In Figures 13 and 14, a ring-wound armature is shown for simplicity. The leads come straight out to the commutator bars and the neutral points, in this case, will be midway between the main poles. In actual practice, the armature conductor, which lies in the exact neutral zone on the surface of the armature, leads to a commutator bar located approximately under the center of a main pole, hence the electrical neutral on the connutator will be found approximately in line with the main pole centers.

To find the electrical neutrals in practice, two pilot brushes are made of wood or fibre to fit the regular brushholders and each brush carries in its center a piece of copper fitted for making line contact with the commutator and for connection to the voltmeter leads. Figure 15.

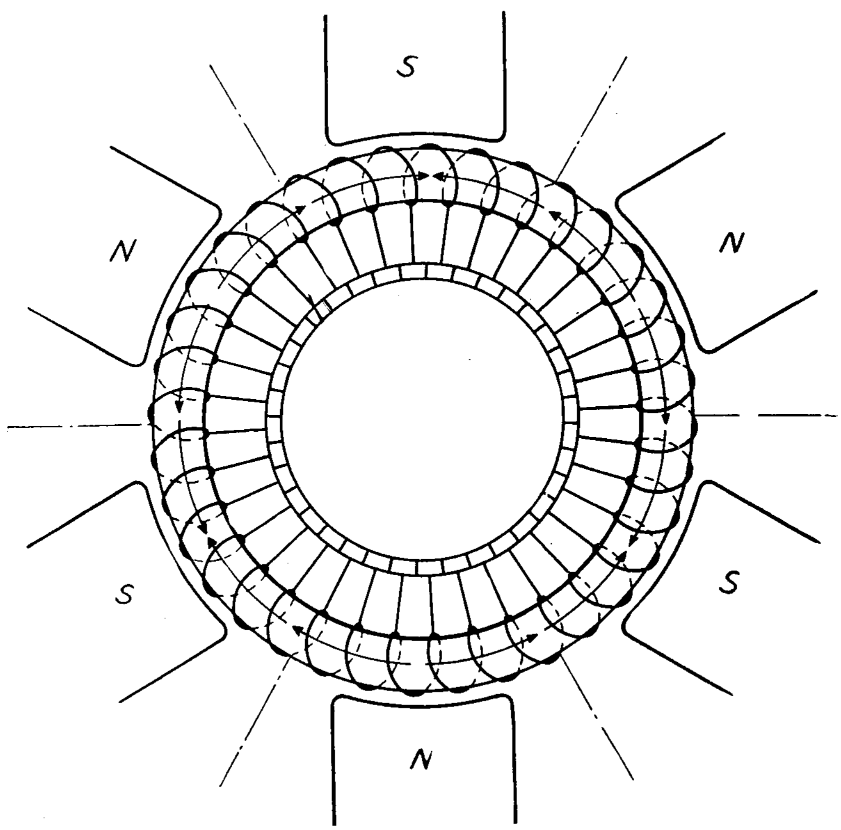


Fig. 13—Ring Wound Armature
Direction of Voltage Induced when Field is Opened

These two brushes are put into regular brushholders located on adjacent brush arms and connected to the terminals of the voltmeter. The holders and brushes are then shifted slightly forward or backward as necessary until breaking the field current occasions no deflection on the voltmeter. It may also be necessary to move the rotor position slightly, so that the coil lying in a slot will be in the electrical neutral position.

This neutral point is noted and the pilot brushes are then similarly used in another pair of brushholders on adjacent arms and so on, all of the way around the commutator, noting whether each position proves to be a neutral point. The average of the positions of neutrals thus obtained gives the correct running location for the brushes.

If the armature winding is perfectly symmetrical and the commutator has an integral number of segments per pole, a position can be obtained where there will be no deflection of the voltmeter connected between adjacent neutral points when the field current is broken; but with two-circuit armature windings extensively used in the smaller sizes of machines, it is impossible to have an integral number of commutator segments per pole. In such cases it is necessary to make a number of repeated trials and to so set the brushes that the sum of the voltmeter deflections obtained by taking readings all of the way around the commutator will be a minimum, the positive and negative signs of the readings being disregarded.

If no deflection occurs between brushes spaced from each other by an odd number of poles, an additional check on the electrical neutral is established. For example, in a 6-pole machine the pilot brushes may be placed in diametrically opposite holders and the neutral found as before described. This method has the advantage that by its use a point of no deflection or zero reading is obtainable where the number of commutator bars is divisible by two, as in many 6-pole machines.

Where double brushholders are used, the two pilot brushes should be inserted in corresponding boxes of double brushholders on adjacent arms, so that the point of these brushes will be exactly one pole pitch apart measured on the commutator periphery. After the neutral point is located and the brushes are in the double brushholders, the rocker ring will have to be shifted until the midpoint of the arc length, covered by the span of the two brushes on the commutator surface, corresponds to the neutral point, in order to locate the brushes on neutral.

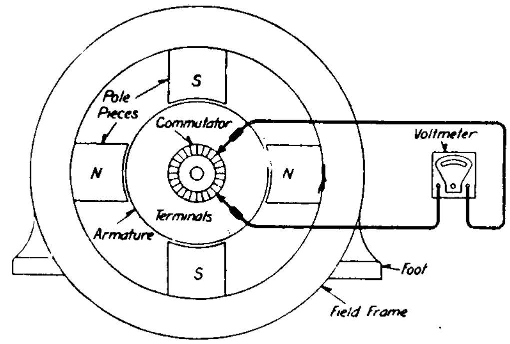


Fig. 14—Ring Wound Armature. Locating Electrical Neutral with Voltmeter

The brush position, as located by factory test, may or may not be on the electrical neutral as the brushes are set on test and the machine shipped with them in a position to give the best operation, both in regards to commutation and other operating characteristics.

This being the case, it is best when the brush position has been once disturbed to re-locate the brushes so that they will be on the factory setting. This can be easily done as described in a preceding section, "Mechanical Re-Determination of Brush Position."

LOCATING THE ELECTRICAL "RUNNING NEUTRAL"

This method is based on the fact that if the brushes are in the correct no load neutral position no active electro-motive force will be generated by the commutating-pole flux when the machine is mechanically driven on open circuit with the commutating windings separately excited.

Beveled brushes should be inserted, one in each arm, and so beveled that the faces on these brushes will be wide enough to bridge one mica segment. The face of the brush must be ground in for good commutator contact and must not be wide enough to make contact with more than two commutator bars with any commutator position. Where double brushholders are used, only single beveled brushes should be inserted in corresponding boxes of the

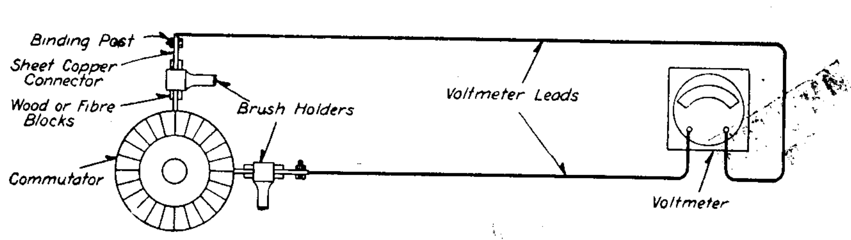


Fig. 15—Construction of Pilot Brushes for Locating Electrical Neutral

double holders, so that the contact of these brushes will be equally spaced around the commutator periphery. After the neutral point is located and the brushes are in the double brushholders, the rocker ring will have to be shifted until the mid-point of the arc length covered by the span of the two brushes on the commutator surface corresponds to the neutral point as located.

A reversing switch should be connected in the separately excited shunt field-circuit and some arrangement made for separately exciting the commutating-pole winding at from two to four percent of its normal current. The commutating-pole circuit should be disconnected from the armature and the armature left open-circuited. Use a low reading voltmeter such as was suggested for the "kick-neutral" across arms of opposite polarity. Bring the machine up to approximately normal speed and by exciting the main field, for an instant only, in a direction contrary to normal, demagnetize it entirely, that is, until no deflection shows on the lowest scale of the voltmeter. Any deflection then obtained by exciting the commutating poles will be due to the commutating pole flux alone. First excite the commutating-pole windings with about two percent of their normal current and shift the brushes until no deflection is obtained on the lowest scale of the voltmeter. Check the residual magnetism of the main poles from time to time keeping it at as low a value as possible by demagnetization as explained above. After determining the best location for the brushes at this excitation, raise the commutating-pole current to about four percent of normal and check results. If no difference is found reverse the current in the commutating-pole and try again still checking the residual from time to time. In some cases higher currents may be used, but the leakage flux soon becomes large enough to destroy the symmetry of the normal field form and indefinite results will be obtained.

This method, if used carefully, gives very accurate results. It may be noted that the position of the brushes is at the peak of the commutating-pole field form and as this peak is rather sharp the effect of displacement will be very marked. Since the machine is running, errors due to brush resistance or to a brush resting on mica only, are entirely eliminated, making this method preferable to the "kick method."

ADJUSTMENT OF COMMUTATING-POLE FIELD STRENGTH

The commutating-pole adjustment to give the best commutating conditions is made at the works and, in general, no reason for changing it after the machine is installed will arise. However, if such reason should arise, the proper change in excitation may be determined as follows:

With a low reading voltmeter read the voltage between the brushholder bracket and the commutator at four equi-distant points across the face of the brush (along the circumference of the commutator) when the machine is running at normal load and voltage. These voltages can be most conveniently read by touching the voltmeter point lead to the commutator surface at the four points shown in Figure 16. Readings should be taken from positions 1 to 4 in the direction of rotation. Take curves for both positive and negative brushes for several brush arms.

These readings, if plotted as shown in Figure 16, indicate for example in curve "A" over compensation; i.e., excessive commutating field strength; curve "B" correct compensation; curve "C" under-compensation.

Changes in commutating-pole strength to secure correct compensation can be made by changing the air-gap or by shunting part of the current from the commutating-pole winding. Adjustment by changing the air-gap is the more usual method. In case of over compensation the air-gap should be increased and in case of under compensation the air-gap should be decreased. When adjustment is made by shunting, an inductive shunt, having approximately the same ratio of self-induction to resistance as the commutating-pole winding is advisable. This insures proper division of current between the field winding and shunt when the load suddenly changes.

The measurement of brush curves and the adjustment of the commutating-pole strength should only be undertaken under the supervision of an experienced engineer.

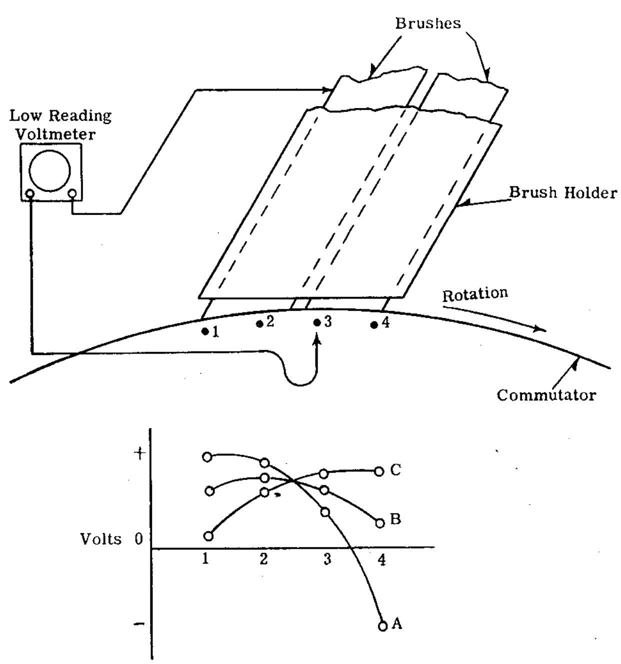


FIG. 16—METHOD FOR DETERMINING PROPER ADJUSTMENT OF COMMUTATING-POLE FIELD STRENGTH WITH DOUBLE BRUSHHOLDERS

OPERATION

CAUTION

Leave all switches open when the machine is not operating.

Do not work on the machine while it is running. Make sure that all switches are open and that the machine cannot be accidentally started by other operators.

Always follow a fixed regular order in closing and opening switches unless there are special reasons for departing from this order. A routine method will aid in avoiding mistakes. Close switches carefully, keeping a firm hold of the handles until completely closed.

When the shunt-field circuit of a generator or motor is excited, never open it quickly unless a path for the inductive discharge is provided. The circuit can be opened slowly, if desired, the arc at the opening serving to reduce the field current gradually. Do not permit any part of the body to bridge this opening, or a serious shock will be received; better use but one hand, keeping all other parts of the body clear of the circuit.

Keep small pieces of iron and bolts and tools away from the frame. Any such object attached to the pole of a field magnet may jam between the armature and pole and cause serious damage.

CLEANLINESS

Particular care should be exercised towards keeping all parts of the machines reasonbly clean. This applies particularly to turbo-generators and other high-speed machines. The high rotative speed in these draws air into the armatures and other parts with a velocity sufficient to carry with it particles of dirt or oil vapor that may be in the air. The rotating part must be cleaned out as necessary or the machines will ultimately short-circuit between commutator necks or break down to ground over insulation surfaces. Some types of stationary windings should be well cleaned for the same reason, and more than merely blowing out with compressed air as described on Page 29 may be required.

In machines partially enclosed by solid end-bells, the end-bells should be removed regularly as required so that access may be had to all parts.

STARTING-UP

Starting Generators—(1) See that the bearings are well supplied with oil and that the oil rings (if any) are free to turn. Inspect all connections for loose screws or wires.

(2) Start slowly. See that the oil rings are revolving properly. If force lubricated be sure oil is reaching the bearings.

(3) Turn in all resistance in the field rheostat, then bring the machine up to speed.

(4) Adjust the rheostat for the normal voltage of the generator.

(5) Throw on the load.

Starting Constant Speed Motors, Compound or Shunt—(1) See that bearings are well supplied with a good lubricating oil and that oil rings (if any) are free to turn. Inspect all connections for loose screws or wires.

(2) Make sure that the lever arm of the starting box or controller is in the "off" position.

(3) Close the main switch or circuit breaker.

(4) Close the field switch.

(5) Move lever arm of starting box or controller to the running position, pausing long enough on each notch to allow the motor to come up to the speed of that notch.

(6) If using a controller, throw the short-circuiting switch and move controller handle back to the starting position. If using a starting box, the lever arm should remain in the running position.

Starting Adjustable-Speed Motors—(1) Examine the shunt field rheostat and see that all resistance is cut out.

(2) Follow all directions given under "Constant Speed Motors."

(3) After motor is running on full-line voltage, gradually cut in resistance in the shunt field rheostat until the motor is up to the desired speed.

Starting Series Motors—(1) Follow same instruction as those given for "Starting Constant Speed Motors," except there is no field switch to close.

OPERATION

To Parallel Generators—To place a generator on the line in parallel with generators already operating (provided that proper connections for parallel operation have been made as directed under "Connections," Page 13):

(1) Bring the generator up to normal speed.

(2) With a voltmeter connected to its terminals, gradually bring up the voltage by cutting out resistance in the field rheostat until approximately the voltage of the other machines is reached.

(3) Throw in the equalizer switch.

(4) Adjust voltage if necessary.

(5) Throw in the main switches.

(6) Adjust the field rheostat until the generator takes its proportion of the load. The proper voltage to obtain before throwing a generator in parallel with others can be found by trial. It may vary slightly from line voltage depending on local conditions, regulations, etc.

Parallel Operation of Generators—The inherent regulation characteristics of the armature of a direct-current generator have much to do with its successful parallel operation with other machines. When two direct-current armatures are coupled in parallel and delivering load to the same external circuit it is necessary, in order to obtain stable conditions, for each armature to tend to "shirk" its load; that is, it must naturally tend to transfer load to the other machine. This tendency to shirk may be either in drooping speed regulation due to the prime-mover which drives the armature, or in the drooping voltage characteristics of the armature itself.

A drooping speed characteristic indirectly produces a drooping voltage characteristic in the armature and therefore both causes lead to the one characteristic, namely, drooping voltage, as the condition for stable parallel operation. This drooping voltage characteristic must be the inherent condition. In some applications, the voltage at the armature terminals may rise with increase in load, but its rise is due to some external condition such as increased field strength and not to conditions in the armature itself.

Direct current machines normally give drooping voltage characteristics in the armature windings. If two such armatures are paralleled they tend to divide the load in a satisfactory manner, provided their prime movers regulate similarly in speed.

If means are applied for giving a rising voltage characteristic to the machines, such as series coils in the field, then the armature circuits, including commutating-pole windings, must be paralleled directly in order to maintain stability. If, for instance, the armatures are not paralleled directly by equalizer connections but the paralleling is done outside the series coils, then the operation will be unstable unless the machines still have drooping voltage characteristics. If they have rising characteristics, then parallel operation is impracticable. If either machine should take an excess of load its voltage would rise while that of the other machine would fall due to decreased load. This condition would naturally force the first machine to take still more load and the second one to take still less until the first machine actually fed current back through the other machine and it would be necessary to cut them apart to avoid injury. However, by paralleling the two armatures inside the series coils, that is, between the series coils and the commutating field coils, this unstable condition is avoided. The armatures inherently have drooping voltage characteristics, and the series coils are paralleled at both terminals, forcing them to take currents inversely proportional to their resistances at all times, thus compounding both machines equally.

If direct-current machines are so designed or operated as to give rising instead of drooping armature characteristics, then parallel operation is liable to be unstable. This condition could be obtained in generators driven by prime movers which tend to speed up with increasing load, thus producing rising voltage on the armature. Ordinarily, such speeding up of the prime mover is rare and would have to be in rather large proportions as the normal drooping characteristics of the ordinary armature are fairly large.

A second condition which can give a rising voltage is not infrequently found in the commutating-pole type of direct-current machine. This condition arises when the brushes are shifted off neutral resulting in a compounding effect independent of any series field. The commutating-pole winding is connected directly in opposition to the winding on the armature. The maximum magnetizing effect of the armature winding is found at the points on the armature corresponding to the coils which are being commutated.

The commutating pole is intended to be placed directly over these points and the winding normally has such a value that it not only neutralizes the magnetizing effect of the armature winding at these points, but it also sets up a small magnetic field in the opposite direction which assists in the commutation of the armature coil.

When this commutating pole winding is placed directly over the commutating position of the armature winding, it will have practically no effect on the armature characteristics. If, however, the commutating-pole winding is not placed over these positions it will have an effect on the voltage characteristics of the machine tending to either raise or lower the voltage.

The commutating points on the armature depend directly upon the brush position. If the brushes are rocked backward or forward from the point corresponding to the mid-position between the poles, then the position of the commutated armature coils moves backward or forward with the brushes. Shift of the brushes in the direction of rotation tends to produce a drooping voltage characteristic with load while brush shift against rotation produces a rising voltage characteristic.

With a back lead, therefore, the commutating pole may have the same effect as a series winding on the main field; that is, it may compound the machine so that the voltage at the terminals is rising instead of falling, even without any series winding on the main poles. Herein lies a possible trouble in parallel operation for, as explained before, this an unstable condition for parallel operation.

It is evident, therefore, from the above considerations that for best results the brushes should be so set that the true point of commutation comes midway under the commutating poles. If this position is found exactly, then the commutating pole should have practically no effect on the voltage characteristics of the armature, and parallel operation with other generators should be practicable.

Adjustment of Load Division of Shunt Generators in Parallel

The drooping voltage regulation characteristics of shunt-wound generators operating in parallel insure against one generator taking all the load and operating inverted (motoring) other machines in parallel with it. However, the division of load between shunt generators in parallel may not be as well balanced over the entire load range as is desired, and, there are no convenient means of adjusting the natural regulations of the generators to obtain better over-all division of load.

The division of load of shunt-wound generators in parallel may be improved by external adjustments, as follows:

(a) The shunt field rheostats may be adjusted to give better overall average division or better division at any selected load.

(b) The field rheostats may be manipulated by hand to maintain correct division of load as the load changes.

(c) Resistance may be added to the connecting leads of the individual generators to equalize the voltages at the point of paralleling. The resistance should be added to the leads for the generators taking more than their share of the load. This method results in increased "drooping" of the voltage regulation of the paralleled machines, and so may be undesirable.

(d) A cumulative compounding effect may be secured on a generator by shifting the brushes against rotation and a differential effect by shifting with rotation. Any shift will be at the expense of commutation, but sometimes machine can stand some brush shift to secure better paralleling characteristics and still have passable commutation.

Adjustment of Load Division of Compound Generators in Parallel

The division of load between compound-wound generators can be adjusted at two load points; the division of load at intermediate points depending on the closeness of the regulation characteristics of the machines. Ordinarily, compound generators parallel satisfactorily when they are adjusted to have the same voltages at no-load and at full-load; that is, they have the same amounts of compounding. If the generators have different amounts of compounding, it will be necessary to adjust the compounding by changing the amounts of current shunted from the series fields. As far as parallel operation is concerned, it is much better to have all generators flat compounded or even with a voltage regulation that droops slightly with load.

In making adjustments, it is advisable to make the changes systematically. The several generators should be operated individually with the shunt field rheostats adjusted for the desired voltage at no-load; then, with rated load applied, the current through the series fields should be changed by adjusting the shunts across the series fields until the desired full-load voltage is obtained. It may be advisable to operate the several generators with different no-load voltages in order to obtain a better average agreement between their voltage regulation curves. It is not so important that the voltages at partial loads agree as it is at full load and overloads. At partial loads the load division may depart from the correct division without overloading the generator that takes the greater share of the load.

When the several regulation curves have been made to agree as nearly as possible, then the resistances of the several equalizer circuits should be checked and changed, when necessary, by changing the resistance of the leads to make the resistances inversely proportional to the generator ratings. For example, if a 500-kilowatt generator and a 1500-kilowatt generator are operated in parallel, the resistance of the series-field circuit (including a shunt if used), the main lead from the series field to main bus, and the equalizer leads should be in the case of the 1500 kilowatt generator one-third of the resistance of the corresponding circuit of the 500-kilowatt.

With compound-wound generators operating in parallel, one of which takes less than its proper share of the load, the division of load can be improved by the following adjustments.

(a) The shunt field rheostats may be adjusted to give better average division. If one generator compounds less than another and if it is desired to maintain the higher full-load voltage, the average load of the former generator can be increased by increasing the shunt field excitation.

(b) The shunts on the series-field winding can be adjusted, decreasing the resistance of the shunt on the overloaded generator, if possible, or increasing the resistance of the shunt on the under-loaded generator. It should be borne in mind, however, that changing the ampere-turns in the series field by changing the shunt resistance also changes the resistance of the complete field circuit. This change in resistance must be compensated for by a corresponding change in resistance in another part of the series-field circuit so that the resistance of the total circuit remains unchanged. From another standpoint, a shunt on one series-field may be considered a shunt on both series-fields, the effect varying only by reason of the resistance of the leads and busses being added to one shunt circuit and not to the other.

(c) If the relative ampere-turns are correct, but the series-field resistances are differently proportioned, the resistance of the leads between the series-field and equalizer bus can be changed to compensate for a difference in the series-field resistances. The resistance in the series circuit of the generator taking more than its share of the load should be increased. This adjustment varies the resistance of one series-field without introducing a third parallel circuit between the equalizer and main bus, and for this reason the adjustment is less complicated than in (b).

Excitation Failure of Generator

When starting up, a self excited generator may fail to excite itself. This may occur even when the generator operated perfectly during the preceding run. It will generally be found that this trouble is caused by a loose connection or break in the field circuit, by poor contact at the brushes due to a dirty commutator or to brushes sticking in their holders, or perhaps to a fault in the field rheostat. Examine all connections; try a temporarily increased pressure on the brushes; look for a broken or burnt-out resistance coil in the rheostat. An open circuit in the field winding may sometimes be traced with the aid of a magneto bell; but this is not an infallible test as some magnetos will not ring through a circuit of such high resistance as some field windings have even though it be intact. If no open circuit is found in the rheostat or in the field winding, the trouble is probably in the armature. But if it be found that nothing is wrong with the connections or the winding it may be necessary to excite the field from another generator or some other outside source.

The residual magnetism may be restored to the generator fields by exciting them from an outside source, with voltage not exceeding the rated generator voltage, as follows (See Figure 17).

(1) Open the line switch and raise all generator brushes from the commutator.

(2) Connect the negative lead from the exciting source to either the negative brushholders or the negative terminal of the machine. Connect the positive lead from the exciting source in series with a switch, 15 ampere fuse, and suitable ammeter to either the positive brushholder or the positive terminal of the machine. If excited from another generator, it may be more convenient to connect from a negative brushholder on the exciting generator to a negative brushholder on the machine being excited and similarly, from a positive brushholder through the switch, fuse, and ammeter to a positive brushholder.

(3) Turn the generator field rheostat to the "all in" position.

(4) Close the exciting switch momentarily while adjusting the generator field rheostat to obtain not more than normal field current. If the shunt winding is all right, its field will show considerable magnetism.

(5) If possible, reduce the exciting voltage before opening the exciting current. If this cannot be done, throw in all resistance of the field rheostat, then open the exciting switch very slowly, lengthening out the arc which will be formed until it breaks.

Where the generator operates in parallel with another generator, the field may be simply excited from the paralleling generator by raising the brushes, turning the field rheostat "all in", and momentarily closing the line switch. The voltage of the exciting generator should be reduced to a minimum before opening the line switch, if possible; otherwise, the arc which forms must be drawn out by opening the switch slowly.

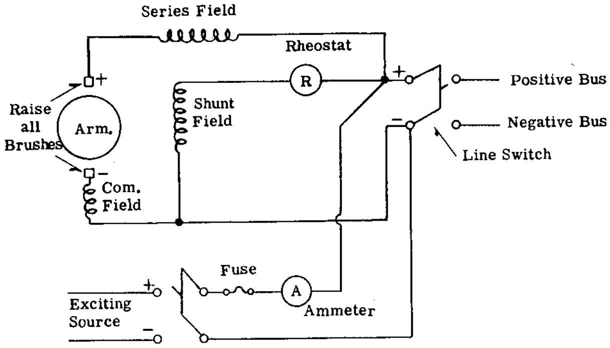


Fig. 17—Connections for Restoration of Residual Magnetism of Generator

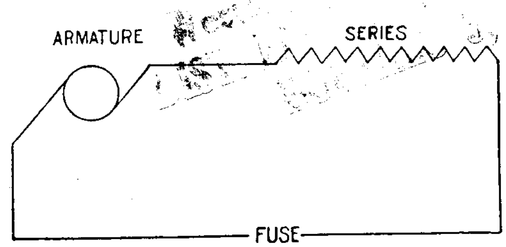


Fig. 18—Showing Convenient Method of Making a Compound-Wound Generator Pick Up Voltage

A very simple means for getting a compound wound machine to pick up is to short-circuit it through a fuse having approximately the current capacity of the generator. (See Figure 18.) If sufficient current to melt this fuse is not generated, it is evident that there is something wrong with the armature, either a short-circuit or an open circuit. If, however, the fuse has blown, make one more attempt to get the machine to excite itself. If it does not pick up, it is evident that something is wrong with the shunt winding or connections.

