I.B. 3500-50

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

DIRECT-CURRENT GENERATORS AND MOTORS

WESTINGHOUSE ELECTRIC CORPORATION
POWER APPARATUS DEPARTMENTS

EAST PITTSBURGH PLANT • EAST PITTSBURGH, PENNA.

SUPERSEDES I.B. 4000-A

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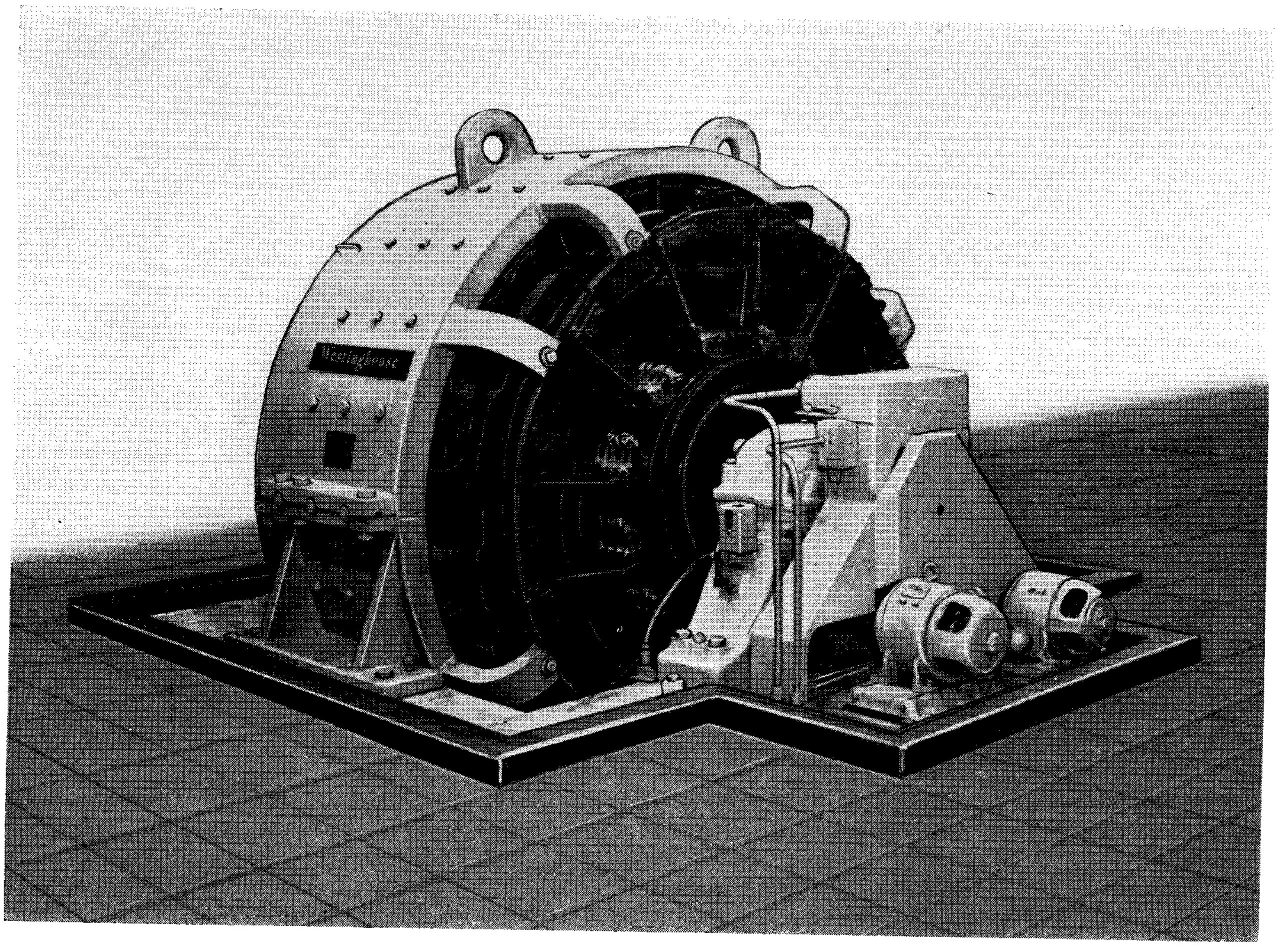
LIST OF ILLUSTRATIONS

TABLE OF CONTENTS

Part Four (Cont'd) **Pages 38-41**



Installation of a Westinghouse Direct Current Motor

DIRECT-CURRENT GENERATORS AND MOTORS

The rotating machines covered by this Instruction Book include all the larger Direct-Current Generators and Motors.

Long life and minimum outage for your d-c machine can be obtained by following carefully the instructions given in this book for installation, operation and maintenance.

Keep all rotating machines clean. A strict maintenance schedule will pay big dividends in reduced repair bills. By inspection at regular intervals, most troubles will be found and corrected before they can become serious enough to cause a shutdown or hazard to personnel.

Of necessity, this book cannot cover all the details and variations in machine construction, operation and maintenance, but it does give the more important principles which apply to every rotating machine.

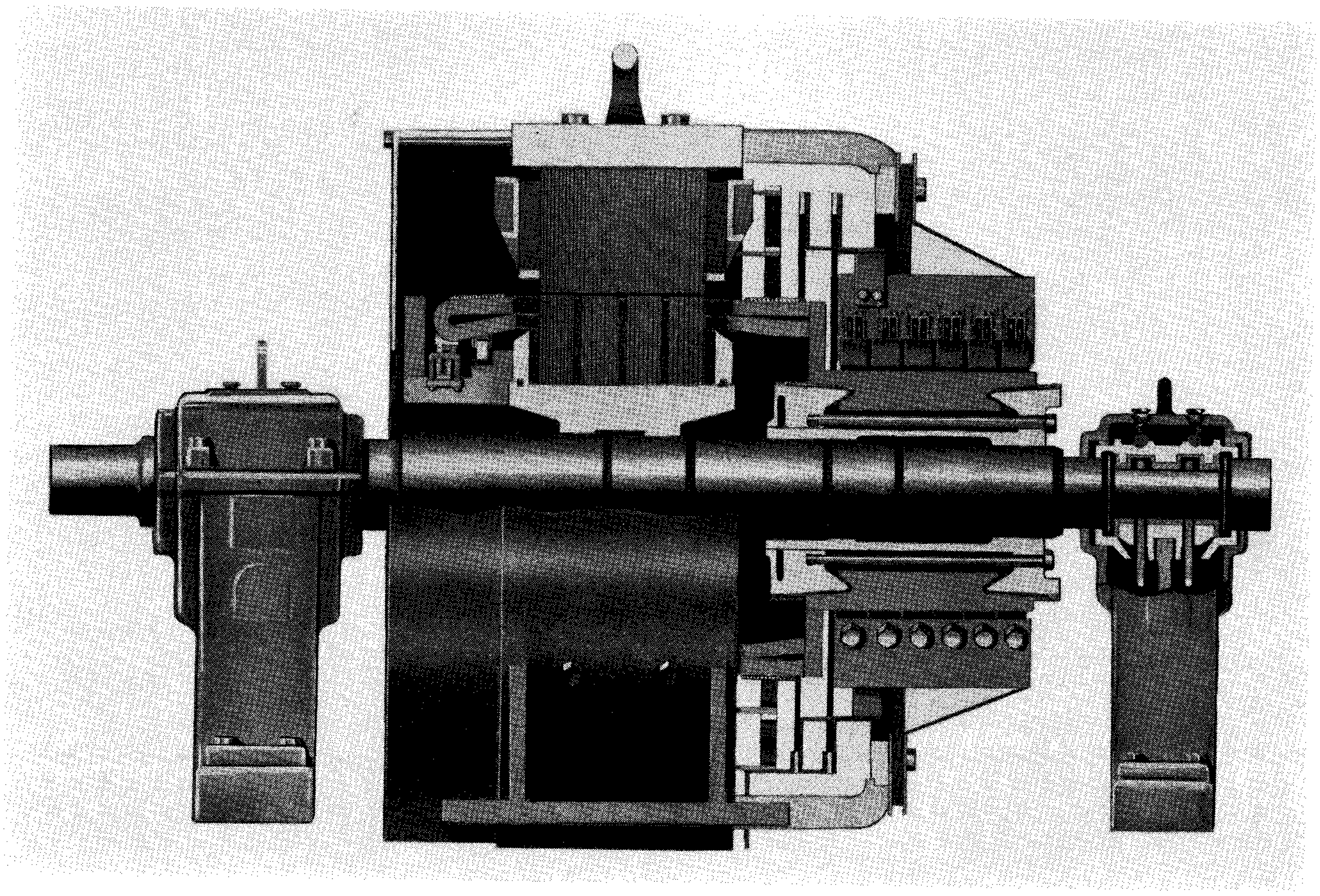


FIG. 1. Section View of Direct-Current Generator

DESCRIPTION OF CONSTRUCTION

A general understanding of the construction features of the apparatus is necessary in order that the succeeding chapters on installations, operation and maintenance be the most helpful. Figure 1 shows cross section of typical machine. It is recommended that the reader study the illustrations along with the following description of component parts.

STATOR

Stator Frame. The frame, which is circular in form and constructed of rolled steel, has a rectangular cross section. The inside of the frame is smoothly bored providing a seat for the main and commutating field poles. The frame is accurately drilled for the pole bolts which pass through into the tapped holes of the poles.