Causes of Insufficient Voltage of Generator

The following causes may prevent generators from developing their normal e.m.f.

(1) The speed of the generator may be below normal.

(2) The switchboard instruments may be incorrect and the voltage may be higher than that indicated or the current may be greater than is shown by the readings.

(3) The series field may be reversed, or part of the shunt field reversed or short-circuited.

(4) The brushes may be incorrectly set.

(5) A part of the field rheostat or other unnecessary resistance may be in the field circuit.

Reversing Polarity of Generator

To change the polarity, if a generator keeps the same direction of rotation:

(1) If the generator shunt field is self-excited, it is necessary to reverse the residual magnetism of the fields, which is done by exciting the shunt field momentarily in the opposite direction from some outside source.

(2) If the generator shunt field is separately excited, it is only necessary to interchange the shunt field leads.

Reversing Rotation of Generator

To change the rotation but not the polarity:

(1) If the generator shunt field is self-excited, it is necessary to reverse either the residual magnetism and the shunt and series fields leads or the armature and commutating field leads.

(2) If the generator shunt field is separately-excited, it is necessary to reverse either the shunt and series field leads or the armature and commutating field leads.

Small machines are often cable connected and the simplest method is to reverse the leads to the armature and commutating-pole windings. In all commutating-pole machines, it must be borne in mind that the direction of current in the armature and in the commutating pole windings must always bear the same relation to each other, and, if the armature current is reversed for any reason, the current in the commutating-pole coils must also be reversed.

Large generators are not often easily reversld since the armature, commutating, and series field windings are usually permanently connected by heavy copper straps inside the machine. The rotation of Westinghouse shunt generators, type QS or QH, can be most easily changed by reversing the shunt field leads, and, the residual magnetism, if self-excited. The rotation of Westinghouse compound generators, type QS or QH, can be changed by reversing the shunt field leads, the residual magnetism, if self-excited, and re-connecting the series field winding, but, this should not be attempted except under the supervision of the Westinghouse Engineering Department or by the Westinghouse Service Department. It is necessary that the series field coils be connected in such a way that the combined effect of the current in both the commutating and the series field connections does not produce ampere-turns around the shaft. Consideration of mimimum ampere-turns about the shaft is essential since, with the high value of current involved, a single turn may cause sufficient current to circulate through the shaft bearings to score the shaft journals. Therefore, in order to reverse the direction of the current in the series coils and still maintain minimum ampere-turns around the shaft, it is necessary to reconnect all the series field coils inside of the machine.

Failure of Motor to Start

When a motor fails to start, it will generally be found that this trouble is caused by a loose connection or break in the field circuit. However, first check the main switches and main fuses, if used. Then close the field switch and check the magnetism of the main poles. If the magnetism of the fields does not increase over the residual, examine all wiring connections and, if a field rheostat is used, look for a burnt-out resistance coil. An open circuit in the field winding may sometimes be traced with the aid of a magneto bell, but this is not an infallible test as some magnetos will not ring through a circuit of such high resistance as some field windings have even though it be intact. If an open is not found in the field circuit, the trouble is probably in the armature.

Causes of Insufficient Speed of Motor

The following causes may prevent motors from operating at their rated speed:

(1) The motor may be overloaded.

(2) The voltage may be low.

(3) The switchboard instruments may be incorrect and the voltage may be lower than that indicated or the current may be greater than is shown by the readings.

(4) If the motor field is separately excited or if a rheostat is included in the field circuit for adjustable speed operation, the shunt field current may be higher than normal.

(5) The brushes may be incorrectly set.

Reversing Rotation of Motor

To change the rotation of a motor, it is necessary to reverse either the shunt and series field leads or the armature and commutating field leads. The problem of reversing a motor is identical with that of reversing a separately excited generator as given under "Reversing Rotation of Generator".

Sparking at the Brushes

Some sparking under the brushes on modern high-speed commutating apparatus should not be construed as discreditable performance. The personal element involved in the interpretation of satisfactory commutation makes the subject a difficult one for reaching agreement in many cases. An effort to arrive at some common basis of reasonable commutation requirements has accordingly been made in the Standards of the American Standards Association. Successful commutation is defined as follows: "Successful commutation is attained if neither the brushes nor the commutator are burned or injured in an acceptance test; or in normal service to the extent that abnormal maintenance is required. The presence of some visible sparking is not necessarily evidence of unsuccessful commutation."

Sparking may either be due to mechanical or electrical causes.

The usual causes of sparking are:

(1) The machine may be overloaded.

(2) The commutator may be rough due to high or loose bars, flat spots, or rough edges of the undercutting.

(3) The commutator bar mica may be high.

(4) The commutator may be dirty, oily, or worn out.

(5) The brushes may not be set exactly on neutral.

(6) The brushes may not be equally spaced around the periphery of the commutator.

(7) Brushholders may be set too far away from the commutator.

(8) The brushes may be sticking in the brushholders or have reached the end of their travel.

(9) The brushes may not be fitted to the circumference of the commutator.

(10) The brushes may not bear on the commutator with sufficient pressure.

(11) Some brushes may have extra pressure and may be taking more than their share of the current.

(12) The carbon brushes may be of an unsuitable grade.

(13) The faces of the brushes may be burned.

(14) Vibration of the brushes.

(15) Incorrect brush angle.

(16) Non-uniformity of main or commutating pole air-gaps.

(17) Commutating-pole field air-gap may not be correct. The commutating-pole adjustment to give the best commutating conditions is made at the works and, in general, no reason for changing it after the machine is installed will arise. However, is such reason should arise, the proper change in excitation may be determined as directed under "Adjustment of Commutating-Pole Field Strength," on Page 19.

These are the more common causes, but sparking may be due to an open circuit or loose connection in the armature. This trouble is indicated by a bright spark which appears to pass completely around the commutator and may be recognized by the scarring of the commutator at the point of open circuit. If a lead from the armature winding to the commutator becomes loose or broken, it will draw a bright spark as the break passes the brush position. This trouble can be readily located, as the commutator on each side of the disconnected bar will be more or less pitted.

If sparking occurs that cannot be accounted for by overloads or other service conditions, wrong adjustments, or mechanical defects, an experienced engineer should be consulted to remedy the fault.

Sparking at Collector Ring Brushes

Sparking at the collector rings on three-wire generators may be due to any of the following causes:

(1) Rough surface of ring. (This condition usually follows prolonged sparking originating from some other cause.)

(2) Eccentric rings.

(3) Brushes tight in holders.

(4) Oil on collector rings.

(5) Vibration of brush rigging.

If sparking exists the rings should be stoned or turned to give a smooth surface and, if possible, the source of the trouble removed. The brushes should have a good fit on the rings and should slide freely in the holders.

"Bucking" or "Flashing"

"Bucking" or "Flashing" is the very expressive term descriptive of what happens when arcing occurs between adjacent brushholder arms. In general, **"bucking"** is caused by excessive voltage, or by abnormally low surface resistance on the commutator between brushholders of opposite polarity. Any condition tending to produce poor commutation increases the danger of bucking. Among other causes are the following:

(1) Rough or dirty commutator.

(2) A drop of water on the commutator, from the roof, leaky steam pipes or other source.

(3) Short-circuits on the line producing excessive overloads.

If "flashing" continues after the first two possible causes have been eliminated, the trouble will usually be due to causes external to the machine which must be corrected before the "flashing" trouble will be eliminated.

Heating of Field Coils

Heating of field coils may develop from any of the following causes:

(1) Too low speed.

(2) Too high voltage.

(3) Too great forward or backward lead of brushes.

(4) Partial short-circuit of one coil.

(5) Overload.

(6) Restricted ventilation.

Heating of Armature

Heating of the armature may develop from any of the following causes:

(1) Too great a load.

(2) A partial short-circuit of two coils heating the two particular coils affected.

(3) Short-circuits or grounds on armature or commutator.

(4) Restricted ventilation.

Heating of Commutator

Heating of the commutator may develop from any of the following causes:

(1) Overload or continued operation at very low loads.

(2) Sparking at the brushes.

(3) Incorrect brush pressure.

(4) Improper grade of brushes.

(5) Restricted ventilation.

Bearings

Most Westinghouse machines have self-oiling bearings. The oil-well should be filled to such a height that the rings will carry sufficient oil upon the shaft. If the bearings are too full, oil will be thrown out along the shaft. Bearing housings are usually supplied with outlet holes for overflow of the oil. The oil should be kept slightly below the level of these holes.

The bearings must be kept clean and free from grit. They should be frequently examined to see that the oil supply is properly maintained and that the oil rings do not stick. The oil should be renewed in small machines about once in six months, or more often if it becomes dirty and causes the bearings to heat. Use only the best quality of oil. New oil should be run through a strainer if it appears to contain any foreign substance. If the oil is used a second time, it should first be filtered and, if warm, allowed to cool.

When a machine is started, particular attention should be given to the bearings to see that they are well supplied with lubricant. The oil rings should revolve freely and carry oil to the top of the journals. A new machine should always be run at slow speed for an hour or so in order to see that the bearings operate satisfactory.

Bearings may be operated safely at a temperature of 80° Centigrade (176° Fahrenheit) and, for a limited time, they may operate as high as 100° Centigrade (212° Fahrenheit). It should be remembered that a bearing may be below this temperature and may be safe even though it is hot enough to burn the hand when held against the outside. A rapid rise in the temperature of a bearing is usually an indication of trouble and requires prompt attention.

Turbine Bearings

For turbine units, a closed oiling system through which a continuous circulation is maintained by means of a pump geared to the main shaft of the turbine, keeps the turbine and generator bearings flooded with oil at a very moderate pressure. From the bearings, the oil drains through a strainer into a collecting reservoir, whence it is pumped through a cooler, and back to the bearings.

Heating of Bearings

A warm bearing or a "hot box" is probably due to one of the following causes:

(1) Insufficient oil in the reservoir, or failure of oiling system if force lubricated.

(2) Use of dirty oil or oil of poor quality.

(3) Excessive belt tension.

(4) Failure of the oil rings (if any) to revolve with the shaft.

(5) Rough bearing surface.

(6) Improper fitting of the journal boxes.

(7) Bent shaft.

(8) Excessive pressure caused by poor alignment of the machine.

(9) End thrust, due to improper leveling. A bearing may become warm because of excessive pressure exerted by the shoulder of the shaft against the side of the bearing.

(10) End thrust, due to the magnetic pull, rotating part being "sucked" into the field because it extends beyond the field poles further at one end than at the other.

(11) Excessive side pull, because the rotating part is out of center.

If a bearing becomes hot, first feed fresh oil copiously through the openings over the oil rings and loosen the nuts on the bearing cap; and then, if the machine is belt-connected, slacken the belt. If relief is not afforded, shut down, keeping the machine running slowly until the shaft is cool, in order that the bearing may not "freeze." Renew the oil supply before starting again. The bearings should be carefully watched to see that the oil rings are revolving and carry a plentiful supply of oil to the shaft.

Belts

The belt on a belt-connected machine should be tight enough to run slowly without slipping, but the tension should not be too great or the bearings will heat.

Whenever practicable, belts should be installed so that the slack side is above and the driving side below the pulleys. If this condition is reversed and the slack side is below, the arc of contact is materially lessened. Belts should be placed on the pulleys with the hair or "grain" side next to the pulleys. The lap-joint of the belt should be inclined relative to the direction of the belt's motion so that the leading edge or point of the lap is on the pulley side to prevent the end from opening; when the leading end is on the outside, it tends to open up, especially if the belt is operated at high speed, owing to the resistance of the air. When the leading end is next to the pulley, any tendency for the point to raise is overcome by frequent contact with the pulleys. The lap-joint should be dressed smooth so that there will be no jarring as it passes over the pulleys.

The crowns of driving and driven pulleys should be alike, as "wobbling" of belts is sometimes caused by pulleys having unlike crowns. If this is caused by bad joints, they should be broken and cemented over again. A wave motion or flapping is usually caused by slippage between the belt and pulley, resulting from grease spots, etc. It may, however, be a warning of an excessive overload. The fault may sometimes be corrected by increasing the tension, but a better remedy is to clean the belt. A back and forth movement on the pulley is caused by unequal stretching of the edges of the belt. If this does not cure itself shortly, examine the joints. If they are evenly made and remain so, the belt is bad and should be discarded.

Static Sparks from Belt

It sometimes occurs on belted machines, especially in dry weather, that charges of static electricity accumulate on the belt which may be of sufficiently high potential to cause discharges to ground. If the frame is not grounded, these charges may jump to the armature or field winding and then to ground, puncturing the insulation.

The belt and frame may be discharged by placing a number of sharp metal points, which are carefully grounded, close to a belt at a point near the machine pulley. If the field frame is grounded, there should be no danger to the insulation.

Opening of Feeder Circuits

If a line fuse blows or a circuit-breaker opens, first open the switch corresponding to that line, and then replace the fuse and close the breaker. The switch may now be closed again. If the circuit opens the second time, there is something wrong on the line—probably a short-circuit—and this should be corrected at once.

If for any reason, such as a short-circuit or a heavy overload on the line, the circuit-breakers or switches hold an arc when opened, such an arc should be extinguished if possible, by using dry sand, a supply of which should always be kept conveniently at hand. In case the arc cannot be extinguished in this manner, as a last resort, open the field circuit of the machine or shut the generator down entirely. When the arc forms on the machine or on the generator side of the breaker, a shut-down is generally imperative, but should not be made if it can possibly be avoided.

SHUTTING DOWN

To Shut Down Generator

(1) Reduce the load as much as possible by throwing in resistance with the field rheostat.

(2) Throw off the load when it is a minimum or zero, by opening the circuit-breaker, if one is used, otherwise open the feeder switches and finally the main generator switches.

(3) Shut down the driving machine.

(4) Wipe off all oil and dirt, clean the machine and put it in good order for the next run.

To Shut-Down Constant-Speed Motors

(1) Open the main switch or circuit-breaker.

(2) After the motor has come to rest, see that the lever arm of the starting box has returned to its original position.

(3) Open the field switches.

(4) Clean the machine thoroughly and put in order for next run.

To Shut Down Adjustable-Speed Motors

(1) Gradually cut out the resistance in the shunt field rheostat until the machine is running on a full field.

(2) Follow directions given under "To Shut Down Constant Speed Motors."

To Shut Down Series Motors

(1) Open main switch or circuit-breaker.

(2) Examine machine carefully, wipe off all dirt or oil, and put in good condition for next run.

MAINTENANCE

GENERAL RULES

(1) At all times keep motors and generators clean and free from oil and dust, especially from copper or carbon dust.

Keep the commutators clean. Oil will penetrate mica and if oil is allowed to get into the mica of a commutator, from an oily vapor atmosphere or from oil leakage from the bearings, the mica will be damaged and burnouts may occur in the armature.

The insulation should be kept free from dirt and oil. An occasional cleaning of the coil ends with an air hose is recommended, and this should be followed by a thorough wiping with a cloth. The dirt which clings to the field coil washers should be removed carefully since it may accumulate and form a conducting path from coil to ground.

An air hose should be applied to the air ducts between the spokes of the armature spider since an accumulation of dirt at these places will impede the free flow of cooling air.

(2) A coat of insulating varnish applied to the armature and field coils after they have been cleaned will protect the insulation.

(3) Occasionally give the machine a thorough inspection. The higher the voltage of the machine, the oftener this should be done.

CAUTIONS

In soldering connections, do not use an acid that will act on the insulation or the copper; an alcoholic solution of resin is a suitable soldering flux.

In soldering commutator connections do not allow bits of solder to drop down where they may short-circuit commutator bars.

Never use emery cloth or emery paper on commutator, collector, or brushes.

CLEANING METHODS

With high-voltage machines a small accumulation of dust on the windings may be the cause of serious burnout. It is advisable to install an air pump for supplying compressed air with a piping system so distributed that a short section of hose will enable the attendant to reach all parts of the winding on any machine to blow out the dust. The pressure used in such service should not exceed 25 pounds per square inch, as a high pressure may lift the insulation wrappings and blow dust within the coils. Always allow any accumulation of water in the pipes to be blown out before turning the air blast on the machine.

In blowing dust out of machines, the adjacent machines should be protected from flying dust by a suitable cover or shield.

A preferable method of cleaning machines is by a vacuum cleaning system whereby all the dirt is carried away from the machines and the danger of blowing dirt into adjacent machines is completely avoided.

Where insulated parts, subject to copper or carbon dust, are accessible they should be wiped clean with a dry cloth, in addition to cleaning as described above.

It will facilitate the cleaning of insulated parts if they are painted with insulating varnish at regular intervals. At the time selected for painting, the machine should be given a suitable high-voltage insulation test to locate possible weaknesses at a time when they can be conveniently repaired.

LUBRICATION OF BEARINGS

The bearings should be examined frequently to see that the proper oil level is maintained and that the oil rings are revolving and carry a plentiful supply of oil to the shaft. It is important that the oil be kept clean and free from grit.

The frequency with which the bearings must be refilled depends so much on local conditions, such as the severity and continuity of the service, the room temperature, the state of cleanliness, etc., that no definite instructions can be given. Until local conditions show another interval to be more suitable, the oil in the bearings should be renewed every six months.

Only the best grade of oil—having a viscosity of from 185 to 200 seconds, Saybolt—should be used.

It always proves to be false economy to use poor oil. If the oil is to be used a second time, it should be filtered and, if warm, allowed to cool before the bearings are refilled. Even new oil should be examined carefully and filtered or rejected if it is found to contain grit.

CARE OF BRUSHES

Modern brushes have characteristics such that they do not require any oiling of the commutator for lubrication. Oil affects mica adversely and should not be allowed to come in contact with the mica of a commutator, as burnouts may result.

Machines which are subject to frequent reversals such as mill motors and street railway motors usually have the brushes set radially or with only a slight angle to the commutator surface. For non-reversing machines, the brushes are always set at an angle, usually against rotation. The proper angle varies depending on brush fruction but usually lies between 15° and 25°.

Besides maintaining the brushes in the proper position as described on Page 14 under "Adjusting and Testing," the following points should be observed:

Make frequent inspection to see that:

(1) Brushes are not sticking in the holders.

(2) Pig tail shunts are properly attached to brushes and holders.

(3) Tension is maintained as the brushes wear.

(4) Copper plating (when used) is cut back so it does not make contact with the commutator.

(5) Worn-out brushes are replaced before they reach their limit of travel and break contact with the commutator, or cut it due to contact with the metal clip.

(6) Remove any free copper picked up by the face of the brush. A much fuller treatise on brush selection and application is given in Instruction Book 5187 on "Selection, Application and Care of Brushes for Commutators and Slip Rings for Power Station Apparatus."

SEATING BRUSHES

The ends of all brushes should be fitted to the commutator so that they make good contact over their entire bearing face. This can be easily accomplished after the brushholders have been adjusted and the brushes inserted. Fit the brushes in each brushholder separately by drawing a sheet of sandpaper under the brushes in the direction of rotation while pressing them firmly against the commutator as shown in Figure 19. Be careful to keep the ends of the sandpaper as close to the commutator surface as possible to avoid rounding the edges of the brushes. The sandpaper should cut the brushes only in the direction

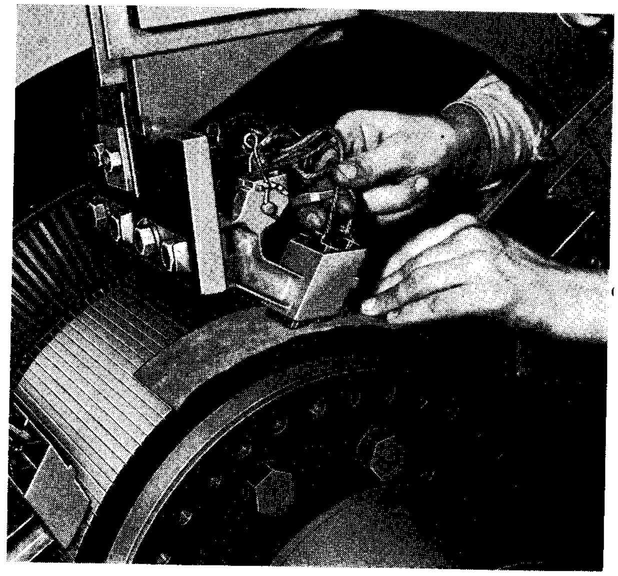


FIG. 19—METHOD OF SEATING BRUSHES

of normal rotation—lift the brushes as the sandpaper is drawn back. **Never use emery cloth or emery paper to seat brushes** on account of the continued abrasive action of the emery which becomes bedded in the brushes.

If the brushes are copper plated, their edges should be slightly sanded so that the copper does not come in contact with the commutator.

CARE OF COMMUTATORS

The commutator is perhaps the most important feature of a D.C. machine and one that is most sensitive to abuse. Under normal conditions, it should require little attention beyond frequent inspection.

The commutator should take on a polished dark brown or chocolate color after a few weeks operation. Such a commutator needs no attention other than to be kept clean. Use of oil or so-called commutator compounds will gum up the commutator causing a deposit of carbon and metal dust on the surface and particularly in the undercutting that may cause "burning" and "flashing." **Do not allow oil to come in contact with the commutator mica, as the oil will penetrate the mica and carbonize it and cause burnouts.**

All commutators are thoroughly baked and tightened before leaving the factory. However, it should be understood that a certain amount of commutator seasoning will take place during the first year after the machine is put into service, particularly if the commutator is of large size. If a bar should work loose it should be attended to promptly by tightening the commutator bolts only in accordance with instructions from the Westinghouse East Pittsburgh engineering department.

That the commutator needs attention will usually be indicated by its becoming rough due to a general unevenness, high or low bars, flat sections, or eccentricity. If these conditions are not corrected, they will result in poor commutation, overheating of the commutator, rapid wear of the brushes, and greatly limit the machines ability to satisfactorily handle overloads.

The surface of the commutator should be kept smooth. Sometimes a little sandpapering is all that is necessary. **Emery cloth or paper should never be used** on a commutator on account of the continued abrasive action of the emery which becomes embedded in the copper bars and brushes. Even when sandpaper is used, the brushes should be raised and the commutator wiped clean with a piece of canvas. Cotton waste should never be used.

If the commutator becomes badly roughened, it will be necessary to turn down or grind the commutator as described in a following section.

All standard commutators have the mica undercut below the surface of the copper to prevent high mica which causes sparking commutation that burns away the copper. As the commutator wears, the mica should be undercut to a depth of $\frac{1}{32}$ to $\frac{1}{16}$ of an inch below the adjacent copper.

Trouble is sometimes experienced from the burning out of mica insulation between segments. This is most commonly caused by allowing the mica to become oil soaked or by the bars loosening and thus allowing foreign conducting material to work its way between them. It is rarely, if ever, definitely traced to excessive voltage between bars. When this burning does occur it may be effectively stopped by scraping out the burned mica and filling the space with a solution of sodium silicate (water glass), or other suitable insulating cement.

GRINDING COMMUTATORS

The surface of the commutator should always be kept smooth. If it becomes badly roughened, the armature should be removed and the commutator turned down in a lathe. Sometimes, with large machines, it is more convenient to rig up a temporary truing device, leaving the armature in its own bearings and running it slowly either as a shunt motor or from a separate belted motor. Ordinarily, unless in very bad condition, the commutator may be pressed down with a piece of sandstone mounted in a device especially designed for this purpose. (See Figure 20).

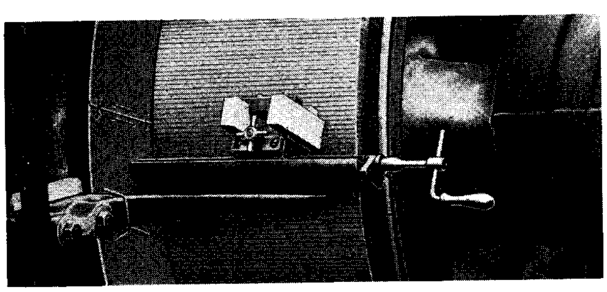


Fig. 20—Grinding Device for Truing Commutators

This grinding device is mounted on one of the brushholder arms or brackets, the brushholders being removed to accommodate it. The stone should be properly adjusted against the rotating commutator until a clean cutting effect is secured; the surface can then be finished with No. 00 sandpaper. Emery cloth or paper should never be used for this purpose on account of the continued abrasive action of the emery which becomes embedded in the copper bars and brushes. Even when sandpaper is used, the brushes should be raised and the commutator wiped clean with a piece of canvas. Cotton waste should never be used.

Before grinding, the brushes should be lifted off the commutator, as the copper and stone dust will rapidly wear them off. The dust will also become embedded in the brush contact surface and later damage the commutator or cause poor commutation. The armature winding should also be thoroughly protected during this operation to prevent an accumulation of dirt and metal chips, which may result in an insulation failure when the machine is again put in service. This protection can usually be best obtained by using a circular shield of fullerboard, or similar material, around the commutator at the end next to the armature. This shield can be easily supported from the brushholder arms and should extend from the ccommutator surface to an inch or two above the surface of the armature. Another method is to shellac circular segments of heavy paper to the commutator necks, making an air-tight shield that revolves with the armature. A shield of some kind should also be put at the front end of the commutator around the shaft, so as to prohibit any dust or chips from being drawn back under the commutator and into the windings.

A vacuum dust collecting outfit is now being used quite generally by our Service Engineers when commutators are being ground. This outfit works on the same principle as the ordinary household vacuum sweeper. The nozzle is of special shape so that it fits close up against the grinding stone and collects the discharge dust as it leaves the stone. A flexible hose permits the nozzle to follow the stone back and forth across the commutator. If has been found that with this arrangement from 85 to 90 percent of the dust is collected that otherwise would be thrown off into the room and into the machine.