Suitable lifting links are provided on the frame for ease in handling. Feet of ample size are electrically welded to the bottom of the frame to insure rigid attachment of the machine to the bedplate or sole-plates. The feet are machined parallel to the shaft and are drilled for the holding down bolts.

Main Poles. The main field poles are built up of steel laminations riveted together under pressure. The poles are held against the frame by bolts which pass through the frame and are threaded into apped holes in the pole.

Main Pole Windings. The main pole has a shunt field winding and stabilized shunt motors and compound wound generators also have a series field winding. Usually the shunt field winding is wound directly on the pole over insulation. Some are wound in two sections so as to provide the necessary area for proper cooling. The series field winding may be insulated and wound in with the shunt field winding or made of copper bus and supported by hangers wound in with the shunt winding, Fig. 2, depending upon the particular design.

On the larger machines, a compensating winding or "pole face" winding is provided which consists of insulated bars inserted in the face of the main poles.

Commutating Poles. Commutating poles are also attached to the inside of the frame by bolts which pass through the frame and thread into the pole. These poles are symmetrically located midway between the main poles. The ends adjacent to the armature surface are properly beveled to give the correct commutating field form to provide the best commutation.

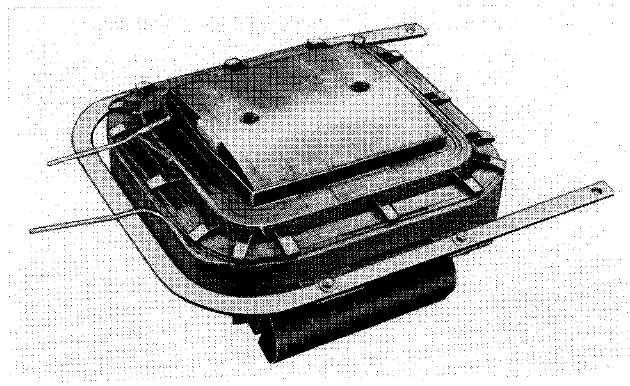


FIG. 2. D-C Shunt and Separate Series Field

Commutating Pole Windings. Assembled on the commutating pole is the commutating field winding. These coils may be formed with edge wound copper and assembled on the poles over an insulating cell such as in Fig. 3, or as in the larger machines, the copper may be flat wound and fastened to the poles over an insulating cell by insulated studs and nuts, Fig. 4.