After grinding a commutator the machine should always be thoroughly cleaned by blowing out with dry compressed air or by wiping out with rags before replacing it in service, or by both.

UNDERCUTTING COMMUTATOR MICA

All standard commutators have the mica between bars undercut to a depth of $\frac{1}{16}$ inch. This is done to prevent high mica which causes sparking at the brushes resulting in burning away of the copper roughening of the commutator surface.

After grinding or turning a commutator, the undercutting should be cleaned out and the edges of the bars scraped to remove burrs. **It is particularly important that the edges of the bars be well rounded.** Failure to do this has caused machines to "buck" on sudden changes in load or when the circuit breaker opens.

Keep the mica undercut to a depth of $\frac{1}{32}$ to $\frac{1}{16}$ of an inch. If it is necessary to re-undercut the mica due to grinding or turning the commutator or due to wear after long operation, this may be done with a hack saw blade held between suitable guides, or, more conveniently and accurately with a commutator slotting tool. The Westinghouse Company makes these tools for either motor or air operation. (See Figure 21).

CARE OF COLLECTOR RINGS

The collector rings on three-wire generators require occasional attention and should be occasionally lubricated with **slightly** oiled canvas. If only slightly roughened, the rings can be trued up with the sandstone and sandpaper, otherwise they must be turned or ground.

On machines with steel collector rings, the rings should be wiped with very light oil whenever the generator is shut down for a protracted period. Before starting again the rings should be wiped with a dry cloth to remove all oil, dirt and dust.

REBABBITTING BEARINGS

The old babbitt should first be melted out and a suitable mandrel pepared. Split bearings should be babbitted one half at a time and the mandrel should consist of a half cylinder with shoulders running along its length on which the bearing-split faces way rest so as to form a close fit when the bearing shell is in position for babbitting. Pieces of felt, wood or similar material should be used to prevent babbitt from running into those portions of the shell where it is not desired.

The babbitt should be heated in an iron or steel pot to the proper temperature recommended by the supplier:

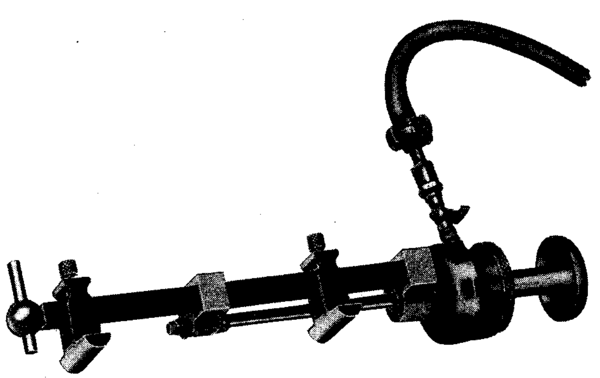


Fig. 21—Small Portable Tool for Undercutting Mica, Attached to Air Motor

430—460°C (806—860°F) For Westinghouse #14 alloy.

480—500°C (896—932°F) For Westinghouse #25 alloy

520—530°C (968—986°F) For Westinghouse #8479-1 or #8479-2 alloy.

Failure to maintain the proper temperature may result in marked loss of some of the babbitt ingredients. Immediately before pouring, mix the metal thoroughly by stirring.

The bearing shell should be cleaned of all grease, oil and dirt by immersing in a suitable cleaning compound. Both the bearing shell and the mandrel should be heated to approximately the same temperature as the babbitt alloy. Immediately before pouring, the surface of the bearing shell should be swabbed with soldering flux such as acid zinc chloride.

Pour the babbitt as soon as possible after the shell and mandrel have been assembled. Pouring should be continuous so that no portion of the babbitt solidifies before the entire bearing has been poured. To obtain the best bond and babbitt structure, the bearing should be cooled so that the babbitt solidifies from the shell or shoe toward the bearing surface, and from the bottom up in the case of vertically cast bearings. Apply water or air spray to the outside of the shell.

After cooling, the bearing halves should be bolted together and bored or reamed to the proper size. The eccentric bores on each side of the bearing should then be added, together with the oil pockets at the bearing split and the oil drain grooves and drain holes at the ends of the bearings. Finally the oil ring slots should be cut or chipped out to the proper depth, the holes for observing the working of the oil rings drilled, and the oil inlet hole drilled through. Finishing can be done with a file and all sharp edges and burrs should be removed.

REPAIRS TO INSULATION

If a defect develops in the outside of a field or armature coil, it can sometimes be repaired by carefully raising the injured wire or wires and applying fresh insulation. More extensive repairs should not be attempted by inexperienced or unskilled workmen.

TEMPORARY ARMATURE REPAIRS

A simple method of making temporary repairs in an armature in case of a short-circuit or open circuit of one of the coils is to cut out that coil by cutting the leads which connect the coil with the commutator bar and then short-circuiting the bar, thus cut out, with the following bar. This may readily be done by simply soldering the two necks together. By this means an armature may be kept in commission until there comes a convenient time to replace the damaged coils.

REPAIRING COMMUTATING FIELD COILS

If it is necessary to remove one of the commutating field coils, disconnect the coil from those on each side, remove the bolts which hold the pole to the frame, and remove the pole and coil. The commutating coil may be removed from its pole and repaired or replaced by a new coil and the complete field reassembled in the frame.

REPAIRING MAIN FIELD COILS

If it is necessary to remove a shunt or series field coil, disconnect both coils from those on each side, remove the bolts which hold the pole to the frame, and remove the pole and coils. The shunt winding is wound directly on its pole with the series winding placed over the shunt coil so that if a new coil is to be installed, it will be necessary to replace the complete pole and coil assembly.

Care should be taken in reconnecting the coils so as to obtain the proper polarity of the coils. A very simple means of testing the polarity of shunt field coils is by means of a needle or a piece of steel wire suspended from the middle by a string. The polarity should be alternately north and south around the frame. Bring the polarity needle within the magnetic field of any pole. One end of the needle will point towards this pole and this end should be repelled by the next pole and so on around the frame. If this reversal of the needle does not occur there must be a wrong connection of the field coil.

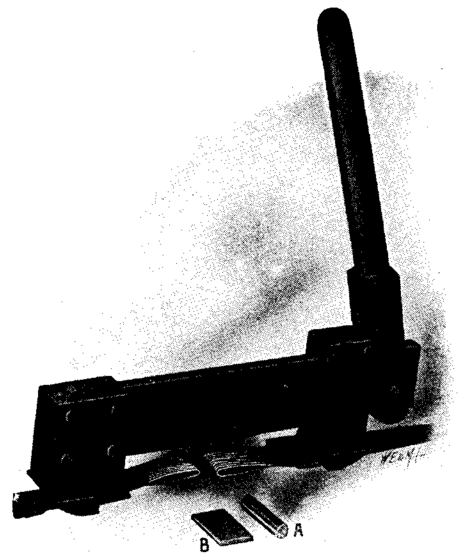


Fig. 22—Tool for Assembling Sectional Band, Open Position

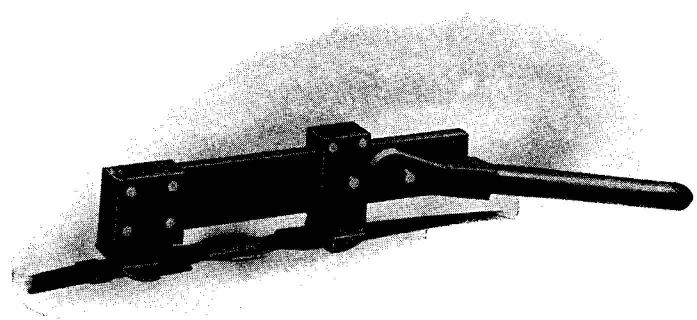


Fig. 23—Tool for Assembling Sectional Band, Closed Position

SECTIONAL BANDS

In repairing direct-current armature windings, particularly large ones, the replacing of band wires becomes a serious problem. To overcome this difficulty, the Westinghouse Company has designed a form of sectional band which retains all the elements of a continuous wire band. yet can be applied or removed quickly and repeatedly without deterioration. These bands are regularly supplied on armatures having a diameter of 50 inches or greater.

Figures 22 and 23, show the tool employed to mount these bands in position. One of these tools is furnished with each machine equipped with sectional bands.

To make the final connection between the free ends, after the different sections have been keyed together into an open hoop and are in position on the armature, place the tool as shown in Figure 22, the two jaws gripping the projecting ends of the fixed pieces inserted into the ends of each section for the purpose. Then bring down the handle to the position of Figure 23, forcing the movable jaws forward along the beam and interweaving the loops on the section ends. Insert the steel pin A in the holes through the movable jaw and the matching hole in the beam, and with the tool clamped in this way remove the handle and advance it to the next hole in the beam. This operation is repeated until the ends of the band are interlocked sufficiently to permit the steel key piece B to be inserted (See Figure 23). All that remains is to remove the tool and paint or shellac the joint.

To remove the band, reverse the preceding process. Relieve the tension on the joint by tightening the band with the tool and then drive out the key piece.

RENEWAL PARTS

Repairing

Repair work can be done most satisfactorily at our nearest Service Shop. However, interchangeable renewal parts can be furnished to customers who are equipped for doing repair work.

Recommended Stock of Renewal Parts

On Page 33 is a list of the renewal parts and the minimum quantities of each that should be carried in stock. These are the parts most subject to wear in ordinary operation and to damage or breaking due to possible abnormal conditions. The maintenance of such stock will minimize service interruptions due to breakdowns. A recommended List of Renewal Parts for your particular equipment will be supplied upon request to the nearest District Office.

Ordering of Repair Parts

Repair parts for any standard Westinghouse generator or motor may be secured on short notice. To avoid misunderstanding, always give the complete nameplate reading and the serial number of the armature, if involved. The former will be found prominently located on the field frame and the latter on the end of the shaft. When material for coils is ordered, also state whether or not insulation for the winding is desired.

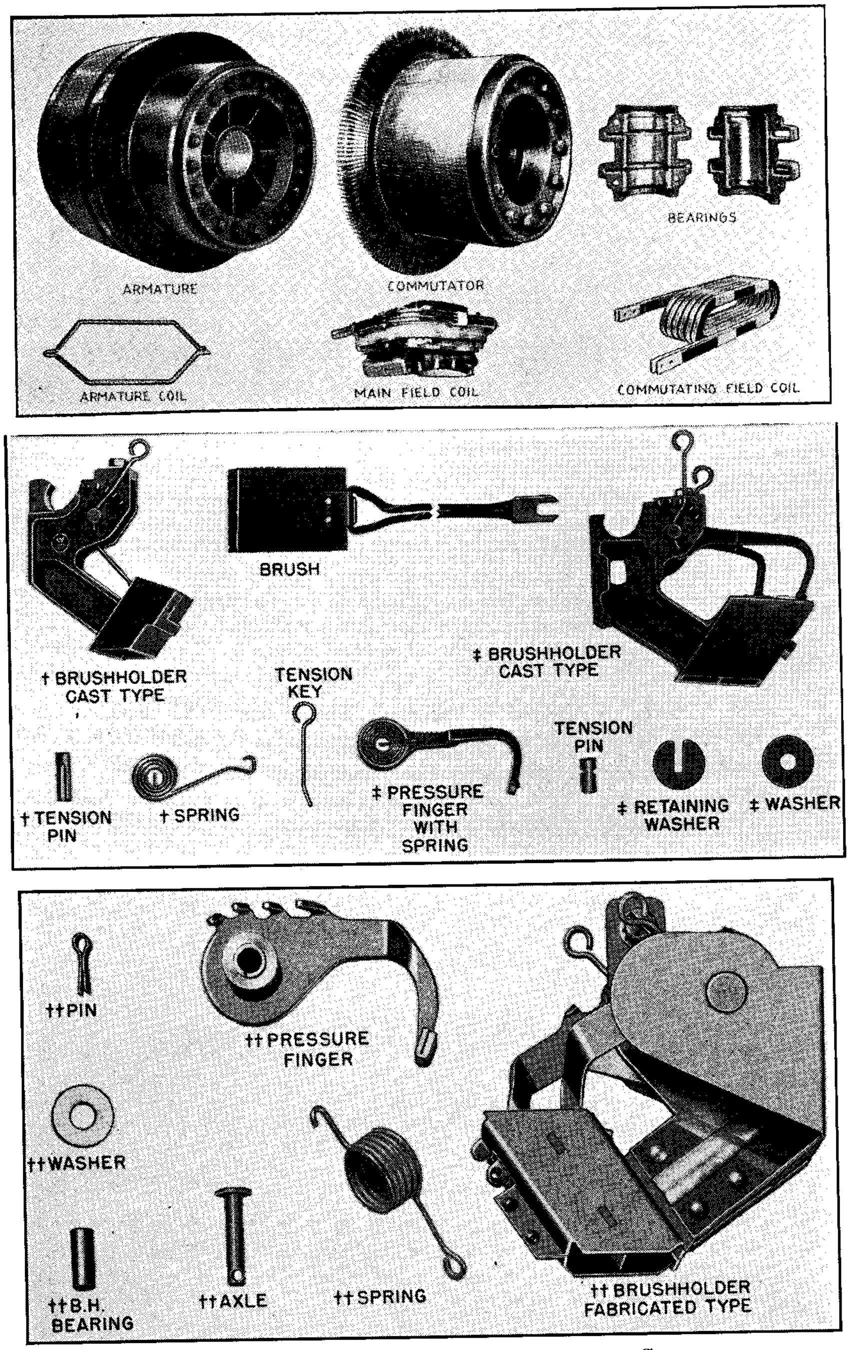


Fig. 24—Typical Renewal Parts for Direct-Current Generators and Motors

RENEWAL PARTS

On the following page is a list of the Renewal Parts and the quantities of each which the user of this apparatus is recommended to stock in order to minimize service interruptions caused by breakdowns.

The parts recommended are those most subject to wear in normal operation, or to damage or breakage due to possible abnormal conditions.

When continuous operation is a primary consideration, more renewal parts should be carried, depending upon the severity of service and the time required to secure replacements.

ORDERING INSTRUCTIONS

Name the part and give its style number. Give the complete name plate reading. State whether shipment is desired by express, freight or by parcel post. Send all orders or correspondence to nearest Sales Office of the Company. Small orders should be combined so as to amount to a value of at least **$1.00** net; where the total of the sale is less than this, the material will be invoiced at **$1.00**.

Number of duplicate units in use..........		1	5
Description of Part	No. Per Unit	Recommended For Stock	
Armature Complete	1	0	0
Armature Coil	1 set	⅓ set	1 set
*Cut Winding Insulation, Class No. 1	1 set	⅓ set	1 set
Commutator	1	0	0
Field Coil, Main	1 set	1	2
Field Coil, Commutating	1 set	0	0
†††Brush	1 set	1 set	2 sets
†††Brushholder	1 set	1	2
††† Tension Pin	1 set	1	
††† Tension Key	1 set	1	2
††† Spring	1 set	1	2
‡ Pressure Finger (short or long	1 set	0	1
‡ Retaining Washer	1 set	2	4
‡ Washer	1 set	2	4
†† Pressure Finger	1 set	1	1
†† Brushholder Bearing	1 set	1	2
†† Axle	1 set	1	2
†† Pin	1 set	1	2
Bearing	2	1	2

Parts indented are included in the part under which they are indented.
*Not illustrated.
†Single Carbon Brushholder (Specify which is desired).
††Double Carbon Brushholder (Specify which is desired).

DIAGRAMS OF CONNECTIONS

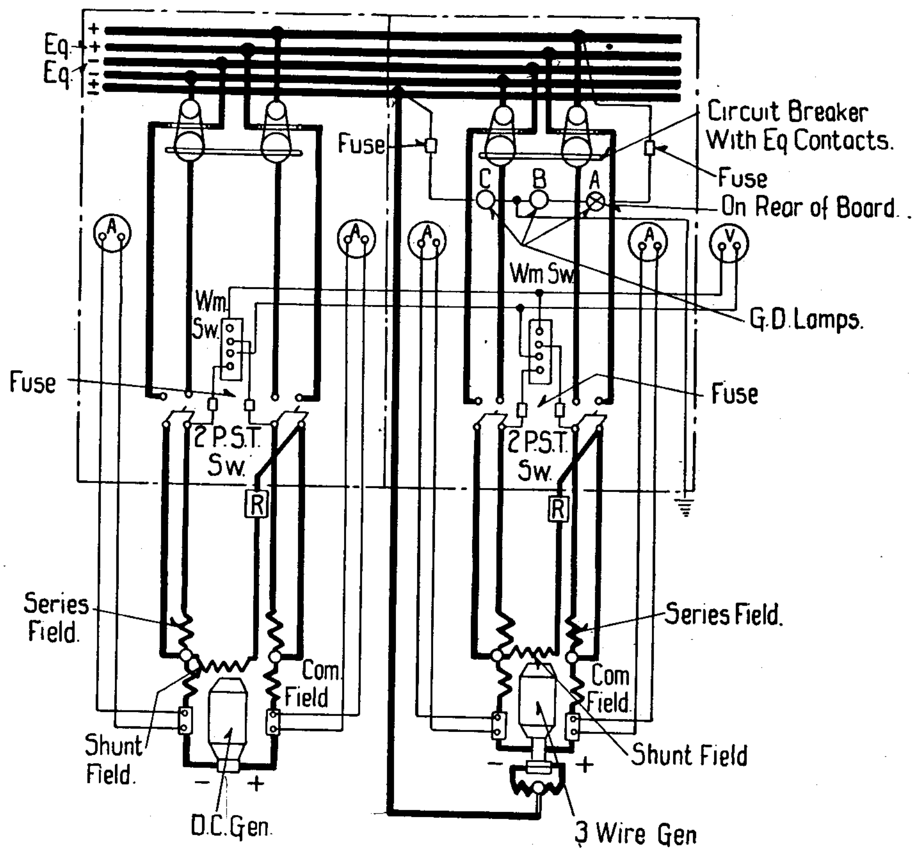


FIG. 25—DIAGRAM OF CONNECTIONS FOR ONE THREE-WIRE COMMUTATING-POLE, 125-250-VOLT D-C. GENERATOR IN PARALLEL WITH ONE TWO-WIRE 240-VOLT GENERATOR

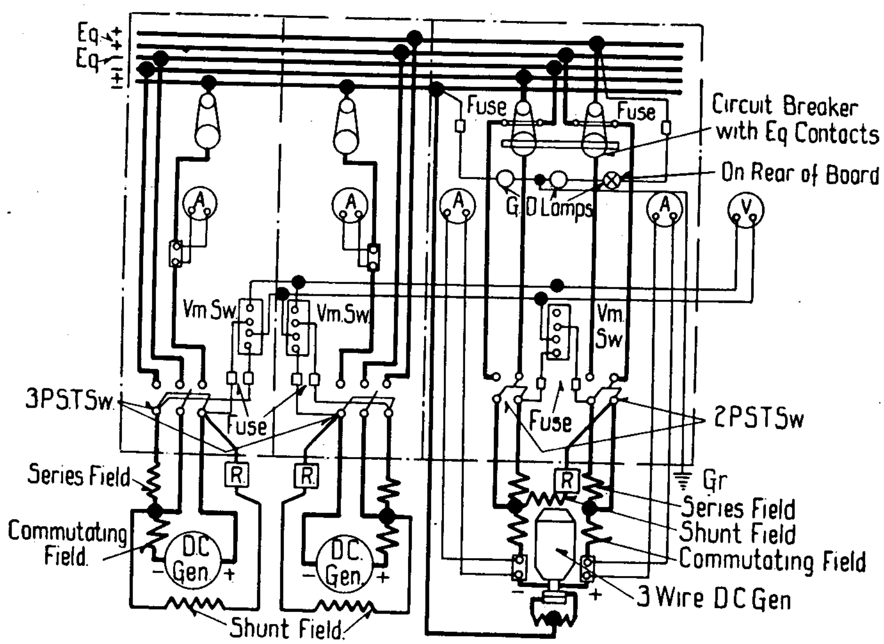


FIG. 26—DIAGRAM OF CONNECTIONS FOR ONE 125-250-VOLT THREE-WIRE D-C. GENERATOR IN PARALLEL WITH TWO 125-VOLT TWO-WIRE GENERATORS

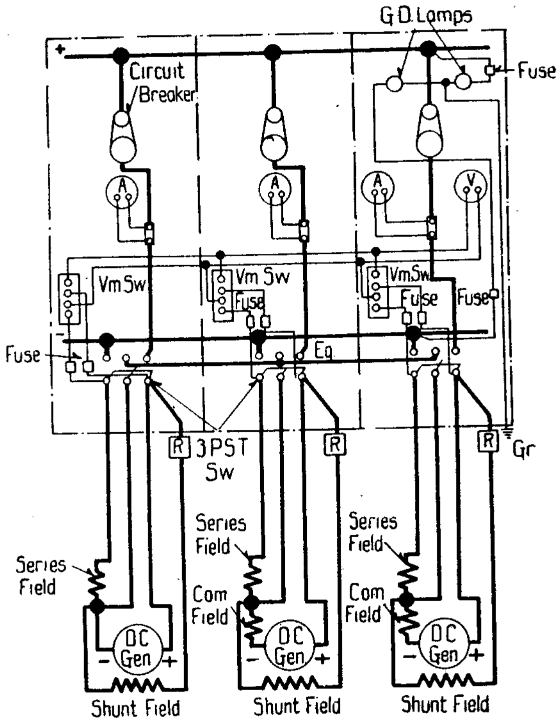


FIG. 27—DIAGRAM OF CONNECTIONS FOR TWO D-C. COMMUTATING-POLE GENERATORS IN PARALLEL WITH ONE D-C. NON-COMMUTATING-POLE GENERATOR. TYPE GD SWITCHBOARD, 250 VOLTS OR LESS

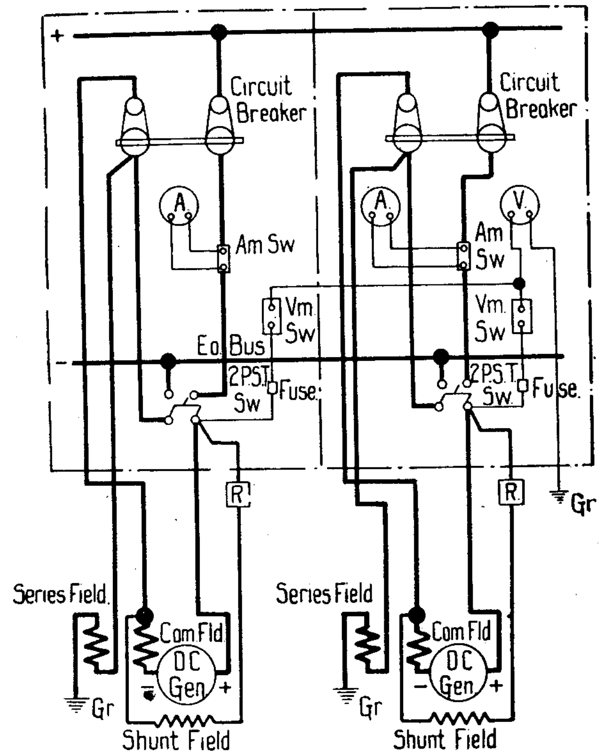


FIG. 28—DIAGRAM OF CONNECTIONS FOR TWO COMMUTATING-POLE ENGINE-DRIVEN MINE GENERATORS IN PARALLEL

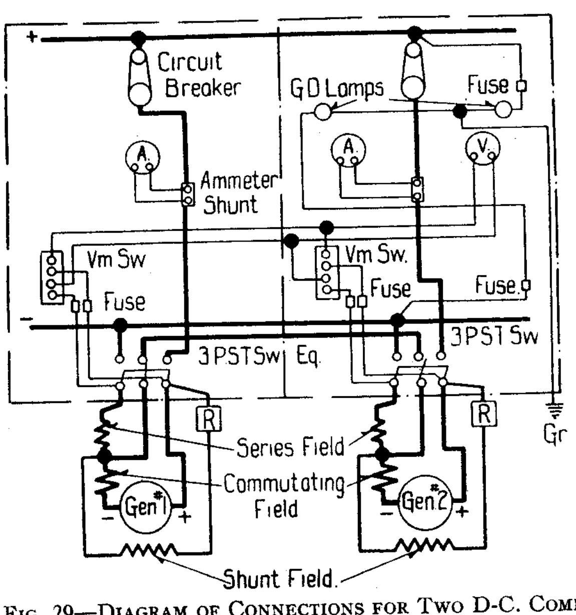


FIG. 29—DIAGRAM OF CONNECTIONS FOR TWO D-C. COMMUTATING-POLE GENERATORS. TYPE GD SWITCHBOARD, 250 VOLTS OR LESS

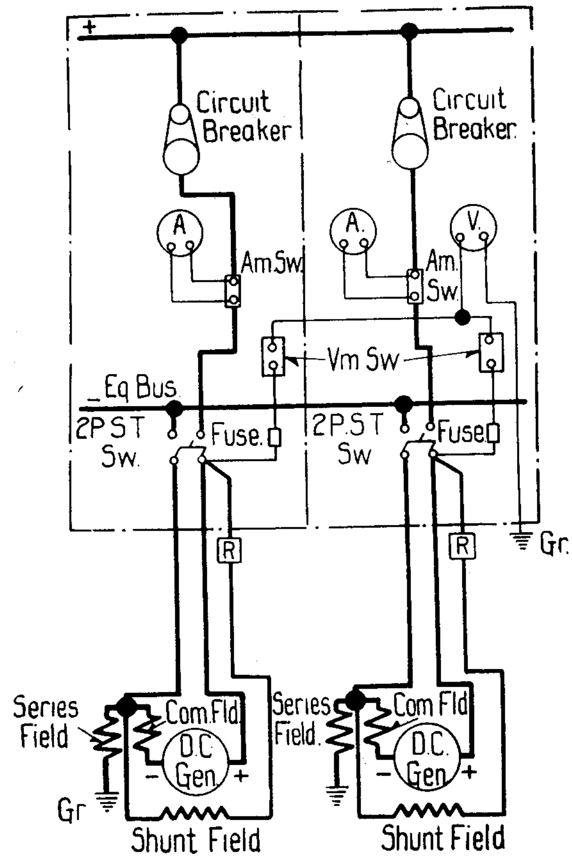


FIG. 30—DIAGRAM OF CONNECTIONS FOR TWO COMMUTATING-POLE MOTOR-DRIVEN MINE GENERATORS IN PARALLEL

Westinghouse

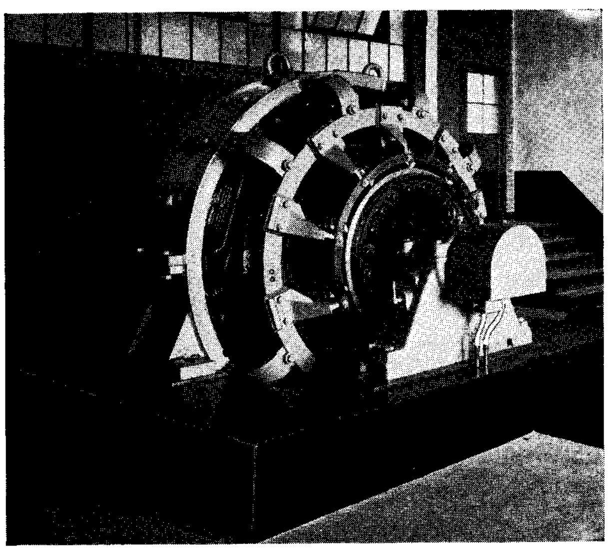
Direct-Current Generators and Motors

Installation

Operation

Maintenance

INSTRUCTION BOOK

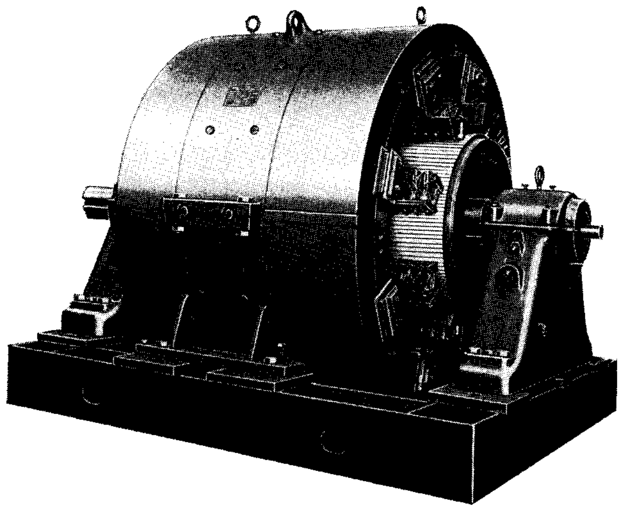


INSTALLATION OF WESTINGHOUSE TYPE QS MOTOR

Westinghouse Electric Corporation
East Pittsburgh, Pa.