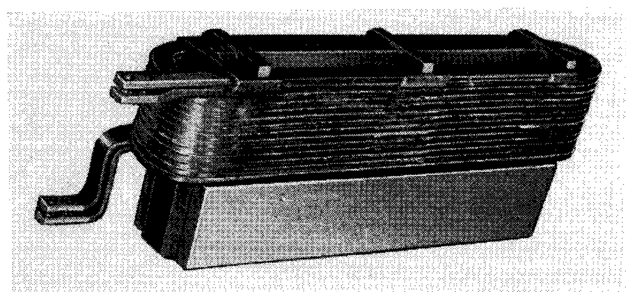


FIG. 3. Edge Wound D-C Commutating Field Coil and Pole

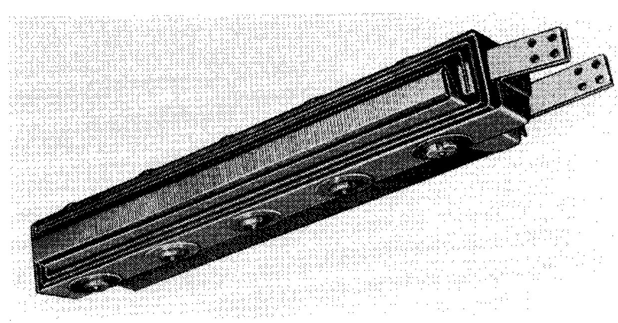


FIG. 4. Flat Wound D-C Commutating Field Coil and Pole

Brush Rigging. The brush rigging is supported by a steel rocker ring which fits into a groove machine into arms welded to the commutator end of the frame. The rocker ring is held in position by a bolt and washer in each supporting arm.

The steel brushholder brackets are supported from the rocker ring by means of insulated bolts and insulating washers.

Double-brush-type brushholders are attached to the brackets. These holders may either be of 2 gang construction as in Fig. 5, or of 3 gang construction as in Fig. 6. Each holder has a finger which presses firmly against the top of the brush by means of a spring, thus insuring uniform pressure between brush and commutator. The brushes have flexible copper shunts that are connected to the brushholder to carry the current and thus the springs and the brushholder box do not conduct current.

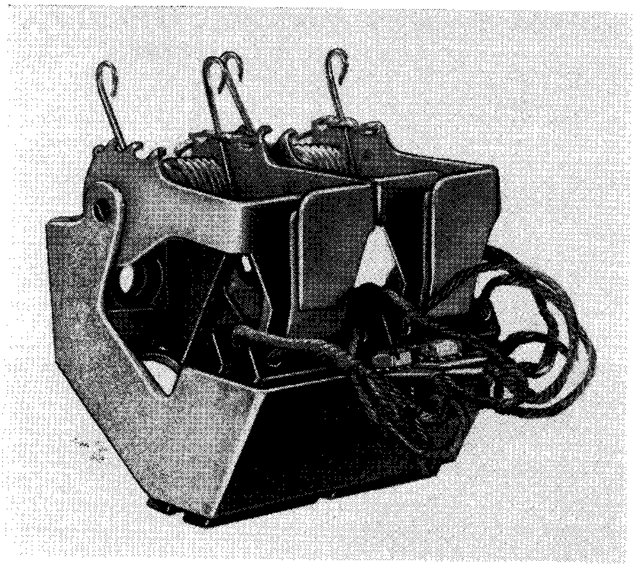


FIG. 5. Two Gang Brushholder for D-C Generators and Motors

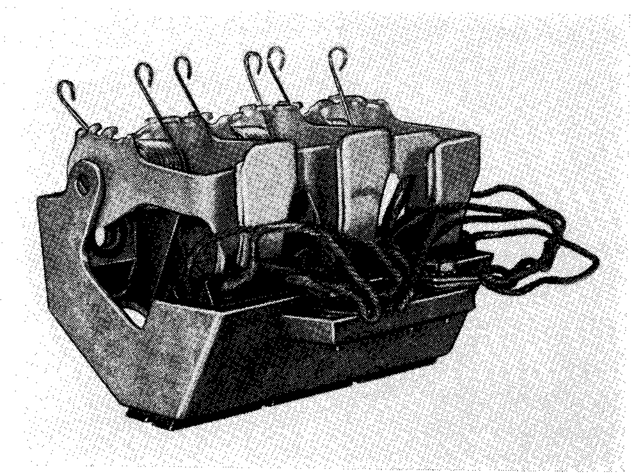


FIG. 6. Three Gang Brushholder for D-C Generators and Motors

Covers. Standard open machines are supplied with a rear endbell that directs the natural flow of air through the windings so as to prevent re-circulation of the air around the rear end turns.

Many types of enclosures may be supplied such as drip-proof, open, or forced ventilated applications and the equipment is so designed to meet the specifications of the order.

ARMATURE

Armature Core. The armature core is built up of punched laminations of special electrical sheet steel which is carefully annealed and treated so that the losses will be a minimum. The punchings are keyed to a spider which in turn is bored and keyed to the shaft. In some machines the punchings are assembled directly on a fluted shaft.

Ventilating spaces are formed between the end-plates and the end of the core as well as at intervals along the length of the core by means of spacers. These vents permit cooling air to flow radially through the core, thus properly cooling the armature.

Armature Windings. The armature coils are form wound. Eddy currents are reduced to a minimum by selection of suitable conductor and strand sizes. The assembled group of insulated wires is impregnated with a solventless thermosetting resin to completely fill all air spaces and to solidify the coil.

Wedges hold the coils in the slot. The armature coils are usually (depending upon type of winding) cross connected in the rear. The front and rear coil extensions are properly banded with magnetic or non-magnetic banding depending upon the design. See Fig. 7.

Commutator. The commutator is made up of hard drawn copper bars held in position by two steel "V" rings which are part of commutator spider. The two "V" rings are drawn together by steel bolts. The commutator necks are of hard-rolled copper brazed to the bars. The armature conductors are soldered or brazed to the upper portion of the commutator necks. Plate mica formed in V-rings is used to insulate the copper from steel. Mica plate is used for the insulation between bars and is undercut 1/16 of an inch.

Shaft. The shaft is of either axle or forged steel. It is to be noted that in many machines, the commutator spider is fastened to the armature spider so that the shaft can be pressed out without disturbing the windings; however, on some machines the commutator and armature spiders have to be separately mounted on the shaft, or the armature punchings

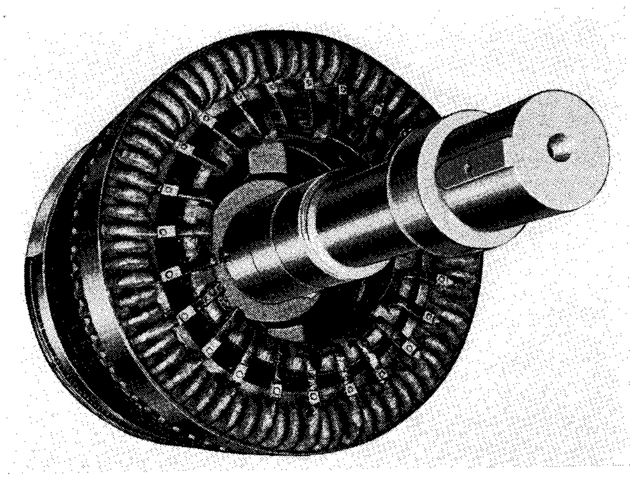


FIG. 7. D-C Armature Cross Connections

are built directly upon flutes on the shaft, in which case the shaft cannot be pressed out as a unit. **The factory representative should be contacted to give specific recommendations on the procedure to follow before any attempt is made to remove a shaft.**

BEARINGS

There are two general styles of bearings used on these machines, sleeve bearings and anti-friction bearings.

The various anti-friction type bearings are usually grease lubricated at low speeds and oil lubricated at high speeds.