I. B. 4000-A
File No. 4600

INDEX



Steel Mill Motor with Special Ventilating Covers

CAUTIONS

Before opening the shipping crates and before installing a machine, read the following instructions carefully, paying particular attention to the section on Installation, Page 8. Adherence to the requirements of foundation, ventilating air, and proper mechanical alignment is essential for continued operation of the machine. Extreme care must be taken when handling parts containing insulated windings as they are easily damaged by careless treatment; see Handling and Unpacking, Page 8.

Keep the generator or motor clean. The finest machines may be shut down by accident if they do not have protection and care. The commutator and winding insulation must be kept clean and dry. Oil and dirt on the insulation are as much out of place as grit or sand in a bearing. On a direct-connected unit, oil may work along the shaft or splash into the machine and cause an insulation failure unless the necessary protection is provided.

COMMUNICATIONS

When communicating regarding a Product covered by this Instruction Book, replies will be greatly facilitated by citing COMPLETE NAME PLATE READINGS of the involved Products. Also, should particular information be desired, please be very careful to clearly and fully STATE THE PROBLEMS AND ATTENDANT CONDITIONS.

Westinghouse

Direct-Current Generators and Motors

GENERAL INFORMATION

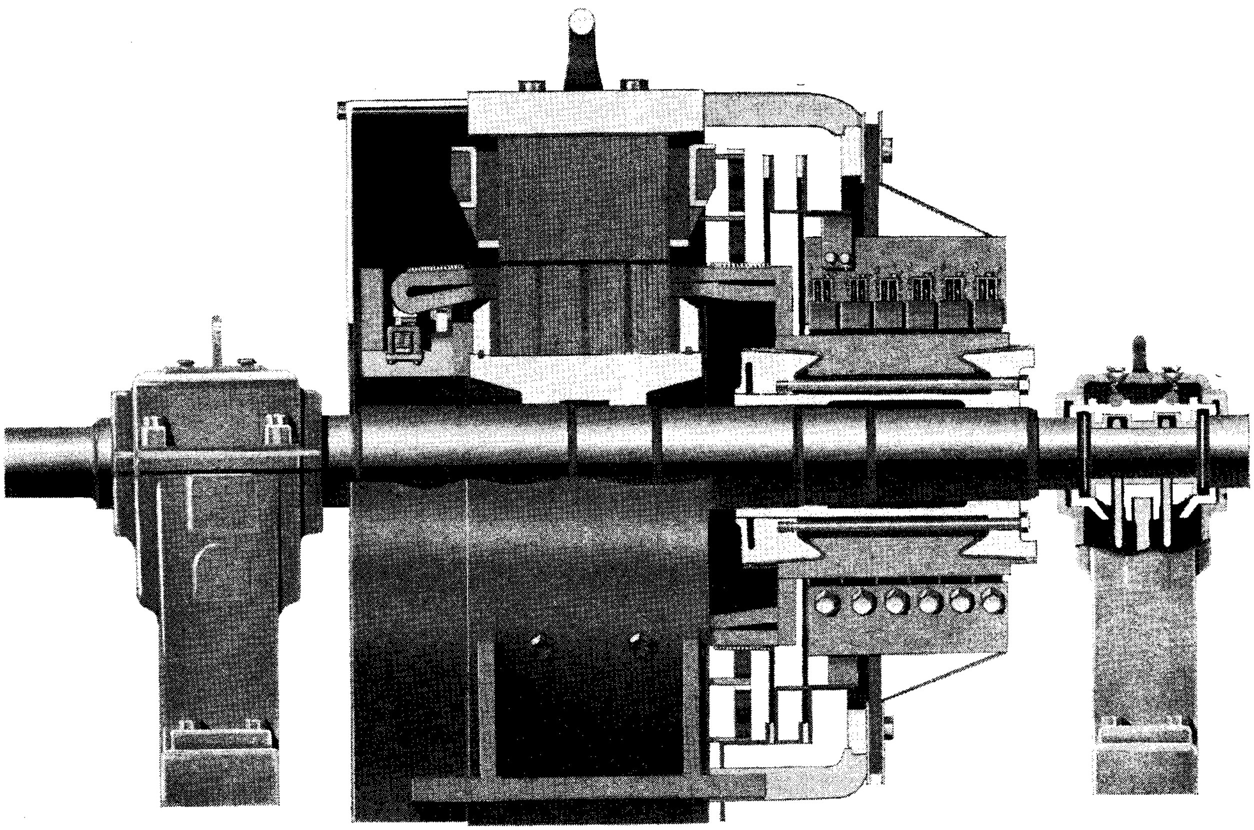


FIG. 1—SECTIONAL VIEW OF DIRECT CURRENT GENERATORS

PURPOSE

These instructions have been especially prepared to provide guidance for the proper installation, operation, and maintenance of Westinghouse direct-current generators and motors. Recommendations for the care of the machines, based on years of experience, are offered as the best assurance of long life and dependable operation. There may be some points about which the operator is not familiar; therefore, before installing or operating the equipment, read the following instructions thoroughly.

GENERAL DESCRIPTION

Types of Construction

Westinghouse standard direct-current generators and motors are divided into the following types:

(1) **Belt Driven, self-contained type,** having two or three bearings, shaft and pulley.

(2) **Coupled, self-contained type,** having two bearings and shaft arranged for direct connection to the prime mover, whether steam, internal-combustion, or hydraulic, if a generator, or to the

element to be driven, if a motor. The frames may or may not be provided with a bedplate.

(3) **Coupled, Marine-type,** having pedestal type bearings and a flanged shaft suitable for direct connection to the prime mover, if a generator, or to the propulsion shafting, if a motor. The frames and pedestals are not furnished with a bedplate, proper support and alignment being provided on the vessel's structure by the shipbuilding contractor.

(4) **Engine type,** consisting of a complete field and armature without bearings or shaft, the armature to be mounted on the extended shaft of the prime mover, if a generator, or on the extended shaft of the machine to be driven, if a motor. Engine-type machines of the larger sizes are not as a rule provided with bedplates. In place of one large bedplate, two smaller supporting pieces, known as sole-plates are supplied. These plates are grouted into the foundation on each side and provide a finished seat for the supporting feet of the field frame.

(5) **Turbo-Generators**—These machines are built for steam turbine drive. They differ from the ordinary engine-type machines mainly in the mechanical features required for the higher rotative speeds at which they operate.

(6) **Turbine Reduction Gear Generators**—These machines are essentially of the coupled type with a forged, flanged shaft which couples directly to the reduction gear shaft. The bedplate is usually supplied by the turbine builder. Generally, only one bearing is supplied, the coupling being attached to and supported by the reduction gear shaft.

(7) **Turbo Generator Exciters** are usually of the flexibly coupled, self contained type with special features to make them suitable for high-speed service and long periods of uninterrupted operation. All sizes are provided with maximum brush accessibility and those with ratings of above 50 kw. are provided with special brush holders which permit the removal of brushes by a workman using only one hand and without the need of tools.

Due to the large volumes of high velocity air which passes through these exciters, special care is taken to provide maximum creepage distances on all electrical parts and to provide for ease of cleaning. This is true in both 3600 rpm. and 1800 rpm. exciters as the brush wear is essentially the same in equivalent exciters at either speed. This is due to the larger diameter commutators required on the 1800 rpm. exciters.

(8) **Water Wheel Generator Exciters**—These exciters have their rotors mounted above the A.C. generator and bolted to the spider or shaft of the A.C. generator. The stator is supported by the upper bracket of the A. C. generator and the pilot exciter (if any) is mounted above the main exciter.

Output

The output of a generator in kilowatts may be obtained by multiplying the current in amperes by the e.m.f. in volts and dividing by 1000. To obtain the horsepower output of a motor, multiply the current in amperes by the applied e.m.f. in volts and multiply this product by the efficiency and divide by 746.

$$\text{Kilowatts} = \frac{\text{Volts x Amperes}}{1000}$$

$$\text{Horsepower} = \frac{\text{Volts x Amperes}}{746} \text{ x Efficiency}$$

Windings

Depending upon the character of field winding employed, a direct-current machine is classified under one of the following three general groups:

1. Shunt wound.
2. Series wound.
3. Compound wound.

Shunt-Wound Generator

The field winding of a shunt-wound generator is composed of a large number of turns of wire or strap of comparatively high resistance, which, in series with a rheostat, is connected directly to the armature terminals, forming, in parallel with the main circuit, a shunt circuit through which only a small percentage of the total current flows. This is a self excited shunt wound generator. A separately excited machine would differ only in having both shunt field leads brought out. This allows the shunt field to be excited from another source of voltage than the generator itself.

The regulation characteristics of a shunt-wound machine are such that the voltage is a maximum at no load, and drops as the load increases unless regulated by the manipulation of a rheostat in the field circuit. This voltage droop is greater in the case of the self excited generator than on a separately excited generator.

Series-Wound Generator

The field winding of a series-wound generator is composed of a few turns of heavy wire or strap which is connected in series with the armature and external circuit. With this type of machine the total current delivered flows through the field winding and the voltage varies directly with the load. The greater the load the higher the voltage. Generally, a slight load is required to make these machines pick up voltage, therefore series generators are very infrequently used.

Compound-Wound Generator

A compound-wound machine has both shunt and series windings. The shunt field is generally so designed that on open circuit, the series field being idle, the machine will generate the desired line voltage. The result of applying load would, as noted under "Shunt Generator," tend to lower the

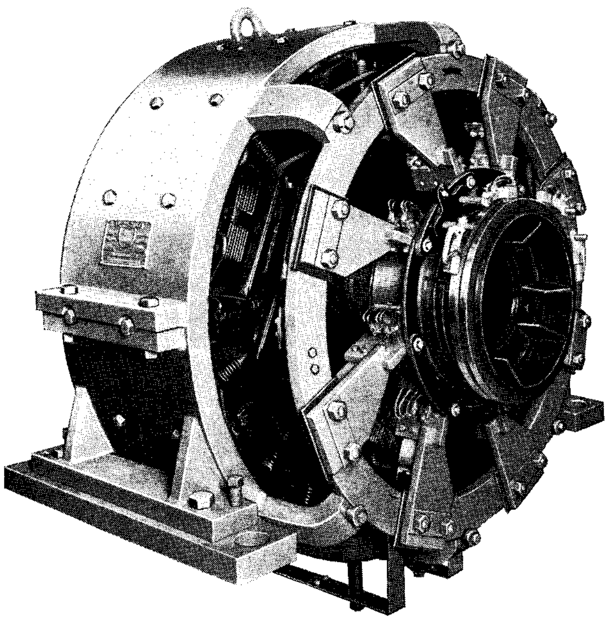


Fig. 2—Commutator End View of Engine Type QS Generator, Showing Collector Rings for 3-Wire Service

terminal voltage; but it is here that the utility of the compound winding becomes apparent. The series coils reinforce the shunt field in direct proportion to the increase of load and thus hold the terminal voltage approximately constant, balancing the drop due to increased copper loss and armature reaction at the heavier loads.

In order to allow some variation and permit adjustments to suit operating conditions, additional hand regulation is provided in the form of a rheostat in the shunt-field circuit.

It is desirable that compound wound generators be supplied with flat compounding, that is, with the same voltage at no load and at full load current, as better division of load between generators in parallel is thus secured.

In some cases the compound winding is connected in reverse, so as to buck the shunt field action. In this case, the machine is called a differentially-compound generator and the voltage droops considerably more than that of a shunt-wound generator.

Long and Short Shunt

When the shunt field winding of a compound-wound generator is connected across the outside terminals of the machine, shunting both the series field and armature windings, it is known as long shunt.

When the shunt field is connected inside the series field it is known as short shunt. This is the more common practice, the voltage applied to the shunt being higher than it would otherwise be by the amount of the drop through the series winding.

Three-Wire Generators

Any of the above types can be made into a three-wire generator. In this modification, equidistant taps are made in the armature winding and carried to collector rings at the end of the armature. The rings are connected through sliding brushes to a choke or balance coil. The middle point of the coil constitutes the neutral point to which the third or neutral wire of the system is connected. A practically constant voltage is maintained between the neutral and outside wires which is one-half the generator voltage. See Figure 9. Two collector rings and one balance coil are used. Three-wire operation requires that one-half the commutating field and series field windings, if any, be connected on each side of the line in order to maintain approximately the same total field strengths under unbalanced load.

Series Motors

Series motors are variable speed machines particularly adapted to a few special uses, such as railway and crane service, but are not extensively employed in the field of work to which this book is devoted. The characteristic features of a series motor are its great torque at starting and low running speeds under heavy loads. A series motor should always be positively connected to a load, as it has a very high run-away speed at no-load.

Compound-Wound Motors

For some special classes of service, in which it is necessary to start under heavy load and later operate at approximately constant speed, a series winding is added to assist the shunt field at the heavy load points.

As in the case of the compound generator, a compound motor combines the characteristics of both shunt and series motors. The series winding gives a drooping speed regulation to the motor and increases the starting torque.

Shunt Motors

This is by far the most common type of winding, and is generally applied to motors designed for operation at constant speed under constant or varying loads. Nearly all commercial applications, particularly those of large capacity, require this type of motor. When necessary, considerable speed variation can usually be secured by means of a rheostat in the field circuit, increased resistance resulting in an increased speed. Practically all so-called "shunt" motors have a slight series field winding, usually known as a stabilizing winding, to maintain stability under load.

INSTALLATION

GENERAL

Storage

Where the equipment is received ahead of the time of actual installation, consideration should be given to proper storage so that exposure to weather, dirt, and moisture will be avoided. It is particularly important to keep the windings and commutator dry since moisture lowers the insulation resistance and increases the likelihood of a breakdown in service. Store the cases containing the machine or its parts in a cool, dry and sheltered location until ready to be put into operation. Do not open the cases and disturb them as little as possible until ready to proceed with the assembly.

Unpacking

The cases containing the machine or any of its parts should be left unopened until the time of assembly. If a machine is brought from cold surroundings into a warm room, it should be kept covered until its temperature has risen to room temperature so as to prevent condensation on the windings and other parts. The safe rule is to open all cases during the cool part of the day.

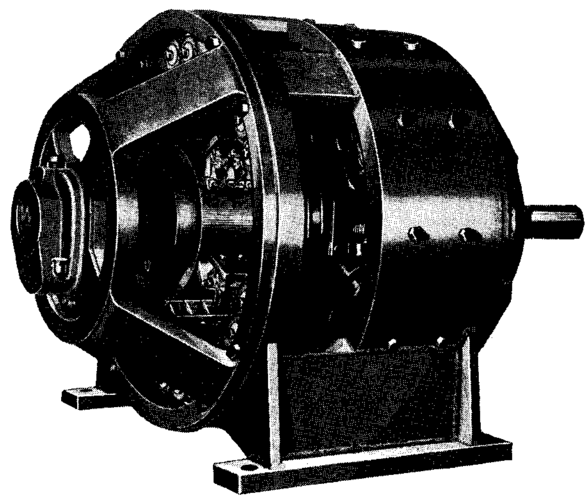


FIG. 3—STANDARD LARGE SIZE TYPE SK FABRICATED MOTOR

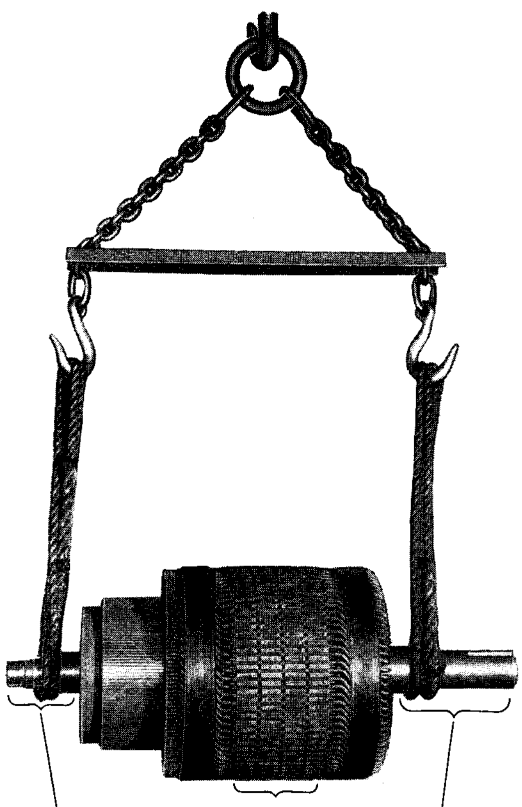


FIG. 4—LIFTING ARMATURE WITH SPREADER-BAR

Handling

It is easily possible, by rough handling or careless use of bars or hooks, to do more damage to a machine before or during erection than it would receive in years of regular service.

Care should be taken in transporting and handling the equipment to see that the windings are not damaged. A blow upon any part of the windings is liable to injure the insulation and result in failure of the coil.

Lifting of machines should be done with the greatest of care. The stators are provided with lifting rings on the top of the frame, into which crane hooks may be inserted. Remember that the field coils and wiring-around-frame connections are exposed during assembly and can be very easily damaged; therefore, careful handling of the stator sections is very essential.

The armature is especially liable to damage since its own weight is sufficient to crush the winding if it is lowered on or swung against a projection. The armature should be lifted, preferably, with rope slings looped around the shaft, taking great care that the rope does not touch the commutator or the windings at the back of the armature. Use a spreader-bar to hold the ropes away from the armature as shown in Figure 4. Chains or wires should not be used unless the shaft journals are adequately protected.

Caution—Never support the armature wholly or in part by the commutator either when raised by blocking or when held in a rope sling. Do not allow workmen to stand on the commutator.

LOCATION OF MACHINES

It is very important that the location be wisely chosen, due regard being paid to the rules of the National Board of Fire Underwriters and to local regulations. The following considerations should also be carefully observed:

1. The machine should be located in a cool, dry place, well ventilated and not exposed to moisture. Remember that the room temperature is added to that developed in the machine, and therefore, the total temperature, and consequently the capacity of the machine depends upon the temperature of the surrounding air.

2. The machine should not be exposed to moisture from leaky pipes, escaping steam, or condensation of atmospheric moisture on an overhead glass or metal roof. Drip-proof covers should be provided if such conditions exist.

3. It should not be exposed to the corrosive action of acid fumes or other injurious gases.

4. The machine should not be exposed to dirt from coal handling or similar operations.

5. A direct-current machine must never be placed in a room where any hazardous process is carried on, or in a place where it will be exposed to inflammable gases or flying chips, sawdust or other combustible material.

6. The machine should be located so as to receive proper ventilation. This is important and means that the air circulation in the room must be such as to carry away the heated air and supply cool air to the machine. To provide this it may be advisable in some cases to put in ducts that will bring air from outside of the building.

7. The machine should be so located that it will be easily accessible for observation, inspection, oiling and cleaning.

8. Belt-driven machines should have proper distance between belt centers.

FOUNDATIONS

Machines not exceeding 50 kilowatts and 1000 amperes capacity may be supported by timber bases, but larger units require solid masonry or concrete foundations, to which they should be secured by foundation bolts. These bolts must be accurately spaced, the approved method of location being to construct a light wood template or frame with the bolt holes carefully bored to dimensions given on the blue print of the generator base. It is advisable to have these bolts, surrounded by iron pipes of proper length and with inside diameter somewhat larger than bolts, set in the foundation with the openings in the masonry to allow access to the nuts at their lower ends in case renewals become necessary. The slight flexibility of position permitted by this pipe construction is often of great convenience on the final lining up of the bedplate.

Be sure that the foundation is carried down to a solid bottom, or is made of sufficient area to prevent sinking or displacement under the full load it is expected to support.

A competent engineer who is familiar with local conditions should lay out this part of the work.

Care should be taken that all pits in the concrete are properly drained and that passages remaining for piping and wiring are easily accessible and so laid out that the work of installing and connecting up will be simplified in every possible way.

Insulation of Frames

The desirability of insulating the frame from the ground is an open question and must be decided upon by the merits of the case. As a matter of fact, frames of machines up to 700 volts are seldom insulated; it is well, however, to keep in mind the following points.

Broadly speaking, the strain on the insulation of the windings is decreased and the danger to the attendant increased by insulating the frame of the machine from the ground. There is also likelihood of flashing to ground with high-voltage machines.

If the frame is to be insulated from the ground, the foundation can be capped with a stout wooden frame bolted to the masonry, care being taken that the bolts are so placed that they do not make electrical contact with the bolts which secure the machine base to the wooden cap. This wooden cap may be covered with some waterproof insulating paint or compound. Porcelain insulators set in the concrete of the foundation have also been used. In any case an insulating platform should extend around the machine of sufficient width so that the attendant must mount it before he can touch part of the frame.

Direct-connected units necessarily have their rotating parts grounded through the driving machine and piping. The stationary parts might be insulated, but it is difficult to accomplish this and at the same time secure the machine firmly to the foundation.

ERECTION

Some of the smaller machines are shipped completely assembled and need only to be set upon their foundations, leveled, and lined up before making connections.

The armatures for larger generators and motors are shipped separately. Whenever possible, the stator frames are shipped assembled and with all internal wiring connected. Preparatory to assembling the machine, the upper half of the rocker ring must be removed, the wiring-around-frame connections at the frame split must be opened, and the top half of the frame must be lifted off.

In all cases where the frame is split to remove the top half, care must be taken in reassembling to tighten the commutating pole bolts at the frame split before the frame lug bolts are tightened.

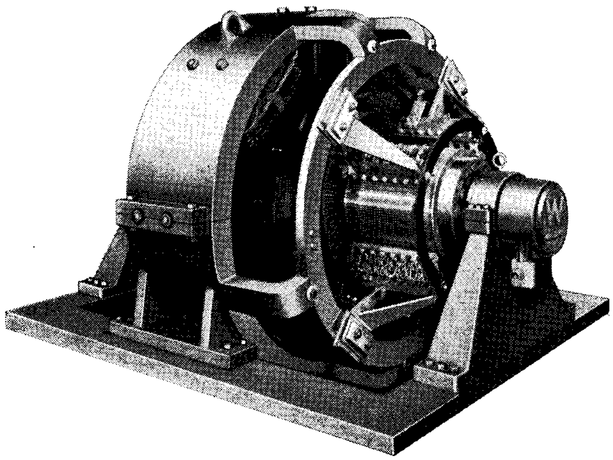


FIG. 5—TYPE QS GENERATOR WITH ANTI-FRICTION BEARINGS

This will spring the two halves of the frame into the proper position and thus avoid incorrect effective commutating pole air gaps for those poles at the split.

The erection of Westinghouse generators and motors is considered as divided into four general classes, namely:

1. Belt-driven, self-contained machines
2. Coupled, self-contained machines
3. Coupled, marine-type machines
4. Engine-type machines

Erection of Belt-Driven, Self-Contained Generators and Motors

1. Set the lower half of the frame and rocker rings in position. Level and insert the bearings, if they are separately shipped. Inspect the bearings and oil reservoirs carefully to be sure they are clean and free from dirt.

2. After covering the journals with a film of oil, lower the rotating part into the bearings. Fill the bearings with oil to the proper level, place the bearing caps in position and screw down the cap bolts lightly.

3. Clean the contact surfaces of both halves of the frame. Set the upper half in position and secure to the lower half by the bolts and feather keys. Swing the upper half of the rocker ring into place and, after bolting the halves together, see that it moves easily in its seat.