Sleeve bearings are oil ring lubricated. They are provided with oil rings which rotate with the shaft, dipping into a bath of oil in the bearing housing, thus carrying oil up and over the journal. There are openings at the top of the bearing cap for inspection of the oil rings. A glass sight gauge is normally provided on the oil reservoir for determining oil level. There is a drain plug which allows the oil in the reservoir to be removed.

On some large high speed machines the loss in the bearings may become sufficient that the heat cannot be dissipated by the bearings alone at a permissible temperature rise. In such cases, an external means of dissipating the excess loss must be provided.

The standard method is to circulate the oil from the reservoir through external coolers to the bearings by means of a motor driven pump. The rate of oil circulation in the bearing and water circulation in the cooler depends upon the bearing loss. Suitable pipe connections are provided in the bearings to permit the use of oil circulating systems.

Bearing assemblies have only minor differences whether assembled in brackets or on pedestals. Some small sleeve bearings on exciters are not split, the bearing being made to slide out from the bracket axially.

When bearing temperature detectors are supplied they are mounted on the side of the bearing housing and the sensitive portion of the instrument is embedded in the bearing shell very close to the bearing babbitt.

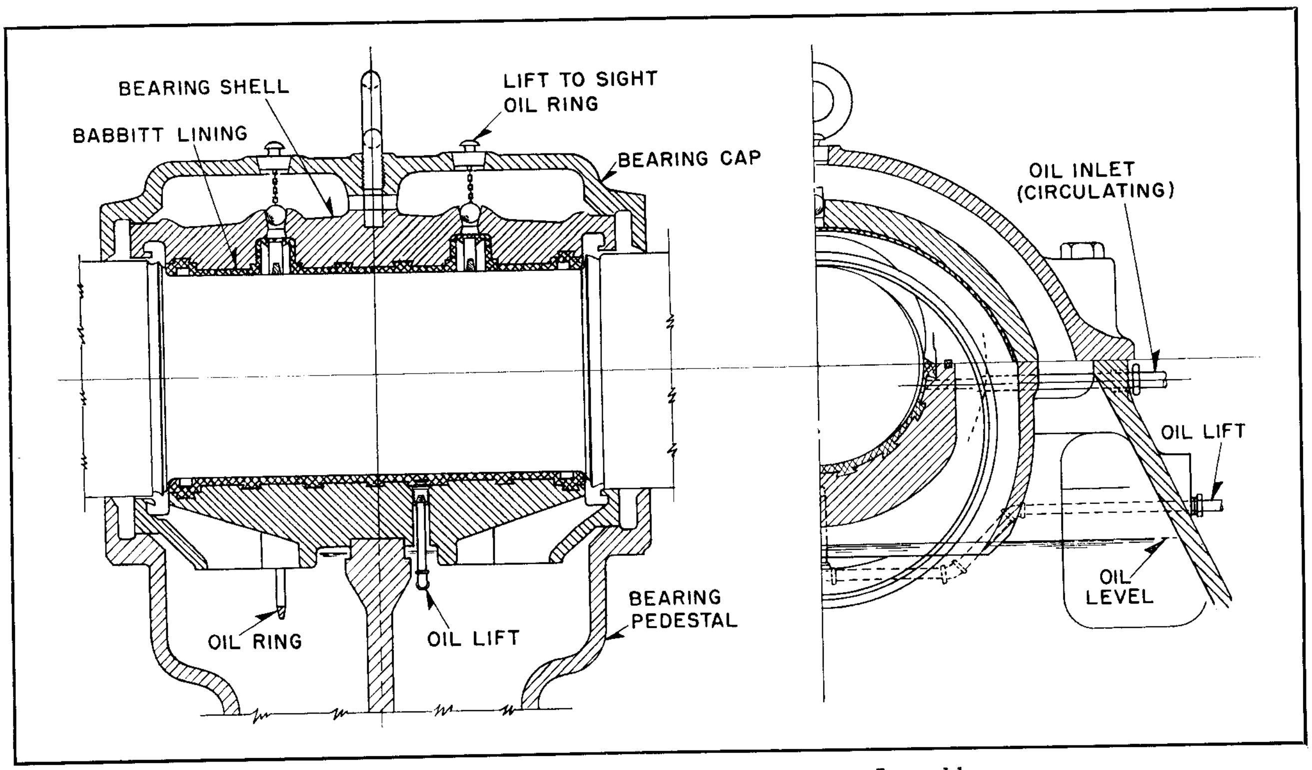


FIG. 8. Cross-Section of Typical Sleeve-Bearing Assembly

All sleeve bearings have babbitted oil ring guides to prevent side wear of the oil rings. Pedestal bearings are split horizontally and have a relief at the split to distribute the oil evenly over the entire bearing surface. See Figs. 8 and 9 for a typical sleeve bearing assembly.

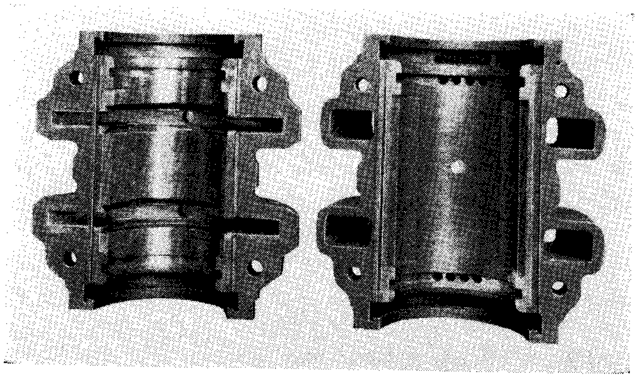


FIG. 9. Split Section of Sleeve-Bearings

Variations in reluctance in the magnetic circuit of rotating machine may cause cyclic changes in the amount of flux which links the shaft. This change in flux may generate sufficient voltage to circulate current through the circuit consisting of shaft, bearings, and bedplate or reinforcing in the concrete. If this current is permitted to flow, it soon has a destructive effect on the shaft journal and bearings.

It is not practicable in the design of all machines to completely avoid the induction of some shaft voltages, therefore, some machines are provided with one or more insulated pedestals. (See Fig. 11.) Pedestal insulation is fully covered on Page 18 of this book.

Bedplates. Bedplates, when provided, are fabricated from standard structural shapes, arranged to obtain the maximum rigidity for the mass of material used. For some machines, soleplates are supplied, which consist of separate side rails and end rails for the bearings. These rails are not joined at the corners but are mounted separately on the foundation.

INSTALLATION

General. The following instructions and precautions are intended to aid in the installation of d-c motors and generators. In many cases the instructions are of a very general nature since the wide variety of types and sizes and the numerous special features that may be included make it difficult to give detailed instructions that are applicable to all units. The service of an experienced erection engineer is invaluable and must be relied upon for a great many of the details of installation.

RECEIVING

Before shipment, all machines are inspected, and tested to eliminate electrical and mechanical defects. If the crate or wrapping appears damaged upon receipt, the machine should be unpacked at once, in the presence of a claim adjuster, and all apparent injuries and breakage reported to the carrier.

Important: When writing to the Westinghouse Electric Corporation concerning the machine, always give the serial number which appears on the nameplate and on the end of the shaft.

Storing. Apparatus which cannot be installed as soon as received should be unpacked, examined, and stored in a room which is clean and dry and where temperature variations are small and slow. It is very important to keep the windings dry since moisture tends to lower the insulation resistance and increase likelihood of insulation breakdown. If possible the machine should be kept warmer than the room air by heaters. Heaters must be such that the products of combustion do not condense on the electrical parts or form a fire hazard. Electric heaters are most suitable for this purpose.

If nothing else is available, it will be possible in some cases to keep the machine dry and warm by placing a number of large light bulbs with the machine in a tarpaulin enclosure. The tarpaulin should allow a small amount of air circulation. Metal surfaces not covered by rust resisting coating should be so covered.