4. Re-connect the armature leads and the field wiring connections inside of the machine. Insert the brushes in the brushholders and check to see that the brush alignment is correct; that is, that the edges of the brushes are parallel to the commutator bars, that the brushes are accurately spaced around the commutator, and that the brushholders are within $\frac{1}{16}$ to $\frac{1}{8}$ inch of the commutator surface. Check that the brushes are set on the "factory brush position" by following out the instructions in regard to "Mechanical Redetermination of Brush Position" as given on Page 16. Grind in the brushes to a perfect seat on the commutator, using sandpaper only; see Figure 16. See that the brushes move freely in the holders and are held under an equal and moderate pressure; 2 to 2½ pounds per square inch of cross-sectional area is a normal pressure.

5. Accurately align the shaft with the driving or driven shaft, with the center lines of pulleys directly opposite. Tighten up the foundation bolts. Place the belt in position and run slowly. If the shafts are parallel, but the pulleys not directly opposite, the belt will run to one side of the larger pulley. If the pulleys are opposite but the shafts not parallel, it will run to one side of the smaller pulley.

6. After final adjustment, set the foundation bolts up hard.

7. Connect the machine to the switchboard. (For further information, see diagrams on Pages 33 and 34.)

Erection of Coupled, Self-Contained Generators and Motors

Proceed as in sections 1, 2, 3 and 4 of the preceding instructions.

5. Align the generator shaft with the driving shaft and mount the coupling.

6. Connect the machine to the switchboard. (For further information, see diagrams on Pages 33 and 34.)

7. Connect the couplings and run slowly; then secure the machine permanently to its foundation.

Erection of Coupled, Single-Bearing Generators and Motors

1. Place the lower half of the field frame and rocker ring in position on the supporting structure which should be of such a height as will allow room for approximately one-half of the liners furnished for adjustment under the frame when the air gap is correct.

2. Locate the bearing pedestals so that the centers of the bearings are on the horizontal axis through the connecting shaft.

3. Lift the armature using rope slings around the shaft, taking care that the ropes do not touch the windings at the back end of the armature. (See Figure 4, Page 8.)

Caution: Never support the armature wholly or in part by the commutator. Do not allow workmen to stand on the commutator.

Inspect the shaft journals for any rough spots or scratches as these may cut the bearings and cause them to run hot. Cover the shaft journals and bearing surfaces with a film of oil and lower the armature carefully into its bearings.

4. Adjust the bearing pedestals to obtain correct coupling alignment, as checked by "breaking" the coupling so that a thickness (feeler) gauge may be inserted between the half coupling faces. With the coupling connected, check for longitudinal clearance at the bearings with the shaft end-play all out in both directions. Bolt the pedestals to the mounting plates, fill with oil to the proper level, and replace the bearing caps.

5. Adjust the frame in position, shifting it in a direction parallel with the shaft until its center line (halfway between the faces of the laminated main pole iron) is directly opposite the center of the rotating part (half-way between the endplates which hold the laminations of the core.)

6. Clean the contact surfaces of both halves of the frame. Place the top half of the frame and the upper part of the rocker ring in position and bolt together.

7. Adjustment of the air-gap—In setting up any machine in which the bearings are independent of the frame, great care must be exercised in the adjustment of the air-gaps between the armature core and the pole faces, as any inequality in the gaps may cause serious electrical unbalance and unequal heating of the armature iron. Adjust the airgap horizontally by shifting the frame, and vertically by means of steel liners placed under the frame feet until equal feeler gauge measurements are obtained between the main poles and the armature at both the front and back of the machine.

8. Re-connect the armature leads and the field wiring connections inside of the machine. Insert the brushes in the brushholders and check to see that the brush alignment is correct; that is, that the edges of the brushes are parallel to the commutator bars, that the brushes are accurately spaced around the commutator, and that the brushholders are within $\frac{1}{16}$ to $\frac{1}{8}$ inch of the commutator surface. Check that the brushes are set on the "factory brush position" by following out the instructions in regard to "Mechanical Re-determination of Brush Position" as given on Page 16. Grind in the brushes to a perfect seat on the commutator, using sandpaper only; see Figure 16. See that the brushes move freely in the holders and are held under an equal and moderate pressure; 2 to $2\frac{1}{2}$ pounds per square inch of cross-sectional area is a normal pressure.

9. Connect the machine to the switchboard. (For further information, see diagrams on Pages 33 and 34.)

Erection of Engine-Type Machines

1. Set the soleplates, if any, in place and level up to proper position; i.e., to such a height as will allow room for approximately one-half of the liners provided for adjustment under the frame when the air-gap is correct.

2. Place the lower half of the field frame and rocker ring in position.

3. With machines of large size, the armature must be pressed upon the shaft at point of installation, if this has not been done at factory.

The shaft is turned accurately to a certain gauge and the hub is bored out to a similar gauge several thousandths of an inch smaller in order to secure a press fit. Before attempting to force the armature on its shaft, inspect the surfaces to be fitted as they may have received injury during transportation. File down any roughness of this sort and smooth with emery cloth.

See that the key has a good bearing on its sides and clears on top about $\frac{1}{32}$ of an inch.

Before proceeding further with the operation, the surfaces on the shaft and the interior of hub finished for the fit should be painted with a mixture of white lead and engine oil to prevent cutting the shaft.

The force required to press the armature on, varies with the temperature, condition of surface, and quality of the metal to such an extent as to make it practically impossible to estimate its value with any degree of accuracy. It is generally safe to assume that from 100 to 200 tons force will be required.

For forcing a large armature on its shaft, a hydraulic press is preferable. When this cannot be secured, make two yokes out of I-beams. Place one of these across the rear of the armature so as to press on the end of the armature spider, and one at the end of the shaft, and draw the armature in place by means of two bolts which pass through the yokes and spider close to the shaft. Care

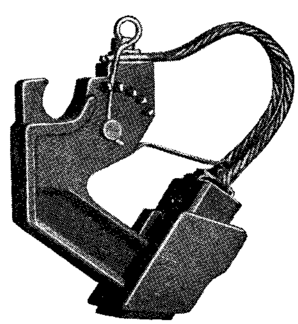


Fig. 6—D-C. Brushholder for QS Generators and Motors

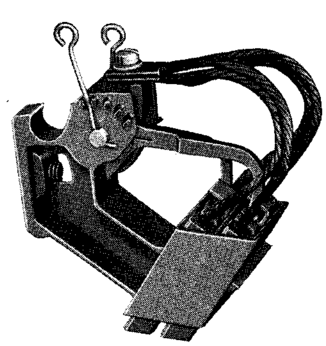


Fig. 7—D-C. Double Brushholder for QS Generators and Motors

should be taken to tighten up evenly on the bolts, otherwise, the spider will twist and bind on the shaft. Once started, this operation should be carried to completion as quickly as possible. If the armature is allowed to set several hours when only part way on the shaft, it may require from 25 to 50 per cent more force than was previously used to start it again.

Do not mar or scratch the shaft, as any roughness may cut the bearings and cause them to run hot. A large armature which must be pressed on the shaft in the station should be supported when possible on the spokes of the spider by passing heavy timbers through the spider and blocking up to them at each end. When this is impossible, it should be set in a cradle cut out of heavy timber to fit, and lined with excelsior or waste, so that the weight will be evenly distributed over a large area of the core. This cradle should be made narrower than the core in order not to injure the winding. An armature so supported should be braced on both sides.

4. After the armature has been pressed upon the shaft, it should be carefully lifted in a sling and lowered into its bearings.

Caution: Never support the armature wholly or in part by the commutator, either when raised by blocking or when held by a rope sling. Lift it by a rope sling about the shaft, taking great care that the ropes do not touch the windings at the back end of the armature. Do not allow workmen to stand on the commutator.

5. Adjust the frame in position, shifting it in a direction parallel with the shaft until its center line (half-way between the faces of the laminated main pole iron) is directly opposite the center of the rotating part (half-way between the endplates which hold the laminations of the core).

6. Clean the contact surfaces of both halves of the frame. Place the top half of the frame in position, mount the upper part of the rocker ring and check adjustments to see if they are still correct.

7. If mounted on soleplates, tighten the soleplate bolts and cement the soleplates to the foundation, using a mixture of one part of Portland cement and two parts of sand, or half cement and half sand; either will give good results. First mix the cement and sand dry and then add water until a very thin solution is obtained. Construct a dam around the bedplate and pour this solution under it continuing the process until the cement stands about half an inch above the bottom of the soleplates. The entire operation of mixing and pouring the cement should be carried on without interruption and as rapidly as possible until completed, otherwise, the cement first poured under the bedplate may partially set and prevent that poured later from flowing freely to all parts. When the cement has sufficiently hardened, remove the surplus from the outside and smooth up the joint under the soleplates.

8. Adjustment of the air-gap—In setting up any machine in which the bearings are independent of the frame, great care must be exercised in the adjustment of the air-gap between the armature core and pole faces, as any inequality in this gap map cause serious electrical unbalance and unequal heating of the armature iron. Adjust the air-gap horizontally by shifting the frame, and vertically by means of thin sheet steel liners placed between the bedplate and the frame feet. During this operation gauge the gaps at different points on the front and back of the machine by inserting thin feelers in the air-gap and measuring the thickness of the stack of feelers.

9. Re-connect the armature leads and the field wiring connections inside of the machine. Insert the brushes in the brushholders and check to see that the brush alignment is correct; that is, that the edges of the brushes are parallel to the commutator bars, that the brushes are accurately spaced around the commutator, and that the brushholders are within $\frac{1}{16}$ to $\frac{1}{8}$ inch of the commutator surface. Check that the brushes are set on the "factory brush position" by following out the instructions in regard to "Mechanical Redetermination of Brush Position" as given on Page 16. Grind in the brushes to a perfect seat on the commutator, using sandpaper only; see Figure 16. See that the brushes move freely in the holders and are held under an equal and moderate pressure; 2 to $2\frac{1}{2}$ pounds per square inch of cross sectional area is a normal pressure.

10. Connect the machine to the switchboard. (For further information, see diagrams on Pages 33 and 34.)

PREPARING FOR OPERATION

It sometimes happens that the insulation of a machine is mechanically injured or exposed to moisture after the factory test but previous to being placed in service. Since the insulation resistance of the windings is an indication of the condition of the insulation, measurements of insulation resistance should be made before the machine is run. For methods of measuring insulation resistance of windings, see "Insulation Resistance Test" on Page 14. Unusually low values of insulation resistance should be corrected by repairing damaged insulation or by drying out the windings, as the case may be.

If there is reason to believe that the windings have been exposed to moisture during shipment or erection, they should be subjected to a drying process before putting the machine into regular operation. See "Drying Out Windings" on Page 15.

CONNECTIONS

CONNECTIONS FOR PARALLEL OPERATION OF GENERATORS

Diagrams of connections for generators operating in parallel are given on Pages 33 and 34.

Parallel operation of direct-current generators is effected in a comparatively easy manner if machines are of the same make and voltage or are designed with similar electrical characteristics. If they are shunt-wound machines, no connections other than the main leads are required; if they are compound-wound machines, the addition of equalizer connections between the machines is required. If the division of load between generators operating in parallel is not sufficiently balanced, it will be necessary to make adjustments as directed under "Operation," Page 19.

In laying out the wiring of generators that are to operate in parallel, particular attention should be paid to the relative resistance of the connecting leads. If generators are of the same size and make, the only feature requiring special attention in connecting to the switchboard is to see that all the cables which lead from the various machines to the bus-bars are of equal resistance. This means that if the machines are at different distances from the switchboard, different sizes of cables should be used, or resistance inserted in the low resistance leads, to equalize the voltage drops in these circuits.

If generators differ in design or size, the matter requires more attention. In this case the difference in potential or drop in voltage between the terminals of the machine and the bus-bars to which they are connected should be exactly the same for every generator when each is carrying its proper share of the load. To secure the best results, the total drop between generator terminals and switchboard must not only be the same at equal loads, but the drop in corresponding sections of the connecting cables

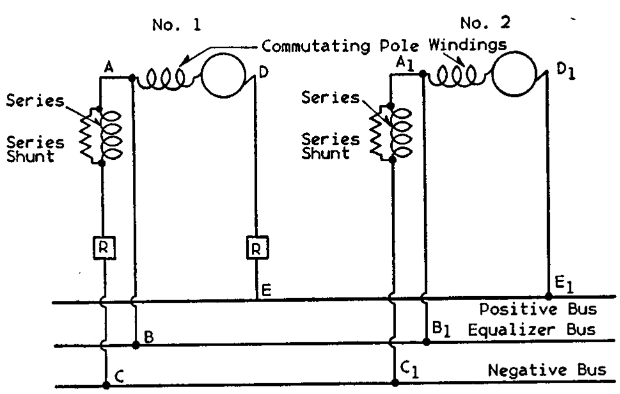


FIG. 8—DIAGRAM SHOWING CONNECTIONS OF GENERATORS FOR PARALLEL OPERATION

of the different machines should also be equal; i.e. the drop in the positive lead from any one generator at full load should equal the drop in each of the other positive leads when carrying full load, and, similarly, the drop in a negative lead should equal the drop in each of the other negative leads. The same conditions should be secured, for compound wound generators, in the series field windings and leads. It may be necessary in achieving the desired results to alter the length or size of connecting cables, and occasionally additional resistance is required.

The diagram in Figure 8 will indicate how this is to be done.

To meet the conditions for parallel operation the volts drop through the leads D_1 E_1 and DE must be equal, and the drop from A_1 to C_1 including series winding must be equal to that from A to C including series winding. R shows resistance added, if required. While the diagram is made for two machines, it, of course, applies to any number.

EQUALIZER

An equalizer, or equalizer connection, connects two or more compound generators operating in parallel at a point where the armature and series field leads join, thus placing the armatures in multiple and the series windings in multiple, in order that the load may be divided between the generators in proportion to their capacities. The arrangement of connections is shown in the diagram, (Figure 8.)

The object of the equalizer, as the name implies, is to divide the total load between the machines according to their capacity. Consider, for example, two compound-wound machines operating in parallel without an equalizer. If for some reason, there is a slight increase in speed of one machine, it would take more than its share of load; and the increased current flowing through the series field would strengthen the magnetism, raise the voltage, and cause the machine to take a still greater amount until it carried the entire load. When equalizers are used, the current flowing through each series coil is inversely proportional to the resistance and is independent of the load on any machine; consequently an increase of voltage on one machine builds up the voltage of the other at the same time, so that the first machine cannot take all the load, but will continue to share it in proper proportion with the other generators.

The equalizer lead must have as little resistance as is practicable, and for this reason it is the usual practice to make the equalizer leads the same size as the main leads. No additional resistance should ever be put in it, irrespective of the lengths.

SERIES SHUNTS

A series shunt consists of a low resistance connection across the terminals of the series field, by means of which the compounding effect of the series winding may be regulated by shunting more or less of the armature current past the series coils. It may be in the form of grids, on large machines, or of ribbon resistors. In the latter case it is usually insulated and folded so as to take up but a small amount of space.

BALANCE COIL CONNECTION FOR THREE-WIRE GENERATORS

A diagram of connections of a Balance Coil to a three-wire d.c. generator is shown in Figure 9.

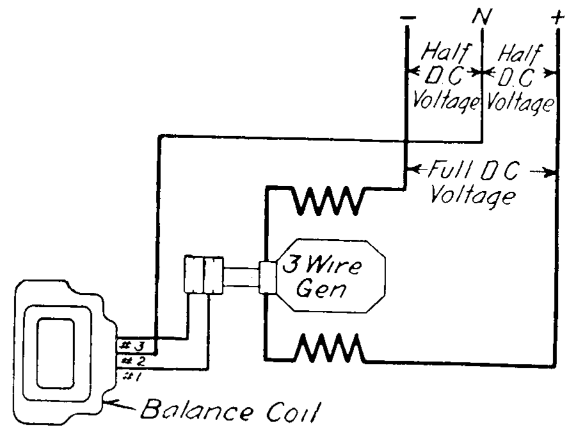


Fig. 9—Diagram Showing Connections of Balance Coil for Three-Wire D-C Generator, 125-250 Volts

Wires connecting the balance coil to the machine must be short and of low resistance. Any considerable resistance in this connection will affect the voltage regulation. The unbalance current flows along these connections, consequently, if they have much resistance, the resulting drop reduces the voltage on the heavily loaded side.

Switches are not ordinarily placed in the circuit connecting the collector rings to the balance coil. When necessary, the coil may be disconnected from the generator by raising the brushes from the collector rings. Switching arrangements sometimes make it necessary to run the balance coil connections to the switchboard and back, requiring heavy leads to keep the drop low; or if heavy leads are not used, then poor regulation may result. The balance coils are so constructed that there is very little likelihood of anything happening to them which will not be taken care of by the main circuit-breakers.

ADJUSTING AND TESTING

INSULATION RESISTANCE TEST

The insulation resistance of windings is measured, usually, with an instrument called a megger. This measurement gives an indication of the condition of the insulation particularly with regard to moisture and dirt. The actual value of resistance varies greatly in different machines depending on the size and voltage. The chief value of the measurement, therefore, is in the relative values of resistance taken on the same machine at various times. When measurements are made at regular intervals as part of the maintenance routine, it is thus possible to detect an abnormal condition of the insulation and take steps to remedy it before a failure occurs.

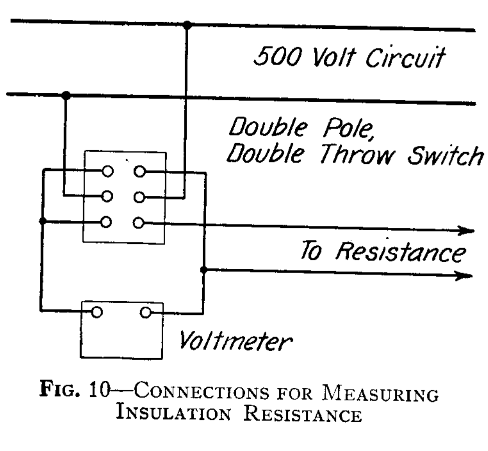


Fig. 10—Connections for Measuring Insulation Resistance

The higher the resistance, the better the general condition of the insulating material. The insulation resistance of the field will be much higher in proportion to its voltage above ground than that of the armature and will in general give little trouble. Since large armatures have much greater areas of insulation, their insulation resistance will be proportionately lower than that of smaller machines even though the material is in exactly the same condition. In general, d-c machines have lower values of insulation resistance than a-c machines of equivalent size. This is due to the existence of exposed creepage areas (commutator to ground) which are inherent in the design of d-c machines. The insulation resistance of the armature windings of machines in good condition is usually not less than 1 megohm.

The insulation resistance of any machine will be much lower when hot than when cool, especially when the machine is rapidly heated.

The only feasible way of increasing the insulation resistance when a machine is complete is be "drying out" the windings with heat. Baking in an oven is to be preferred but is often impracticably-the usual method being to circulate current through the windings. See section on "Drying Out Wind; ings," Page 15.

In case a "megger" is not available for making the insulation resistance measurements, a 500-volt direct-current circuit and a 500-volt direct-current voltmeter may be conveniently used. The method of making a measurement is to first read the voltage of the line, then to connect the resistance to be measured in series with the voltmeter and take a second reading.

The measured resistance can be readily calculated by using the following formula and the method of connecting the apparatus shown in the diagram Figure 10.

$$R = \frac{r\,(V-v)}{v\,(1{,}000{,}000)}$$

V = voltage of the line.

v = voltage reading with insulation in series with voltmeter.

r = resistance of voltmeter in ohms (generally marked on label inside the instrument cover.)

R = resistance of insulation in megohms.

Voltmeters having a resistance of one megohm are now made for this purpose so that, if one of these instruments is used, the calculation is somewhat simplified, since r = 1,000,000 and the above formula becomes

$$R = \frac{V-v}{v} = \frac{V}{v} - 1 \text{ megohms.}$$

If a grounded circuit is used in making this measurement care must be taken to connect the grounded side of the line to the frame of the machine to be measured, and the voltmeter between the windings and the other side of the circuit.

DRYING OUT WINDINGS

If the armature and field windings have absorbed moisture, as evidenced by low values of insulation resistance, it is well to dry them out by heat. The windings can be dried by the use of external heat as from space heaters. Baking in an oven is to be preferred but is often impractical. They are usually dried out by circulating current through the windings. The current should be increased so as to raise the temperature to about 70°C. and then adjusted to maintain that temperature until the coils become thoroughly dry. The temperature should not be allowed to drop to that of the surrounding atmosphere, as the moisture would then again be condensed on the coils, and the effect of the previous drying would be largely lost. The low value of insulation resistance may be due to surface moisture on the exposed creepage surfaces. In this case the armature can very easily be dried by blowing hot air on these surfaces at each end of the commutator.

In the case of a generator armature, this may be accomplished by short-circuiting the armature leads beyond the ammeter through a fuse with current capacity equal to that of the machine and adjusting the field current until sufficient current is circulated to raise the temperature to about 70°C.

There is always danger of overheating the windings of a machine when drying them with current, as the inner parts, which cannot quickly dissipate the heat generated in them may get dangerously hot, while the more exposed and more easily cooled portions are still at a comparatively moderate temperature. The temperature of the hottest part accessible should always be observed while the machine is being dried out in this way and should not be allowed to exceed 80 degrees Centigrade total temperature. Keep in mind that insulation is more easily injured by overheating when damp than when dry. It may require several hours or even days to thoroughly dry out the machine, especially if it is of large capacity. Large field coils dry very slowly.

DIELECTRIC TEST

A high-voltage test is sometimes useful in determining the strength of the insulation of the machine. It is made by subjecting the insulation to an e.m.f. greater than it will have to stand in actual service. As this test is in the nature of an overstrain, it must be applied with great caution. Such tests are always made in the factory and rarely need to be repeated. However, when they must be made, it is well to remember that the insulation is more easily broken down when hot than when cold and that the test should not be made immediately after the machine is started the first time but after it has run hot for some hours and had a chance to dry out. Tests of this character should not be made when the insulation resistance is low.

Large machines, when tested at high voltage, require a considerable output from the charging transformer, as a heavy current is taken by the machine. The transformer capacity required for testing varies with the square of the voltage of the test, with the frequency of the circuit, and with the static capacity of the apparatus under test. A 5-kva transformer has sufficient output for testing machines up to 500 kilowatts at a testing e.m.f. of 6000 volts.

When making a high-voltage test, the low-voltage circuit should always be closed or opened to throw the e.m.f. on or off.

The severity of the test depends to a marked degree upon the time the e.m.f. is applied. All dielectric tests are supposed to be applied for not more than one minute, as long continued test is liable to permanently injure the insulation even if no immediate fault is developed.

Machines which have been in service will have some dirt deposited on the creepage paths regardless of strenuous cleaning. These machines should never be subjected to the high voltage test that would be applied to a new machine. A clean machine that has been in service should not be subjected to more than ⅔ the voltage specified for a new machine. A.I.E.E. rules state that a new machine should be subjected to a voltage of 2 x rated volts plus 1000. Of course old machines not entirely clean must have even the ⅔ figure reduced.

BRUSH POSITION

For commutating-pole machines, accurate adjustment of the brush position is necessary in order to obtain satisfactory commutation and regulation. If the brushes are given a backward lead on a commutating-pole generator, the machine will over-compound and may not commutate properly; with a forward lead of the brushes, a generator will under-compound and will not commutate properly. For a commutating-pole motor, a backward lead of the brushes will increase the speed and a forward lead will decrease the speed, with less satisfactory commutation resulting for both positions.

When the brush position on a commutating-pole machine has once been properly located, no shifting is afterwards required or should be made. The correct brush position is located at the factory during test. This position is known as the "factory brush position". Provision is made wherever possible to locate the factory brush position directly from the frame as given under "Mechanical Re-determination of Factory Brush Position."

Two methods for locating the electrical neutral brush position are given, but should not be used unless absolutely necessary or when it is impossible to locate the "Factory Brush Position" by the mechanical method.

MECHANICAL RE-DETERMINATION OF FACTORY BRUSH POSITION

In the event that the brush position has been disturbed, the brushes should be re-located so that they are on the original factory setting. The following is the mechanical method for checking the factory brush position: (See Figure 11).

With a convenient constant radius, using the two center punch marks inside the circle marks on the front edge of the frame as centers, scribe two arcs to intersect on the front end of the commutator bars near the commutator surface. Draw through this intersection a radial line to the commutator surface. The point of intersection of this radial line with the commutator surface is the correct location for the center of the brush fit on the commutator. The center of the brush fit is found by scribing a bisecting line along the outside edge of the end brush to the riding face, or in the case of double-brushholders is midway between the two brushes at the commutator surface. This point is the factory brush position; it may or may not be the electrical neutral position, as machines are shipped with the brushes in a position to give the best operation both in regards to commutation and other operating characteristics.

SPACING OF BRUSHES

The position of one row of brushes having been located, the other brushes should be equally spaced around the commutator with reference to this first row of brushes. The brush spacing between all rows to brushes should be accurate to within $\frac{1}{32}$″. The best way to secure this spacing is to cut a narrow strip of tough paper exactly equal in length to the circumference of the commutator. This strip is then marked off into equal parts, corresponding to the number of brush-arms, after which it is stretched around the commutator and the brushes spaced accordingly. This method gives far more accurate results than those obtained by spacing the brushes an equal number of commutator bars, which is dependent upon the uniform spacing of the bars. The latter method, however, may be used as a rough check.

STAGGERING BRUSHES

The brushes are staggered at the factory to give an even wear to the commutator. The staggering is done in pairs of brush arms (not alternate arms); that is, one positive set of brushes with an adjacent negative set, is offset to the right or left of an initial pair of positive and negative brush arms ⅜ inch or more. The third pair of brush arms trail the first pair; the fourth, the second, and so on. See Figure 12. If the brushholder supports are removed from the rocker ring they should be re-assembled so that correct staggering is obtained.

LOCATING THE ELECTRICAL "KICK-NEUTRAL"

Where it is necessary for any reason to locate the electrical neutral position on commutating-

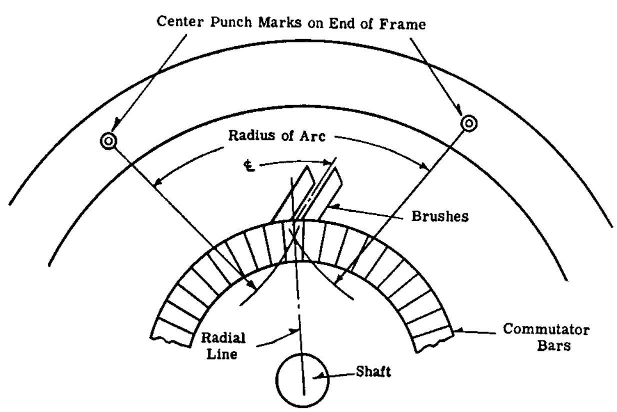


FIG. 11—METHOD FOR LOCATING FACTORY BRUSH POSITION

pole machines in the field, it may be correctly and simply located by the Electrical or "Kick" method, if due care is exercised.

This method is based on measurement of voltages induced in the armature coils as the current in the main field of the machine is interrupted. Voltages induced in the conductors located at equal distances to the right and left of the pole centers are equal in magnitude and opposite in direction. If the terminals of a low-range voltmeter be connected to commutator bars corresponding to conductors located midway between poles, no deflection will be caused by breaking the field current. When the brushes are set so that the center lines of their faces correspond with the center lines of the commutator bars between which there is no induced voltage, they are on neutral.

If the number of commutator bars is not evenly divisible by the number of poles, use the following method. With the machine at standstill, raise all brushes. Replace one of them on each arm by a special brush of the same thickness. This special brush should be beveled to a knife edge parallel with its longer side and in the center of its face. Connect leads from adjacent brush arms to a d-c voltmeter, preferably one having 0.5, 1.5, and 15-volt scales. Separately excite the shunt field from a d-c source through a quick-break switch. Insert enough external resistance in the excitation circuit to keep the field current small at the beginning. Use the smallest field current that gives a good deflection on the low scale of the voltmeter. When "kick" voltage is read for the first time, begin with the 15-volt scale and change to lower scales only when it is certain that the voltage is within their respective ranges. Before the switch is opened for each reading, wait long enough for the induced voltage caused by closing the circuit to decay. Shift the rocker ring to the point at which voltage is minimum when the field circuit is opened. If the machine has double brush holders, the center of the brush holder is placed on the neutral mark instead of either of the double-holder brushes.

If the number of bars between center lines of brushes on adjacent arms results in half a bar being included in the commutator pitch (such as 20½ bars between center lines), this alternative method is used. Raise all brushes. With voltmeter points on bars 1 and 21 in the approximate neutral zone, open the field circuit as described in the previous paragraph and read deflection. Move voltmeter points to bars 1 and 22 and read deflection as the field circuit is opened. Rotate the armature slightly until the two readings are equal but opposite in polarity. This indicates that the correct neutral is exactly on the center line of bar 1 and on the mica between bars 21 and 22. The rocker ring is shifted until the center lines of the arc of the brush surfaces are exactly over these positions. The same procedure applies here for double brush holders.

If the number of bars is evenly divisible by the number of poles, use the following method. Raise all brushes. Determine commutator pitch. For example, if the machine has 20 bars per pole pitch, the throw for a multiple-wound armature would be bar 1 to bar 21. With voltmeter points on bars 1 and 21 in the approximate neutral zone, open the field circuit as described in the previous paragraph and read deflection. Move voltmeter points to bars 2 and 22 and read deflection as the field is opened. Rotate the armature in either direction and repeat these operations until the two readings are equal but opposite. This indicates that the correct neutral is exactly on the mica between bars 1 and 2 or between bars 21 and 22. The rocker ring is shifted to these points as explained in the previous paragraph.

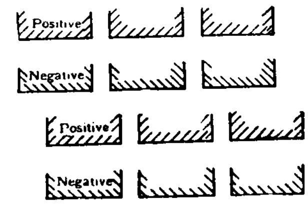


FIG 12—CORRECT METHOD OF STAGGERING BRUSHES

If the armature cannot be rotated, the neutral is located by the use of a curve or a calculation. If the number of bars is divisible by the number of poles, proceed as outlined in the previous paragraph. Read induced voltages between bars 1 and 21, 2 and 22, 3 and 23, etc., until a point is reached at which the polarity of the induced voltage reverses. Then record four readings, two on either side of the reversing point, plot induced voltages as ordinates and the numbers of commutator bars as abscissae. Keep in mind that the number indicates the center line of the end of the bar. After the exact point of reversal has been determined from the curve, mark the relative position on the commutator. This is the correct neutral. Shift the rocker ring as described in two paragraphs previous to this.

LOCATING THE ELECTRICAL "RUNNING NEUTRAL"

This method is based on the fact that if the brushes are in the correct no load neutral position no active electro-motive force will be generated by the commutating-pole flux when the machine is mechanically driven on open circuit with the commutating windings separately excited.

Beveled brushes should be inserted, one in each arm, and so beveled that the faces on these brushes will be wide enough to bridge one mica segment. The face of the brush must be ground in for good commutator contact and must not be wide enough to make contact with more than two commutator bars with any commutator position. Where double brushholders are used, only single beveled brushes should be inserted in corresponding boxes of the double holders, so that the contact of these brushes will be equally spaced around the commutator periphery. After the neutral point is located and the brushes are in the double brushholders, the rocker ring will have to be shifted until the mid-point of the arc length covered by the span of the two brushes on the commutator surface corresponds to the neutral point as located.

A reversing switch should be connected in the separately excited shunt field-circuit and some arrangement made for separately exciting the commutating-pole winding at from two to four percent of its normal current. The commutating-pole circuit should be disconnected from the armature and the armature left open-circuited. Use a low reading voltmeter such as was suggested for the "kick-neutral" across arms of opposite polarity. Bring the machine up to approximately normal speed and by exciting the main field, for an instant only, in a direction contrary to normal, demagnetize it entirely, that is, until no deflection shows on the lowest scale of the voltmeter Any deflection then obtained by exciting the c mmutating poles will be due to the commutating pole flux alone. First excite the commutating-pole windings with about two percent of their normal current and shift the brushes until no deflection is obtained on the lowest scale of the voltmeter. Check the residual magnetism of the main poles from time to time keeping it at as low a value as possible by demagnetization as explained above. After determining the best location for the brushes at this excitation, raise the commutating-pole current to about four percent of normal and check results. If no difference is found reverse the current in the commutating-pole and try again still checking the residual from time to time. In some cases higher currents may be used, but the leakage flux soon becomes large enough to destroy the symmetry of the normal field form and indefinite results will be obtained.

This method, if used carefully, gives very accurate results. It may be noted that the position of the brushes is at the peak of the commutating-pole field form and as this peak is rather sharp the effect of displacement will be very marked. Since the machine is running, errors due to brush resistance or to a brush resting on mica only, are entirely eliminated, making this method preferable to the "kick method."

ADJUSTMENT OF COMMUTATING-POLE FIELD STRENGTH

The commutating-pole adjustment to give the best commutating conditions is made at the works and, in general, no reason for changing it after the machine is installed should arise. However, if such reason does arise, the proper change in excitation may be determined as follows:

With a low reading voltmeter read the voltage between the brushholder bracket and the commutator at four equi-distant points across the face of the brush (along the circumference of the commutator) when the machine is running at normal load and voltage. These voltages can be most conveniently read by touching the voltmeter point lead to the commutator surface at the four points shown in Figure 13. Readings should be taken from positions 1 to 4 in the direction of rotation. Take curves for both positive and negative brushes for several brush arms.

These readings, if plotted as shown in Figure 13, indicate for example in curve "A" over compensation; i.e., excessive commutating field strength; curve "B" correct compensation; curve "C" under-compensation.

Changes in commutating-pole strength to secure correct compensation can be made by changing the air-gap or by shunting part of the current from the commutating-pole winding. Adjustment by changing the air-gap is the more usual method. In case of over compensation the air-gap should be increased and in case of under compensation the air-gap should be decreased. When adjustment is made by shunting, an inductive shunt, having approximately the same ratio of self-inductance to resistance as the commutating-pole winding is advisable. This insures proper division of current between the field winding and shunt when the load suddenly changes.

The measurement of brush curves and the adjustment of the commutating-pole strength should only be undertaken under the supervision of an experienced engineer.

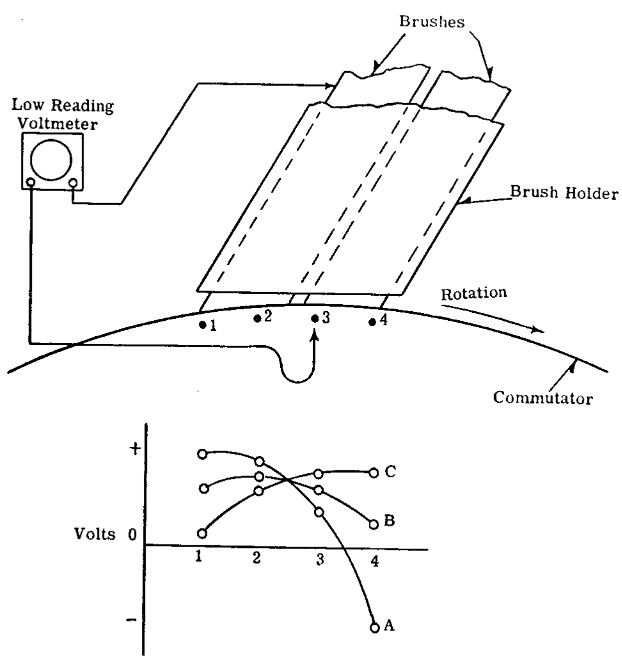


FIG. 13—METHOD FOR DETERMINING PROPER ADJUSTMENT OF COMMUTATING-POLE FIELD STRENGTH WITH DOUBLE BRUSHHOLDERS

OPERATION

CAUTION

Leave all switches open when the machine is not operating.

Do not work on the machine while it is running. Make sure that all switches are open and that the machine cannot be accidentally started by other operators.

Always follow a fixed regular order in closing and opening switches unless there are special reasons for departing from this order. A routine method will aid in avoiding mistakes. Close switches carefully, keeping a firm hold of the handles until completely closed.

When the shunt-field circuit of a generator or motor is excited, never open it quickly unless a path for the inductive discharge is provided. The circuit can be opened slowly, if desired, the arc at the opening serving to reduce the field current gradually. Do not permit any part of the body to bridge this opening, or a serious shock will be received; better use but one hand, keeping all other parts of the body clear of the circuit.

Keep small pieces of iron and bolts and tools away from the frame. Any such object attached to the pole of a field magnet may jam between the armature and pole and cause serious damage.

CLEANLINESS

Particular care should be exercised towards keeping all parts of the machines reasonbly clean. This applies particularly to turbo-generators and other high-speed machines. The high rotative speed draws air into the armatures and other parts with a velocity sufficient to carry with it particles of dirt or oil vapor that may be in the air. The rotating part must be cleaned out as necessary or the machines will ultimately short-circuit between commutator necks or break down to ground over insulation surfaces. Some types of stationary windings should be well cleaned for the same reason, and more than merely blowing out with compressed air as described on Page 26 may be required.

In machines partially enclosed by solid end-bells, the end-bells should be removed regularly as required so that access may be had to all parts.

STARTING-UP

Starting Generators—(1) See that the bearings are well supplied with oil and that the oil rings (if any) are free to turn. Inspect all connections for loose screws or wires.

(2) Start slowly. See that the oil rings are revolving properly. If force lubricated be sure oil is reaching the bearings.

(3) Turn in all resistance in the field rheostat, then bring the machine up to speed.

(4) Adjust the rheostat for the normal voltage of the generator.

(5) Throw on the load.

Starting Constant Speed Motors, Compound or Shunt—(1) See that bearings are well supplied with a good lubricating oil and that oil rings (if any) are free to turn. Inspect all connections for loose screws or wires.

(2) Make sure that the lever arm of the starting box or controller is in the "off" position.

(3) Close the main switch or circuit breaker.

(4) Close the field switch.

(5) Move lever arm of starting box or controller to the running position, pausing long enough on each notch to allow the motor to come up to the speed of that notch.

(6) If using a controller, throw the short-circuiting switch and move controller handle back to the starting position. If using a starting box, the lever arm should remain in the running position.

Starting Adjustable-Speed Motors—(1) Examine the shunt field rheostat and see that all resistance is cut out.

(2) Follow all directions given under "Constant Speed Motors."

(3) After motor is running on full-line voltage, gradually cut in resistance in the shunt field rheostat until the motor is up to the desired speed.

Starting Series Motors—(1) Follow same instruction as those given for "Starting Constant Speed Motors," except there is no field switch to close.

OPERATION

To Parallel Generators—To place a generator on the line in parallel with generators already operating (provided that proper connections for parallel operation have been made as directed under "Connections," Page 13):

(1) Bring the generator up to normal speed.

(2) With a voltmeter connected to its terminals, gradually bring up the voltage by cutting out resistance in the field rheostat until approximately the voltage of the other machines is reached.

(3) Throw in the equalizer switch.

(4) Adjust voltage if necessary.

(5) Throw in the main switches.

(6) Adjust the field rheostat until the generator takes its proportion of the load. The proper voltage to obtain before throwing a generator in parallel with others can be found by trial. It may vary slightly from line voltage depending on local conditions, regulations, etc.

Parallel Operation of Generators—The inherent regulation characteristics of the armature of a direct-current generator have much to do with its successful parallel operation with other machines. When two direct-current armatures are coupled in parallel and delivering load to the same external circuit it is necessary, in order to obtain stable conditions, for each armature to tend to "shirk" its load; that is, it must naturally tend to transfer load to the other machine. This tendency to shirk may be either in drooping speed regulation due to the prime-mover which drives the armature, or in the drooping voltage characteristics of the armature itself.

A drooping speed characteristic indirectly produces a drooping voltage characteristic in the armature and therefore both causes lead to the one characteristic, namely, drooping voltage, as the condition for stable parallel operation. This drooping voltage characteristic must be the inherent condition. In some applications, the voltage at the armature terminals may rise with increase in load, but its rise is due to some external condition such as increased field strength and not to conditions in the armature itself.

Direct current machines normally give drooping voltage characteristics in the armature windings. If two such armatures are paralleled they tend to divide the load in a satisfactory manner, provided their prime movers regulate similarly in speed.

If means are applied for giving a rising voltage characteristic to the machines, such as series coils in the field, then the armature circuits, including commutating-pole windings, must be paralleled directly in order to maintain stability. If, for instance, the armatures are not paralleled directly by equalizer connections but the paralleling is done outside the series coils, then the operation will be unstable unless the machines still have drooping voltage characteristics. If they have rising characteristics, then parallel operation is impracticable. If either machine should take an excess of load its voltage would rise while that of the other machine would fall due to decreased load. This condition would naturally force the first machine to take still more load and the second one to take still less until the first machine actually fed current back through the other machine and it would be necessary to cut them apart to avoid injury. However, by paralleling the two armatures inside the series coils, that is, between the series coils and the commutating field coils, this unstable condition is avoided. The armatures inherently have drooping voltage characteristics, and the series coils are paralleled at both terminals, forcing them to take currents inversely proportional to their resistances at all times, thus compounding both machines equally.

If direct-current machines are so designed or operated as to give rising instead of drooping armature characteristics, then parallel operation is liable to be unstable. This condition could be obtained in generators driven by prime movers which tend to speed up with increasing load, thus producing rising voltage on the armature. Ordinarily, such speeding up of the prime mover is rare and would have to be in rather large proportions as the normal drooping characteristics of the ordinary armature are fairly large.

A second condition which can give a rising voltage is not infrequently found in the commutating-pole type of direct-current machine. This condition arises when the brushes are shifted off neutral resulting in a compounding effect independent of any series field. The commutating-pole winding is connected directly in opposition to the winding on the armature. The maximum magnetizing effect of the armature winding is found at the points on the armature corresponding to the coils which are being commutated.

The commutating pole is intended to be placed directly over these points and the winding normally has such a value that it not only neutralizes the magnetizing effect of the armature winding at these points, but it also sets up a small magnetic field in the opposite direction which assists in the commutation of the armature coil.

When this commutating pole winding is placed directly over the commutating position of the armature winding, it will have practically no effect on the armature characteristics. If, however, the commutating-pole winding is not placed over these positions it will have an effect on the voltage characteristics of the machine tending to either raise or lower the voltage.

The commutating points on the armature depend directly upon the brush position. If the brushes are rocked backward or forward from the point corresponding to the mid-position between the poles, then the position of the commutated armature coils moves backward or forward with the brushes. Shift of the brushes in the direction of rotation tends to produce a drooping voltage characteristic with load while brush shift against rotation produces a rising voltage characteristic.

With a back lead, therefore, the commutating pole may have the same effect as a series winding on the main field; that is, it may compound the machine so that the voltage at the terminals is rising instead of falling, even without any series winding on the main poles. Herein lies a possible trouble in parallel operation for, as explained before, this an unstable condition for parallel operation.

It is evident, therefore, from the above considerations that for best results the brushes should be so set that the true point of commutation comes midway under the commutating poles. If this position is found exactly, then the commutating pole should have practically no effect on the voltage characteristics of the armature, and parallel operation with other generators should be practicable.

Adjustment of Load Division of Shunt Generators in Parallel

The drooping voltage regulation characteristics of shunt-wound generators operating in parallel insure against one generator taking all the load and operating inverted (motoring) other machines in parallel with it. However, the division of load between shunt generators in parallel may not be as well balanced over the entire load range as is desired, and, there are no convenient means of adjusting the natural regulations of the generators to obtain better over-all division of load.

The division of load of shunt-wound generators in parallel may be improved by external adjustments, as follows:

(a) The shunt field rheostats may be adjusted to give better overall average division or better division at any selected load.

(b) The field rheostats may be manipulated by hand to maintain correct division of load as the load changes.

(c) Resistance may be added to the connecting leads of the individual generators to equalize the voltages at the point of paralleling. The resistance should be added to the leads for the generators taking more than their share of the load. This method results in increased "drooping" of the voltage regulation of the paralleled machines, and so may be undesirable.

(d) A cumulative compounding effect may be secured on a generator by shifting the brushes against rotation and a differential effect by shifting with rotation. Any shift will be at the expense of commutation, but sometimes machine can stand some brush shift to secure better paralleling characteristics and still have passable commutation.

Adjustment of Load Division of Compound Generators in Parallel

The division of load between compound-wound generators can be adjusted at two load points; the division of load at intermediate points depending on the closeness of the regulation characteristics of the machines. Ordinarily, compound generators parallel satisfactorily when they are adjusted to have the same voltages at no-load and at full-load; that is, they have the same amounts of compounding. If the generators have different amounts of compounding, it will be necessary to adjust the compounding by changing the amounts of current shunted from the series fields. As far as parallel operation is concerned, it is much better to have all generators flat compounded or even with a voltage regulation that droops slightly with load.

In making adjustments, it is advisable to make the changes systematically. The several generators should be operated individually with the shunt field rheostats adjusted for the desired voltage at no-load; then, with rated load applied, the current through the series fields should be changed by adjusting the shunts across the series fields until the desired full-load voltage is obtained. It may be advisable to operate the several generators with different no-load voltages in order to obtain a better average agreement between their voltage regulation curves. It is not so important that the voltages at partial loads agree as it is at full load and overloads. At partial loads the load division may depart from the correct division without overloading the generator that takes the greater share of the load.

When the several regulation curves have been made to agree as nearly as possible, then the resistances of the several equalizer circuits should be checked and changed, when necessary, by changing the resistance of the leads to make the resistances inversely proportional to the generator ratings. For example, if a 500-kilowatt generator and a 1500-kilowatt generator are operated in parallel, the resistance of the series-field circuit (including a shunt if used), the main lead from the series field to main bus, and the equalizer leads should be in the case of the 1500 kilowatt generator one-third of the resistance of the corresponding circuit of the 500-kilowatt.

With compound-wound generators operating in parallel, one of which takes less than its proper share of the load, the division of load can be improved by the following adjustments.

(a) The shunt field rheostats may be adjusted to give better average division. If one generator compounds less than another and if it is desired to maintain the higher full-load voltage, the average load of the former generator can be increased by increasing the shunt field excitation.

(b) The shunts on the series-field winding can be adjusted, decreasing the resistance of the shunt on the overloaded generator, if possible, or increasing the resistance of the shunt on the under-loaded generator. It should be borne in mind, however, that changing the ampere-turns in the series field by changing the shunt resistance also changes the resistance of the complete field circuit. This change in resistance must be compensated for by a corresponding change in resistance in another part of the series-field circuit so that the resistance of the total circuit remains unchanged. From another standpoint, a shunt on one series-field may be considered a shunt on both series-fields, the effect varying only by reason of the resistance of the leads and busses being added to one shunt circuit and not to the other.

(c) If the relative ampere-turns are correct, but the series-field resistances are differently proportioned, the resistance of the leads between the series-field and equalizer bus can be changed to compensate for a difference in the series-field resistances. The resistance in the series circuit of the generator taking more than its share of the load should be increased. This adjustment varies the resistance of one series-field without introducing a third parallel circuit between the equalizer and main bus, and for this reason the adjustment is less complicated than in (b).

Excitation Failure of Generator

When starting up, a self excited generator may fail to excite itself. This may occur even when the generator operated perfectly during the preceding run. It will generally be found that this trouble is caused by a loose connection or break in the field circuit, by poor contact at the brushes due to a dirty commutator or to brushes sticking in their holders, or perhaps to a fault in the field rheostat. Examine all connections; try a temporarily increased pressure on the brushes; look for a broken or burnt-out resistance coil in the rheostat. An open circuit in the field winding may sometimes be traced with the aid of a magneto bell; but this is not an infallible test as some magnetos will not ring through a circuit of such high resistance as some field windings have even though it be intact. If no open circuit is found in the rheostat or in the field winding, the trouble is probably in the armature. But if it be found that nothing is wrong with the connections or the winding it may be necessary to excite the field from another generator or some other outside source.

The residual magnetism may be restored to the generator fields by exciting them from an outside source, with voltage not exceeding the rated generator voltage, as follows (See Figure 14).

(1) Open the line switch and raise all generator brushes from the commutator.

(2) Connect the negative lead from the exciting source to either the negative brushholders or the negative terminal of the machine. Connect the positive lead from the exciting source in series with a switch, 15 ampere fuse, and suitable ammeter to either the positive brushholder or the positive terminal of the machine. If excited from another generator, it may be more convenient to connect from a negative brushholder on the exciting generator to a negative brushholder on the machine being excited and similarly, from a positive brushholder through the switch, fuse, and ammeter to a positive brushholder.

(3) Turn the generator field rheostat to the "all in" position.

(4) Close the exciting switch momentarily while adjusting the generator field rheostat to obtain not more than normal field current. If the shunt winding is all right, its field will show considerable magnetism.

(5) If possible, reduce the exciting voltage before opening the exciting current. If this cannot be done, throw in all resistance of the field rheostat, then open the exciting switch very slowly, lengthening out the arc which will be formed until it breaks.

Where the generator operates in parallel with another generator, the field may be simply excited from the paralleling generator by raising the brushes, turning the field rheostat "all in", and momentarily closing the line switch. The voltage of the exciting generator should be reduced to a minimum before opening the line switch, if possible; otherwise, the arc which forms must be drawn out by opening the switch slowly.

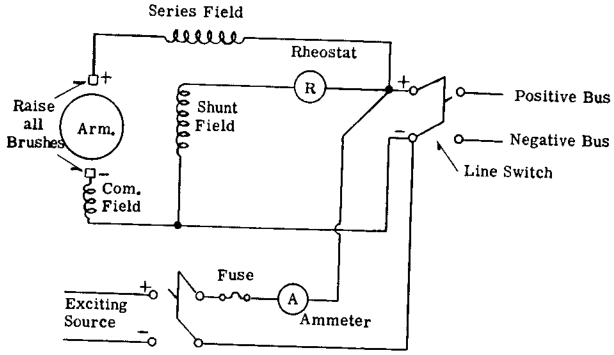


FIG. 14—CONNECTIONS FOR RESTORATION OF RESIDUAL MAGNETISM OF GENERATOR

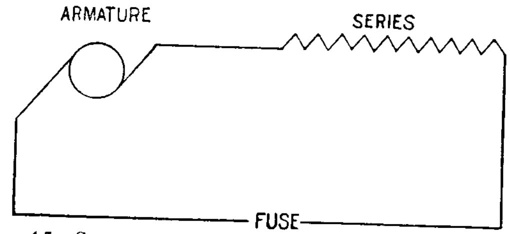


FIG. 15—SHOWING CONVENIENT METHOD OF MAKING A COMPOUND-WOUND GENERATOR PICK UP VOLTAGE

A very simple means for getting a compound wound machine to pick up is to short-circuit it through a fuse having approximately the current capacity of the generator. (See Figure 15.) If sufficient current to melt this fuse is not generated, it is evident that there is something wrong with the armature, either a short-circuit or an open circuit. If, however, the fuse has blown, make one more attempt to get the machine to excite itself. If it does not pick up, it is evident that something is wrong with the shunt winding or connections.

Causes of Insufficient Voltage of Generator

The following causes may prevent generators from developing their normal e.m.f.

(1) The speed of the generator may be below normal.

(2) The switchboard instruments may be incorrect and the voltage may be higher than that indicated or the current may be greater than is shown by the readings.

(3) The series field may be reversed, or part of the shunt field reversed or short-circuited.

(4) The brushes may be incorrectly set.

(5) A part of the field rheostat or other unnecessary resistance may be in the field circuit.

Reversing Polarity of Generator

To change the polarity, if a generator keeps the same direction of rotation:

(1) If the generator shunt field is self-excited, it is necessary to reverse the residual magnetism of the fields, which is done by exciting the shunt field momentarily in the opposite direction from some outside source.

(2) If the generator shunt field is separately excited, it is only necessary to interchange the shunt field leads.

Reversing Rotation of Generator

To change the rotation but not the polarity:

(1) If the generator shunt field is self-excited, it is necessary to reverse either the residual magnetism and the shunt and series fields leads or the armature and commutating field leads.

(2) If the generator shunt field is separately-excited, it is necessary to reverse either the shunt and series field leads or the armature and commutating field leads.

Small machines are often cable connected and the simplest method is to reverse the leads to the armature and commutating-pole windings. In all commutating-pole machines, it must be borne in mind that the direction of current in the armature and in the commutating pole windings must always bear the same relation to each other, and, if the armature current is reversed for any reason, the current in the commutating-pole coils must also be reversed.

Large generators are not often easily reversed since the armature, commutating, and series field windings are usually permanently connected by heavy copper straps inside the machine. The rotation of Westinghouse shunt generators, type QS or QH, can be most easily changed by reversing the shunt field leads, and, the residual magnetism, if self-excited. The rotation of Westinghouse compound generators, type QS or QH, can be changed by reversing the shunt field leads, the residual magnetism, if self-excited, and re-connecting the series field winding, but, this should not be attempted except under the supervision of the Westinghouse Engineering Department or by the Westinghouse Service Department. It is necessary that the series field coils be connected in such a way that the combined effect of the current in both the commutating and the series field connections does not produce ampere-turns around the shaft. Consideration of mimimum ampere-turns about the shaft is essential since, with the high value of current involved, a single turn may cause sufficient current to circulate through the shaft bearings to score the shaft journals. Therefore, in order to reverse the direction of the current in the series coils and still maintain minimum ampere-turns around the shaft, it is necessary to reconnect all the series field coils inside of the machine.

Failure of Motor to Start

When a motor fails to start, it will generally be found that this trouble is caused by a loose connection or break in the field circuit. However, first check the main switches and main fuses, if used. Then close the field switch and check the magnetism of the main poles. If the magnetism of the fields does not increase over the residual, examine all wiring connections and, if a field rheostat is used, look for a burnt-out resistance coil. An open circuit in the field winding may sometimes be traced with the aid of a magneto bell, but this is not an infallible test as some magnetos will not ring through a circuit of such high resistance as some field windings have even though it be intact. If an open is not found in the field circuit, the trouble is probably in the armature.

Causes of Insufficient Speed of Motor

The following causes may prevent motors from operating at their rated speed:

(1) The motor may be overloaded.

(2) The voltage may be low.

(3) The switchboard instruments may be incorrect and the voltage may be lower than that indicated or the current may be greater than is shown by the readings.

(4) If the motor field is separately excited or if a rheostat is included in the field circuit for adjustable speed operation, the shunt field current may be higher than normal.

(5) The brushes may be incorrectly set.

Reversing Rotation of Motor

To change the rotation of a motor, it is necessary to reverse either the shunt and series field leads or the armature and commutating field leads. The problem of reversing a motor is identical with that of reversing a separately excited generator as given under "Reversing Rotation of Generator".

Sparking at the Brushes

Some sparking under the brushes on modern high-speed commutating apparatus should not be construed as discreditable performance. The personal element involved in the interpretation of satisfactory commutation makes the subject a difficult one for reaching agreement in many cases. An effort to arrive at some common basis of reasonable commutation requirements has accordingly been made in the Standards of the American Standards Association. Successful commutation is defined as follows: "Successful commutation is attained if neither the brushes nor the commutator are burned or injured in an acceptance test; or in normal service to the extent that abnormal maintenance is required. The presence of some visible sparking is not necessarily evidence of unsuccessful commutation."

Sparking may either be due to mechanical or electrical causes.

The usual causes of sparking are:

(1) The machine may be overloaded.

(2) The commutator may be rough due to high or loose bars, flat spots, or rough edges of the undercutting.

(3) The commutator bar mica may be high.

(4) The commutator may be dirty, oily, or worn out.

(5) The brushes may not be set exactly on neutral.

(6) The brushes may not be equally spaced around the periphery of the commutator.

(7) Brushholders may be set too far away from the commutator.

(8) The brushes may be sticking in the brushholders or have reached the end of their travel.

(9) The brushes may not be fitted to the circumference of the commutator.

(10) The brushes may not bear on the commutator with sufficient pressure.

(11) Some brushes may have extra pressure and may be taking more than their share of the current.

(12) The carbon brushes may be of an unsuitable grade.

(13) The faces of the brushes may be burned.

(14) Vibration of the brushes.

(15) Incorrect brush angle.

(16) Non-uniformity of main or commutating pole air-gaps.

(17) Commutating-pole field air-gap may not be correct. The commutating-pole adjustment to give the best commutating conditions is made at the works and, in general, no reason for changing it after the machine is installed will arise. However, if such reason should arise, the proper change in excitation may be determined as directed under "Adjustment of Commutating-Pole Field Strength," on Page 18.

These are the more common causes, but sparking may be due to an open circuit or loose connection in the armature. This trouble is indicated by a bright spark which appears to pass completely around the commutator and may be recognized by the scarring of the commutator at the point of open circuit. If a lead from the armature winding to the commutator becomes loose or broken, it will draw a bright spark as the break passes the brush position. This trouble can be readily located, as the commutator on each side of the disconnected bar will be more or less pitted.

If sparking occurs that cannot be accounted for by overloads or other service conditions, wrong adjustments, or mechanical defects, an experienced engineer should be consulted to remedy the fault.

Sparking at Collector Ring Brushes

Sparking at the collector rings on three-wire generators may be due to any of the following causes:

(1) Rough surface of ring. (This condition usually follows prolonged sparking originating from some other cause.)

(2) Eccentric rings.

(3) Brushes tight in holders.

(4) Oil on collector rings.

(5) Vibration of brush rigging.

If sparking exists the rings should be stoned or turned to give a smooth surface and, if possible, the source of the trouble removed. The brushes should have a good fit on the rings and should slide freely in the holders.

"Bucking" or "Flashing"

"Bucking" or "Flashing" is the very expressive term descriptive of what happens when arcing occurs between adjacent brushholder arms. In general, **"bucking"** is caused by excessive voltage, or by abnormally low surface resistance on the commutator between brushholders of opposite polarity. Any condition tending to produce poor commutation increases the danger of bucking. Among other causes are the following:

(1) Rough or dirty commutator.

(2) A drop of water on the commutator, from the roof, leaky steam pipes or other source.

(3) Short-circuits on the line producing excessive overloads.

If "flashing" continues after the first two possible causes have been eliminated, the trouble will usually be due to causes external to the machine which must be corrected before the "flashing" trouble will be eliminated.

Heating of Field Coils

Heating of field coils may develop from any of the following causes:

(1) Too low speed.

(2) Too high voltage.

(3) Too great forward or backward lead of brushes.

(4) Partial short-circuit of one coil.

(5) Overload.

(6) Restricted ventilation.

Heating of Armature

Heating of the armature may develop from any of the following causes:

(1) Too great a load.

(2) A partial short-circuit of two coils heating the two particular coils affected.

(3) Short-circuits or grounds on armature or commutator.

(4) Restricted ventilation.

Heating of Commutator

Heating of the commutator may develop from any of the following causes:

(1) Overload or continued operation at very low loads.

(2) Sparking at the brushes.

(3) Incorrect brush pressure.

(4) Improper grade of brushes.

(5) Restricted ventilation.

Sleeve Bearings

Most Westinghouse machines have self-oiling bearings. The oil-well should be filled to such a height that the rings will carry sufficient oil upon the shaft. If the bearings are too full, oil will be thrown out along the shaft. Bearing housings are usually supplied with outlet holes for overflow of the oil. The oil should be kept slightly below the level of these holes.

When a machine is started, particular attention should be given to the bearings to see that they are well supplied with lubricant. The oil rings should revolve freely and carry oil to the top of the journals. A new machine should always be run at slow speed for an hour or so in order to see that the bearings operate satisfactory.

Bearings may be operated safely at a temperature of 80° Centigrade (176° Fahrenheit) and, for a limited time, they may operate as high as 100° Centigrade (212° Fahrenheit). It should be remembered that a bearing may be below this temperature and may be safe even though it is hot enough to burn the hand when held against the outside. A rapid rise in the temperature of a bearing is usually an indication of trouble and requires prompt attention.

Turbine Bearings

For turbine units, a closed oiling system through which a continuous circulation is maintained by means of a pump geared to the main shaft of the turbine, keeps the turbine and generator bearings flooded with oil at a very moderate pressure. From the bearings, the oil drains through a strainer into a collecting reservoir, whence it is pumped through a cooler, and back to the bearings.

Anti-Friction Bearings

Ball and roller bearings are oil or grease lubricated, depending on the service conditions of the machine.

A nameplate attached to the frame of the machine below the rating nameplate gives information about the lubricant to be used.

When grease is used the bearings are packed with grease when assembled in the factory. Only Westinghouse roller and ball bearing grease is used for lubrication.

For oil lubricated bearings #600 W grade of oil or equivalent is to be used.

This is a heavy cylinder oil of a viscosity of 150-180 seconds SUV at 210°F. The oil level in the bearing to be not higher than the center of the lowest rolling element. The top of the oil cup is located at this height.

Heating of Bearings

A warm bearing or a "hot box" is probably due to one of the following causes:

(1) Insufficient oil in the reservoir, or failure of oiling system if force lubricated.

(2) Use of dirty oil or oil of poor quality.

(3) Excessive belt tension.

(4) Failure of the oil rings (if any) to revolve with the shaft.

(5) Rough bearing surface.

(6) Improper fitting of the journal boxes.

(7) Bent shaft.

(8) Excessive pressure caused by poor alignment of the machine.

(9) End thrust, due to improper leveling. A bearing may become warm because of excessive pressure exerted by the shoulder of the shaft against the side of the bearing.

(10) End thrust, due to the magnetic pull, rotating part being "sucked" into the field because it extends beyond the field poles further at one end than at the other.

(11) Excessive side pull, because the rotating part is out of center.

If a bearing becomes hot, first feed fresh oil copiously through the openings over the oil rings and loosen the nuts on the bearing cap; and then, if the machine is belt-connected, slacken the belt. If relief is not afforded, shut down, keeping the machine running slowly until the shaft is cool, in order that the bearing may not "freeze." Renew the oil supply before starting again. The bearings should be carefully watched to see that the oil rings are revolving and carry a plentiful supply of oil to the shaft.

Belts

The belt on a belt-connected machine should be tight enough to run slowly without slipping, but the tension should not be too great or the bearings will heat.

Whenever practicable, belts should be installed so that the slack side is above and the driving side below the pulleys. If this condition is reversed and the slack side is below, the arc of contact is materially lessened. Belts should be placed on the pulleys with the hair or "grain" side next to the pulleys. The lap-joint of the belt should be inclined relative to the direction of the belt's motion so that the leading edge or point of the lap is on the pulley side to prevent the end from opening; when the leading end is on the outside, it tends to open up, especially if the belt is operated at high speed, owing to the resistance of the air. When the leading end is next to the pulley, any tendency for the point to raise is overcome by frequent contact with the pulleys. The lap-joint should be dressed smooth so that there will be no jarring as it passes over the pulleys.

The crowns of driving and driven pulleys should be alike, as "wobbling" of belts is sometimes caused by pulleys having unlike crowns. If this is caused by bad joints, they should be broken and cemented over again. A wave motion or flapping is usually caused by slippage between the belt and pulley, resulting from grease spots, etc. It may, however, be a warning of an excessive overload. The fault may sometimes be corrected by increasing the tension, but a better remedy is to clean the belt. A back and forth movement on the pulley is caused by unequal stretching of the edges of the belt. If this does not cure itself shortly, examine the joints. If they are evenly made and remain so, the belt is bad and should be discarded.

Static Sparks from Belt

It sometimes occurs on belted machines, especially in dry weather, that charges of static electricity accumulate on the belt which may be of sufficiently high potential to cause discharges to ground. If the frame is not grounded, these charges may jump to the armature or field winding and then to ground, puncturing the insulation.

The belt and frame may be discharged by placing a number of sharp metal points, which are carefully grounded, close to a belt at a point near the machine pulley. If the field frame is grounded, there should be no danger to the insulation.

Opening of Feeder Circuits

If a line fuse blows or a circuit-breaker opens, first open the switch corresponding to that line, and then replace the fuse and close the breaker. The switch may now be closed again. If the circuit opens the second time, there is something wrong on the line—probably a short-circuit—and this should be corrected at once.

If for any reason, such as a short-circuit or a heavy overload on the line, the circuit-breakers or switches hold an arc when opened, such an arc should be extinguished if possible, by using dry sand, a supply of which should always be kept conveniently at hand. In case the arc cannot be extinguished in this manner, as a last resort, open the field circuit of the machine or shut the generator down entirely. When the arc forms on the machine or on the generator side of the breaker, a shut-down is generally imperative, but should not be made if it can possibly be avoided.

SHUTTING DOWN

To Shut Down Generator

(1) Reduce the load as much as possible by throwing in resistance with the field rheostat.

(2) Throw off the load when it is a minimum or zero, by opening the circuit-breaker, if one is used, otherwise open the feeder switches and finally the main generator switches.

(3) Shut down the driving machine.

(4) Wipe off all oil and dirt, clean the machine and put it in good order for the next run.

To Shut-Down Constant-Speed Motors

(1) Open the main switch or circuit-breaker.

(2) After the motor has come to rest, see that the lever arm of the starting box has returned to its original position.

(3) Open the field switches.

(4) Clean the machine thoroughly and put in order for next run.

To Shut Down Adjustable-Speed Motors

(1) Gradually cut out the resistance in the shunt field rheostat until the machine is running on a full field.

(2) Follow directions given under "To Shut Down Constant Speed Motors."

To Shut Down Series Motors

(1) Open main switch or circuit-breaker.

(2) Examine machine carefully, wipe off all dirt or oil, and put in good condition for next run.

MAINTENANCE

GENERAL RULES

(1) At all times keep motors and generators clean and free from oil and dust, especially from copper or carbon dust.

Keep the commutators clean. Oil will penetrate mica and if oil is allowed to get into the mica of a commutator, from an oily vapor atmosphere or from oil leakage from the bearings, the mica will be damaged and burnouts may occur in the armature.

The insulation should be kept free from dirt and oil. An occasional cleaning of the coil ends with an air hose is recommended, and this should be followed by a thorough wiping with a cloth. The dirt which clings to the field coil washers should be removed carefully since it may accumulate and form a conducting path from coil to ground.

An air hose should be applied to the air ducts between the spokes of the armature spider since an accumulation of dirt at these places will impede the free flow of cooling air.

(2) A coat of insulating varnish applied to the armature and field coils after they have been cleaned will protect the insulation.

(3) Occasionally give the machine a thorough inspection. The higher the voltage of the machine, the oftener this should be done.

CAUTIONS

In soldering connections, do not use an acid that will act on the insulation or the copper; an alcoholic solution of resin is a suitable soldering flux.

In soldering commutator connections do not allow bits of solder to drop down where they may short-circuit commutator bars.

Never use emery cloth or emery paper on commutator, collector, or brushes.

CLEANING METHODS

With high-voltage machines a small accumulation of dust on the windings may be the cause of serious burnout. It is advisable to install an air pump for supplying compressed air with a piping system so distributed that a short section of hose will enable the attendant to reach all parts of the winding on any machine to blow out the dust. The pressure used in such service should not exceed 25 pounds per square inch, as a high pressure may lift the insulation wrappings and blow dust within the coils. Always allow any accumulation of water in the pipes to be blown out before turning the air blast on the machine.

In blowing dust out of machines, the adjacent machines should be protected from flying dust by a suitable cover or shield.

A preferable method of cleaning machines is by a vacuum cleaning system whereby all the dirt is carried away from the machines and the danger of blowing dirt into adjacent machines is completely avoided.

Where insulated parts, subject to copper or carbon dust, are accessible they should be wiped clean with a dry cloth, in addition to cleaning as described above.

It will facilitate the cleaning of insulated parts if they are painted with insulating varnish at regular intervals. At the time selected for painting, the machine should be given a suitable high-voltage insulation test to locate possible weaknesses at a time when they can be conveniently repaired.

LUBRICATION OF SLEEVE BEARINGS

The bearings should be examined frequently to see that the proper oil level is maintained and that the oil rings are revolving and carry a plentiful supply of oil to the shaft. It is important that the oil be kept clean and free from grit.

The frequency with which the bearings must be refilled depends so much on local conditions, such as the severity and continuity of the service, the room temperature, the state of cleanliness, etc., that no definite instructions can be given. Until local conditions show another interval to be more suitable, the oil in the bearings should be renewed every six months.

Only the best grade of oil—having a viscosity of from 185 to 200 seconds, Saybolt—should be used.

It always proves to be false economy to use poor oil. If the oil is to be used a second time, it should be filtered and, if warm, allowed to cool before the bearings are refilled. Even new oil should be examined carefully and filtered or rejected if it is found to contain grit.

LUBRICATION OF ANTI-FRICTION BEARINGS

Grease Lubricated Bearings

Partial change of grease has to be made at intervals after 3 to 6 months of operation. The relief plug has to be removed first. The amount of grease to be added is shown in the following table:

Shaft Extension Dia.	Volume of Grease to be Added (Approx.)
¾ to 1¼	1 cu. in.
Above 1¼ to 1⅞	1¼ cu. in.
Above 1⅞ to 2⅜	2½ cu. in.
Above 2⅜ to 3	4 cu. in.
Above 3 to 4	7 cu. in.
Above 4 to 5	10 cu. in.

The relief plug is to be replaced after approx. ½ hour of operation. Too much grease will cause overheating and grease leakage. In general the increase in temperature will be temporary because the excess grease will be worked out through the relief hole or through seals. If overheating persists for more than four or five hours, some grease should be removed from the bearing.

At intervals of approximately two years, depending upon application, the bearing should be cleaned thoroughly and repacked with grease. The space within the bearing as well as in the end housings, should be filled from ⅓ to ½ full on sizes up to 3″ shaft diameter and from ½ to ¾ full in the larger sizes.

Dirt is the biggest foe of anti-friction bearings, and one of the most common ways for it to get into the bearings is with the grease at the time the bearing is relubricated. It is imperative to keep grease free of foreign matter, both in handling and in storage. Cover the bearings and interior of the housing with clean wrapping material if they are to be left dismantled or exposed. Never open the bearing housing under conditions which would permit entrance of dirt into bearing.

Oil Lubricated Bearings

Bearings are to be flushed and refilled every year. When checking the oil level, the machine has to be warmed up and the filling pipe with the oil cup is to be in level position. Check to see that the filling pipe is not bent.

Excessive amount of oil would increase the fluid friction and thus raise the bearing temperature and would tend to originate oil leakage through the seals.

CARE OF BRUSHES

Modern brushes have characteristics such that they do not require any oiling of the commutator for lubrication. Oil affects mica adversely and should not be allowed to come in contact with the mica of a commutator, as burnouts may result.

Machines which are subject to frequent reversals such as mill motors and street railway motors usually have the brushes set radially or with only a slight angle to the commutator surface. For non-reversing machines, the brushes are always set at an angle, usually against rotation. The proper angle varies depending on brush fruction but usually lies between 15° and 35°.

Besides maintaining the brushes in the proper position as described on Page 14 under "Adjusting and Testing," the following points should be observed:

Make frequent inspection to see that:

(1) Brushes are not sticking in the holders.

(2) Pig tail shunts are properly attached to brushes and holders.

(3) Tension is maintained as the brushes wear.

(4) Copper plating (when used) is cut back so it does not make contact with the commutator.

(5) Worn-out brushes are replaced before they reach their limit of travel and break contact with the commutator, or cut it due to contact with the metal clip.

(6) Remove any free copper picked up by the face of the brush. A much fuller treatise on brush selection and application is given in Instruction Book 5187 on "Selection, Application and Care of Brushes for Commutators and Slip Rings for Power Station Apparatus."

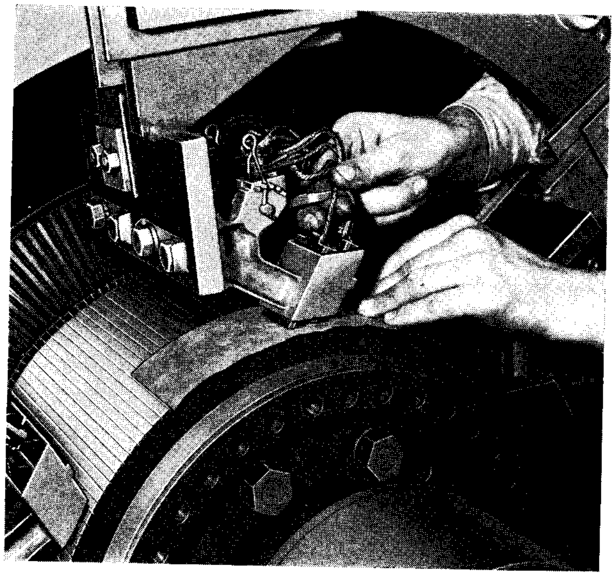


Fig. 16—Method of Seating Brushes

SEATING BRUSHES

The ends of all brushes should be fitted to the commutator so that they make good contact over their entire bearing face. This can be easily accomplished after the brushholders have been adjusted and the brushes inserted. Fit the brushes in each brushholder separately by drawing a sheet of sandpaper under the brushes in the direction of rotation while pressing them firmly against the commutator as shown in Figure 16. Be careful to keep the ends of the sandpaper as close to the commutator surface as possible to avoid rounding the edges of the brushes. The sandpaper should cut the brushes only in the direction of normal rotation—lift the brushes as the sandpaper is drawn back. **Never use emery cloth or emery paper to seat brushes** on account of the continued abrasive action of the emery which becomes bedded in the brushes.

If the brushes are copper plated, their edges should be slightly sanded so that the copper does not come in contact with the commutator.

CARE OF COMMUTATORS

Commutator roughness is usually characterized by an abrupt change from one bar to the next as distinguished from an eccentric commutator in which there is a very gradual change in the surface where the commutator might be said to be egg-shaped. Variations from one bar to the next of as much as one ten-thousandth of an inch are sufficient to cause a commutator to perform badly, break brushes or cause excessive brush wear on high speed commutators.

Roughness of a commutator surface can be detected by placing a pencil on a brush while the machine is rotating. Care should be taken to stand on a board or insulating platform of some kind, not to touch any metal part of the machine, and to use a wooden pencil if the machine has voltage on it. The surface of a commutator should be concentric within one thousandth of an inch on commutators whose peripheral speeds are around 5500 feet per minute. For peripheral speeds in the neighborhood of 9000 ft. per minute, commutators should be concentric to less than one thousandth, which is about the practical limit for grinding.

Slow speed, large diameter commutators will operate successfully with greater eccentricity than mentioned above because the angular velocity is low and the brushes can follow the surface, but it is poor practice to operate even very slow speed commutators with an eccentricity greater than three thousandths as this may be enough to cause side wear of the brushes. The concentricity of a commutator can be checked with a dial gauge mounted on a brush.

Resurfacing of a commutator should always be done with a grinding rig, whether it is to be ground concentric or in order to remove high bars or flat spots. A hand stone should never be used on a commutator to obtain a true surface, because it simply follows the irregularities in the surface and in some cases may even exaggerate them. The grinding rig consists of an abrasive stone set up similar to a lathe tool in a rigging or carriage which may be moved back and forth in an axial direction and equipped with a radial feed. It should be supported very rigidly so that the stone is subjected to a very minimum of vibration. In large D-C equipment, such a rigging can be mounted on a brush arm by removing the brushholders on that arm. In some cases, it may even be desirable to brace the brushholder bracket arm, while grinding, to obtain maximum rigidity. It is also possible by removing the brush rigging to support the grinder on parallels supported from the bedplate.

Grinding should be done when the machine is running in its own bearings and at rated speed in the case of a constant speed machine. If grinding is done at low speed, any slight unbalance will cause the commutator to run eccentric at rated speed.

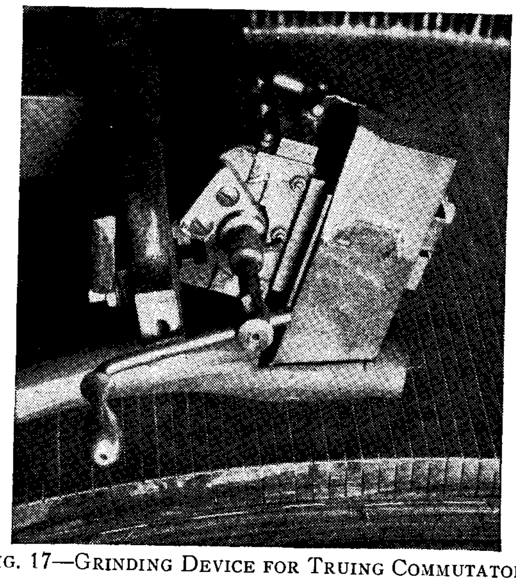


Fig. 17—Grinding Device for Truing Commutator

Great care must be exercised to prevent copper and stone dust from entering the windings. The grinding rig should be equipped with a vacuum cleaner arrangement, fitted over the stone to catch all dust. If a suction system is not available, the necks of the commutator and the front end windings should be protected by pasting heavy paper over them or by covering with a cloth hood properly applied. See Fig. 17.

In order to rotate the machine, it may be belted to an auxiliary driving motor or in the case of an M-G Set, it can be run from the machine on opposite end of shaft.

The stones used in grinding commutators might be classed as rough, medium and fine. The rough stone has a grit of about 80 mesh and is used only where a very large amount of copper is to be removed. It should be used very seldom because if sufficient copper is to be removed to warrant its use, it would be better to take a cut off the surface in a lathe. The medium stone has a grit of about 120 mesh and is used for the bulk of the grinding work, the fine stone being used only to obtain a fine finish. The fine stone should have a grit of about 200 mesh.

After grinding, all commutator slots should be cleaned out thoroughly and the edges of the bars beveled. This beveling accomplishes two things; it removes the burrs caused by the stone dragging copper over the slots, and eliminates the sharp edge at the entering side of the bar under a brush. The bevel on the bars is done with a special beveling tool and should be about 1/32 chamfer at 45°, for medium thickness of bars. For thinner or wider bars, the beveling can be changed accordingly.

Practically all up to date machines have undercut mica. This undercutting should be kept 1/16″ deep ±1/64″. If it is apparent that enough copper is going to be removed by grinding so that the undercutting will be shallow, the commutator should be reundercut before grinding. This is done by means of a small circular high speed saw about .003″ thicker than the nominal thickness of the mica. In undercutting, great care must be taken to see that a thin sliver of mica is not left against one side of the slot. Sometimes this sliver must be removed by scraping by hand. See Fig. 18.

After grinding, undercutting the mica, and beveling the edges of the bars, the commutator surface should be polished, while operating at rated speed. Aloxite or sandpaper should first be used (never emery cloth or paper) as this will remove the burrs due to beveling. After a very fine grade of sandpaper is used, a high polish can be used by burning the commutator with dense felt or canvas.

Some years ago it was practically taken for granted that a certain amount of commutator seasoning would take place in the field during the first year of operation and that commutators should be tightened periodically as the mica baked out. Factory methods and equipment have been greatly improved, so that almost all commutators are now shipped thoroughly seasoned and it is no longer necessary to tighten them in the field. Tightening, therefore, should be done only upon advice from the manufacturer's Service Department.

CARE OF COLLECTOR RINGS

The collector rings on three-wire generators require occasional attention and should be occasionally lubricated with **slightly** oiled canvas. If only slightly roughened, the rings can be trued up with the sandstone and sandpaper, otherwise they must be turned or ground.

On machines with steel collector rings, the rings should be wiped with very light oil whenever the generator is shut down for a protracted period. Before starting again the rings should be wiped with a dry cloth to remove all oil, dirt and dust.

REBABBITTING BEARINGS

The old babbitt should first be melted out and a suitable mandrel pepared. Split bearings should be babbitted one half at a time and the mandrel should consist of a half cylinder with shoulders running along its length on which the bearing-split faces may rest so as to form a close fit when the bearing shell is in position for babbitting. Pieces of felt, wood or similar material should be used to prevent babbitt from running into those portions of the shell where it is not desired.

The babbitt should be heated in an iron or steel pot to the proper temperature recommended by the supplier:

430—460°C (806—860°F) For Westinghouse #14 alloy.

480—500°C (896—932°F) For Westinghouse #25 alloy

520—530°C (968—986°F) For Westinghouse #8479-1 or #8479-2 alloy.

Failure to maintain the proper temperature may result in marked loss of some of the babbitt ingredients. Immediately before pouring, mix the metal thoroughly by stirring.

The bearing shell should be cleaned of all grease, oil and dirt by immersing in a suitable cleaning compound. Both the bearing shell and the mandrel

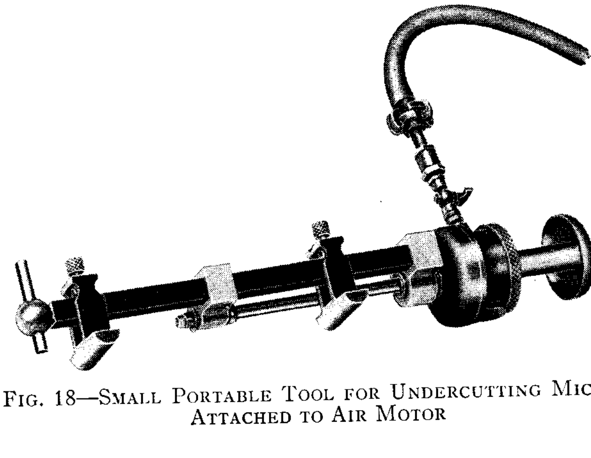


Fig. 18—Small Portable Tool for Undercutting Mica, Attached to Air Motor

should be heated to approximately the same temperature as the babbitt alloy. Immediately before pouring, the surface of the bearing shell should be swabbed with soldering flux such as acid zinc chloride.

Pour the babbitt as soon as possible after the shell and mandrel have been assembled. Pouring should be continuous so that no portion of the babbitt solidifies before the entire bearing has been poured. To obtain the best bond and babbitt structure, the bearing should be cooled so that the babbitt solidifies from the shell or shoe toward the bearing surface, and from the bottom up in the case of vertically cast bearings. Apply water or air spray to the outside of the shell.

After cooling, the bearing halves should be bolted together and bored or reamed to the proper size. The eccentric bores on each side of the bearing should then be added, together with the oil pockets at the bearing split and the oil drain grooves and drain holes at the ends of the bearings. Finally the oil ring slots should be cut or chipped out to the proper depth, the holes for observing the working of the oil rings drilled, and the oil inlet hole drilled through. Finishing can be done with a file and all sharp edges and burrs should be removed.

REPAIRS TO INSULATION

If a defect develops in the outside of a field or armature coil, it can sometimes be repaired by carefully raising the injured wire or wires and applying fresh insulation. More extensive repairs should not be attempted by inexperienced or unskilled workmen.

TEMPORARY ARMATURE REPAIRS

A simple method of making temporary repairs in an armature in case of a short-circuit or open circuit of one of the coils is to cut out that coil by cutting the leads which connect the coil with the commutator bar and then short-circuiting the bar, thus cut out, with the following bar. This may readily be done by simply soldering the two necks together. By this means an armature may be kept in commission until there comes a convenient time to replace the damaged coils.

REPAIRING COMMUTATING FIELD COILS

If it is necessary to remove one of the commutating field coils, disconnect the coil from those on each side, remove the bolts which hold the pole to the frame, and remove the pole and coil. The commutating coil may be removed from its pole and repaired or replaced by a new coil and the complete field reassembled in the frame.

REPAIRING MAIN FIELD COILS

If it is necessary to remove a shunt or series field coil, disconnect both coils from those on each side, remove the bolts which hold the pole to the frame, and remove the pole and coils. The shunt winding is wound directly on its pole with the series winding placed over the shunt coil so that if a new coil is to be installed, it will be necessary to replace the complete pole and coil assembly.

Care should be taken in reconnecting the coils so as to obtain the proper polarity of the coils. A very simple means of testing the polarity of shunt field coils is by means of a needle or a piece of steel wire suspended from the middle by a string. The polarity should be alternately north and south around the frame. Bring the polarity needle within the magnetic field of any pole. One end of the needle will point towards this pole and this end should be repelled by the next pole and so on around the frame. If this reversal of the needle does not occur there must be a wrong connection of the field coil.

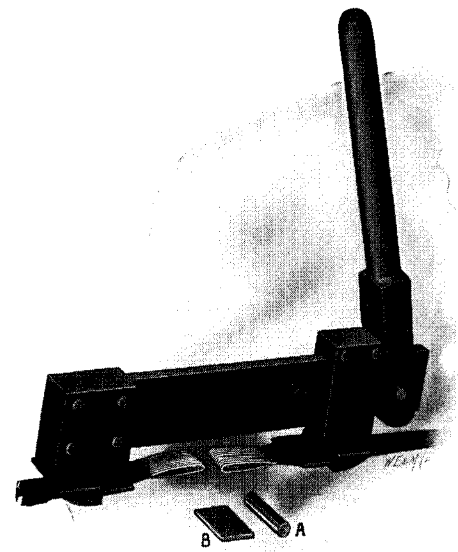


Fig. 19—Tool for Assembling Sectional Band, Open Position

SECTIONAL BANDS

In repairing direct-current armature windings, particularly large ones, the replacing of band wires becomes a serious problem. To overcome this difficulty, the Westinghouse Company has designed a form of sectional band which retains all the elements of a continuous wire band. yet can be applied or removed quickly and repeatedly without deterioration. These bands are regularly supplied on armatures having a diameter greater than 120 inches.

Figures 19 and 20, show the tool employed to mount these bands in position. One of these tools is furnished with each machine equipped with sectional bands.

To make the final connection between the free ends, after the different sections have been keyed together into an open hoop and are in position on the armature, place the tool as shown in Figure 19,

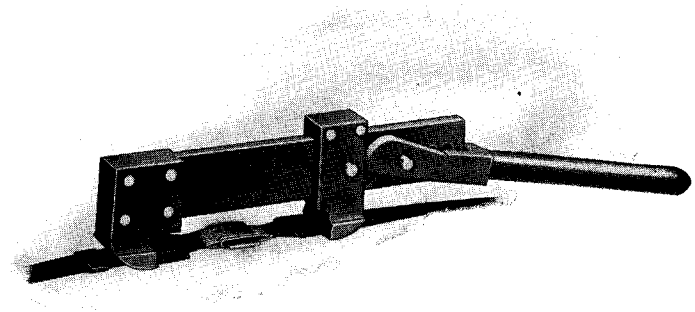


FIG. 20—TOOL FOR ASSEMBLING SECTIONAL BAND, CLOSED POSITION

the two jaws gripping the projecting ends of the fixed pieces inserted into the ends of each section for the purpose. Then bring down the handle to the position of Figure 20, forcing the movable jaws forward along the beam and interweaving the loops on the section ends. Insert the steel pin A in the holes through the movable jaw and the matching hole in the beam, and with the tool clamped in this way remove the handle and advance it to the next hole in the beam. This operation is repeated until the ends of the band are interlocked sufficiently to permit the steel key piece B to be inserted (See Figure 20). All that remains is to remove the tool and paint or shellac the joint.

To remove the band, reverse the preceding process. Relieve the tension on the joint by tightening the band with the tool and then drive out the key piece.

RENEWAL PARTS

Repairing

Repair work can be done most satisfactorily at our nearest Service Shop. However, interchangeable renewal parts can be furnished to customers who are equipped for doing repair work.

Recommended Stock of Renewal Parts

On Page 32 is a list of the renewal parts and the minimum quantities of each that should be carried in stock. These are the parts most subject to wear in ordinary operation and to damage or breaking due to possible abnormal conditions. The maintenance of such stock will minimize service interruptions due to breakdowns. A recommended List of Renewal Parts for your particular equipment will be supplied upon request to the nearest District Office.

Ordering of Repair Parts

Repair parts for any standard Westinghouse generator or motor may be secured on short notice. To avoid misunderstanding, always give the complete nameplate reading and the serial number of the armature, if involved. The former will be found prominently located on the field frame and the latter on the end of the shaft. When material for coils is ordered, also state whether or not insulation for the winding is desired.

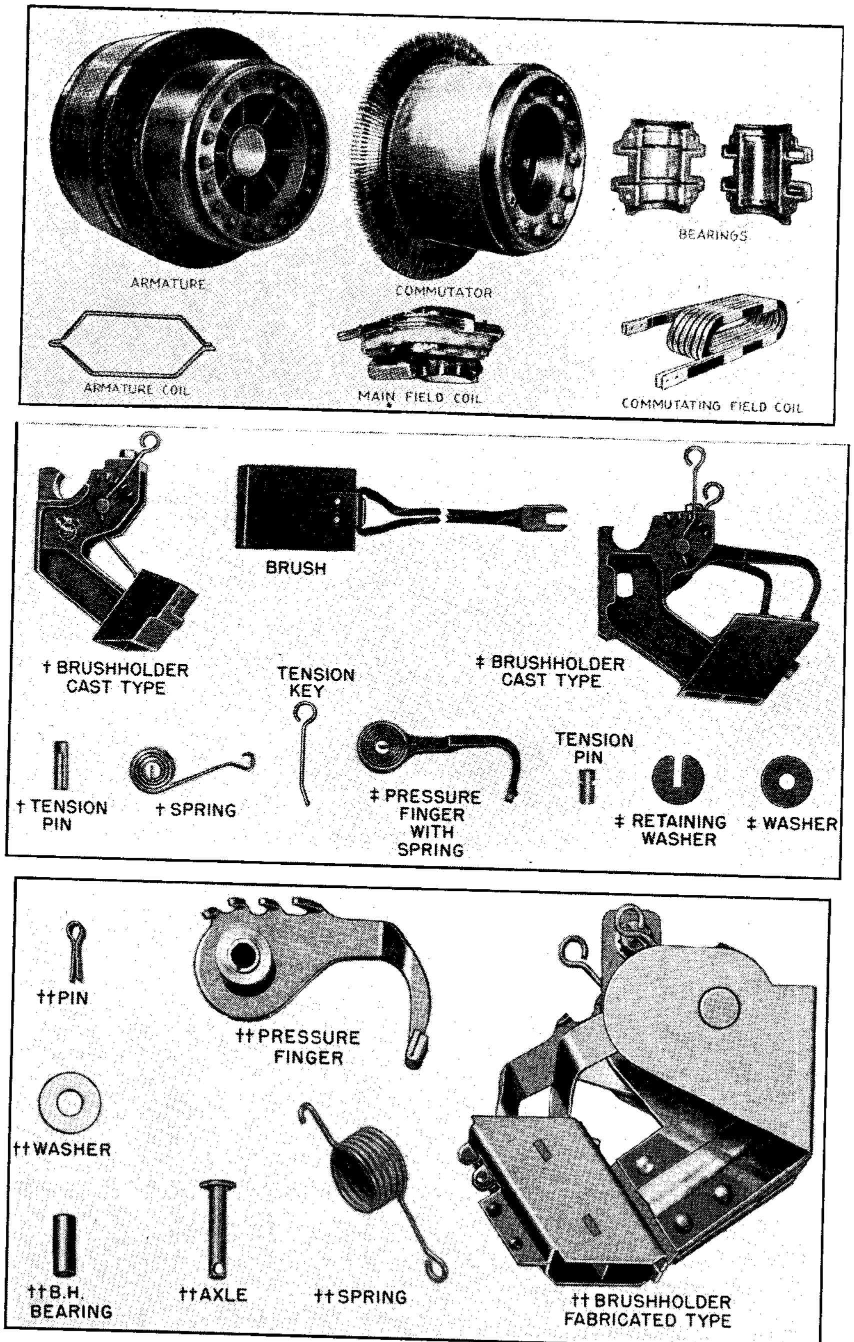


FIG. 21—TYPICAL RENEWAL PARTS FOR DIRECT-CURRENT GENERATORS AND MOTORS

RENEWAL PARTS

On the following page is a list of the Renewal Parts and the quantities of each which the user of this apparatus is recommended to stock in order to minimize service interruptions caused by breakdowns.

The parts recommended are those most subject to wear in normal operation, or to damage or breakage due to possible abnormal conditions.

When continuous operation is a primary consideration, more renewal parts should be carried, depending upon the severity of service and the time required to secure replacements.

ORDERING INSTRUCTIONS

Name the part and give its style number. Give the complete name plate reading. State whether shipment is desired by express, freight or by parcel post. Send all orders or correspondence to nearest Sales Office of the Company. Small orders should be combined so as to amount to a value of at least $1.00 net; where the total of the sale is less than this, the material will be invoiced at $1.00.

Number of duplicate units in use...........		1	5
Description of Part	No. Per Unit	Recommended For Stock	
Armature Complete...............	1	0	0
Armature Coil...............	1 set	⅓ set	1 set
*Cut Winding Insulation, Class No. 1	1 set	⅓ set	1 set
Commutator..................	1	0	0
Field Coil, Main..................	1 set	1	2
Field Coil, Commutating..........	1 set	0	0
†††Brush..........................	1 set	1 set	2 sets
†††Brushholder.....................	1 set	1	2
††† Tension Pin................	1 set	1	
††† Tension Key	1 set	1	2

Description of Part	No. Per Unit	Recommended For Stock	
††† Spring.....................	1 set	1	2
‡ Pressure Finger (short or long	1 set	0	1
‡ Retaining Washer...........	1 set	2	4
‡ Washer...................	1 set	2	4
†† Pressure Finger............	1 set	1	1
†† Brushholder Bearing.......	1 set	1	2
†† Axle	1 set	1	2
†† Pin	1 set	1	2
Bearing........................	2	1	2

Parts indented are included in the Part under which they are indented.
*Not illustrated.
†Single Carbon Brushholder (Specify which is desired).
††Double Carbon Brushholder (Specify which is desired).

DIAGRAMS OF CONNECTIONS

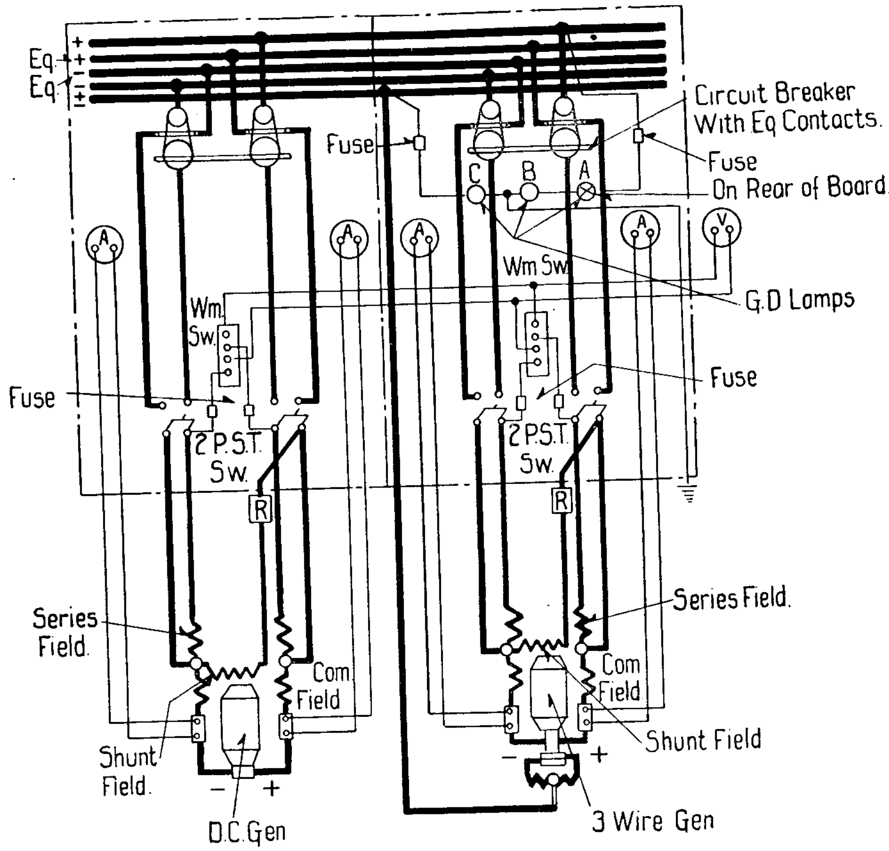


Fig. 22—Diagram of Connections for One Three-Wire Commutating-Pole, 125-250-Volt D-C. Generator in Parallel with One Two-Wire 240-Volt Generator

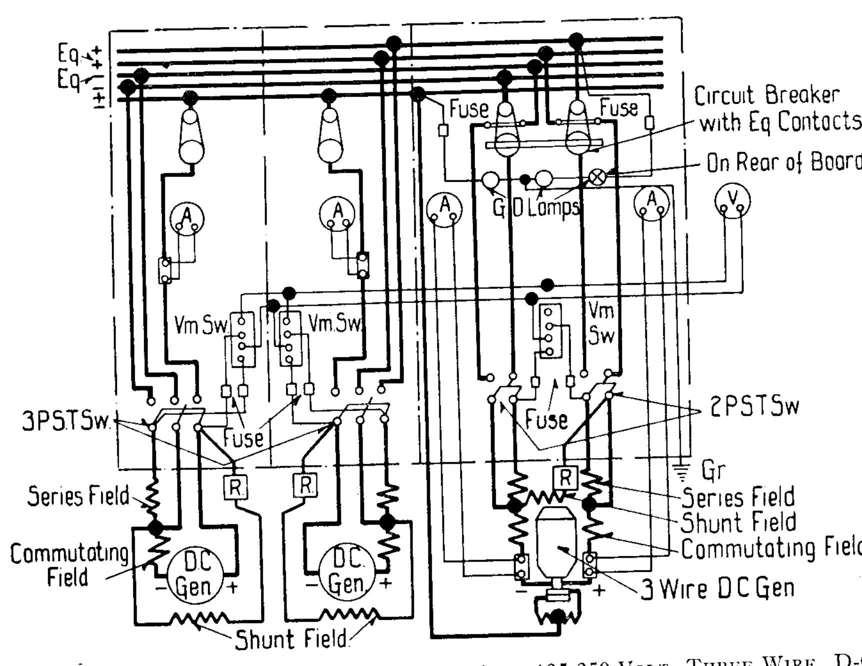


Fig. 23—Diagram of Connections for One 125-250-Volt Three-Wire D-C. Generator in Parallel with Two 125-Volt Two-Wire Generators

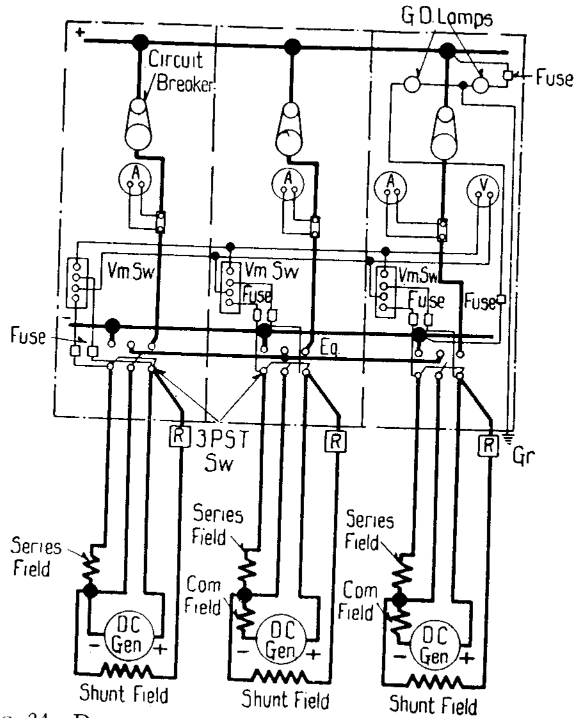


FIG. 24—DIAGRAM OF CONNECTIONS FOR TWO D-C. COMMUTATING-POLE GENERATORS IN PARALLEL WITH ONE D-C. NON-COMMUTATING-POLE GENERATOR. TYPE GD SWITCHBOARD, 250 VOLTS OR LESS

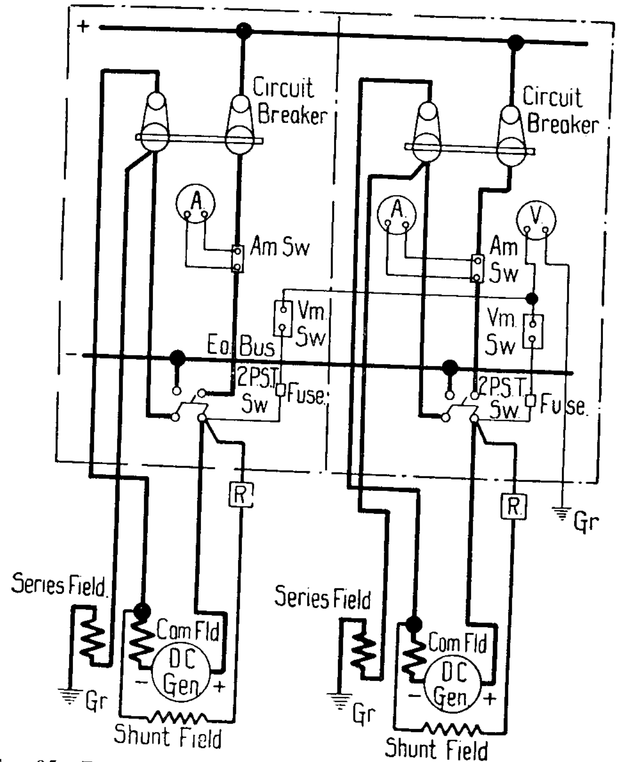


FIG. 25—DIAGRAM OF CONNECTIONS FOR TWO COMMUTATING-POLE ENGINE-DRIVEN MINE GENERATORS IN PARALLEL

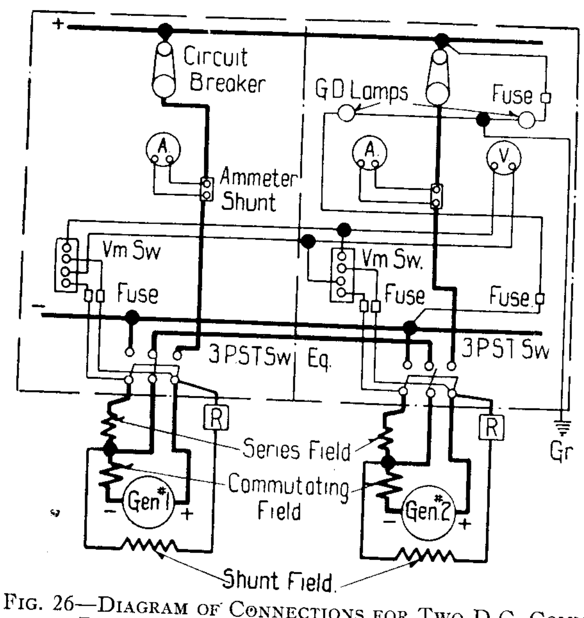


FIG. 26—DIAGRAM OF CONNECTIONS FOR TWO D-C. COMMUTATING-POLE GENERATORS. TYPE GD SWITCHBOARD, 250 VOLTS OR LESS

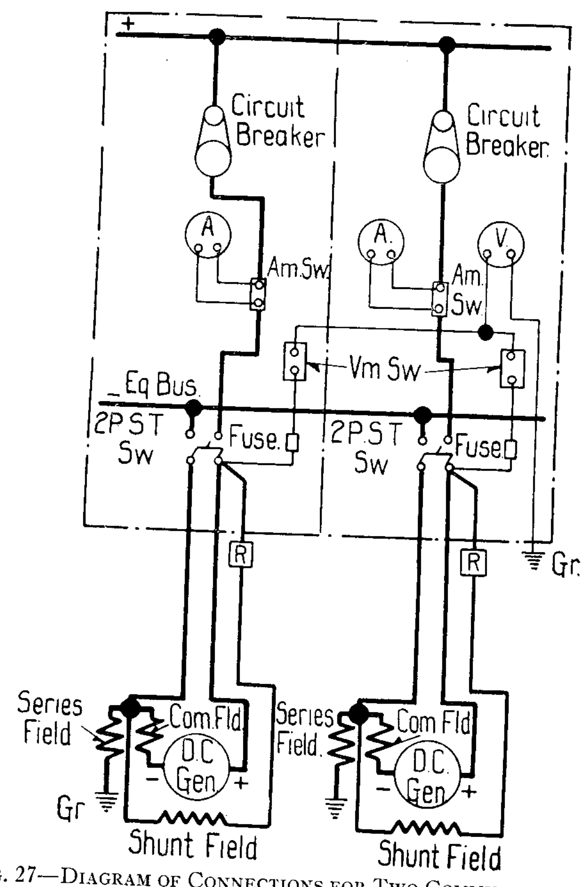


FIG. 27—DIAGRAM OF CONNECTIONS FOR TWO COMMUTATING-POLE MOTOR-DRIVEN MINE GENERATORS IN PARALLEL

MEMORANDUM

(Use Ink)