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

Lifting of machines should be done with the greatest of care. The stators are provided with lifting eyes 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 rotors should be lifted preferably with rope slings looped around the shafts. In no case should the ropes or chains be allowed to exert pressure on the windings, commutator, collector rings or journals.

Reference to the outline drawing will indicate whether the assembled machine can be lifted as a unit.

The armature and stator may be lifted as a unit in machines whose armature diameters are 45 inches or less.

LOCATION

It is important that the location of the machines meet the requirements of the National Board of Fire Underwriters and all local regulations. The following additional considerations should also govern the location:

1. Install the machines so that they are well ventilated and easily accessible for cleaning, inspection and assembly.

2. Avoid exposure to mill and coal dust or any other injurious substances.

3. Protect the machines from moisture and chemical or oil fumes.

The motor room must be well ventilated so that the hot air can escape and will not be recirculated through the machine. Unless the room is large and well ventilated, natural ventilation will not be sufficient. If the machine is designed to take air from the pit, suitable ducts must be provided in the foundation. The outline drawing shows the recommended minimum size of the pit and location of ducts.

FOUNDATION

The foundation should consist preferably of solid concrete walls or piers and should be carried down far enough to rest on a solid sub-base. A competent consulting engineer who is familiar with foundation design should design and supervise this part of the installation.

If it is necessary to support the bedplate on steel girders instead of concrete, the girders should be well braced and supported by adequate columns so as to prevent vibration. A rigid foundation is essential so that vibration and misalignment during operation will be reduced to a minimum.

The pit beneath the machines, if required, should be deep enough to give ample working space for connecting the leads which are normally brought out below the machine.

Foundation bolts should be accurately and firmly located in proper location.

PROCEDURE BEFORE ERECTION

The erection or "setting up" of the d-c machine is a matter requiring great care and attention to detail, for the subsequent successful performance of the machine will depend to a great extent on its line-up and rigidity with respect to the foundation. Before beginning to erect the machine, the following points should be checked to avoid trouble once the operation has begun:

1. Check all items at the site of the erection against the manufacturer's shipping report. If all the equipment cannot be accounted for, the shortage should be reported at once to avoid undue delay in erection. Likewise, any damaged equipment should be reported as soon as discovered.

2. Locate foundation bench marks to permit establishing the centerline of the unit and the elevation of the foundation surface.

3. Check the foundation against the outline drawing of the machine to be sure that the pit, if any, and any cable, bus or ventilating ducts that may be indicated have been provided in their proper locations and are of suitable dimensions to permit correct assembly of the unit and its accessory equipment.

4. Check the size, location and elevation of the top of the foundation bolts against the outline drawing.

5. Refer to schematic arrangement shown in Fig. 10. The forms for the rough concrete foundation should provide about 6 inches space at all sides of the bedplate and 2 inches space below the bedplate when unit is to be grouted in place. Foundation bolts can be set with clearance pipe or galvanized sheet metal cones as shown in Fig. 10. A tight fit is required at the bottom to the bolt and at the top to the form to prevent leakage of concrete into the clearance area. The top cone diameter may be 2 inches larger in diameter than the bolt.

Leveling pad locations may be determined from the outline drawing. These pads must be located on each side of and adjacent to each foundation bolt. At points of heavy load or at wide spans such as below the motor pedestal support section, additional pads should be placed as shown in Fig. 10. These leveling pads may be cut from ½ inch by 2 inches hot-rolled steel bars and the length will vary from 6 inches up, depending on the size of the bedplate. The pads must be straight and free from burrs on the top side. The pads should be set in a stiff grout and must be leveled to the correct elevation. Small forms for the pad grouting may be made from either sheet metal or wood. The sides of the forms should be tapered to allow easy removal. The pad elevation should be selected so that a shim may be used at every pad for preliminary alignment in case lowering of the bedplate elevation is necessary. It is good practice to use 1/16 inch

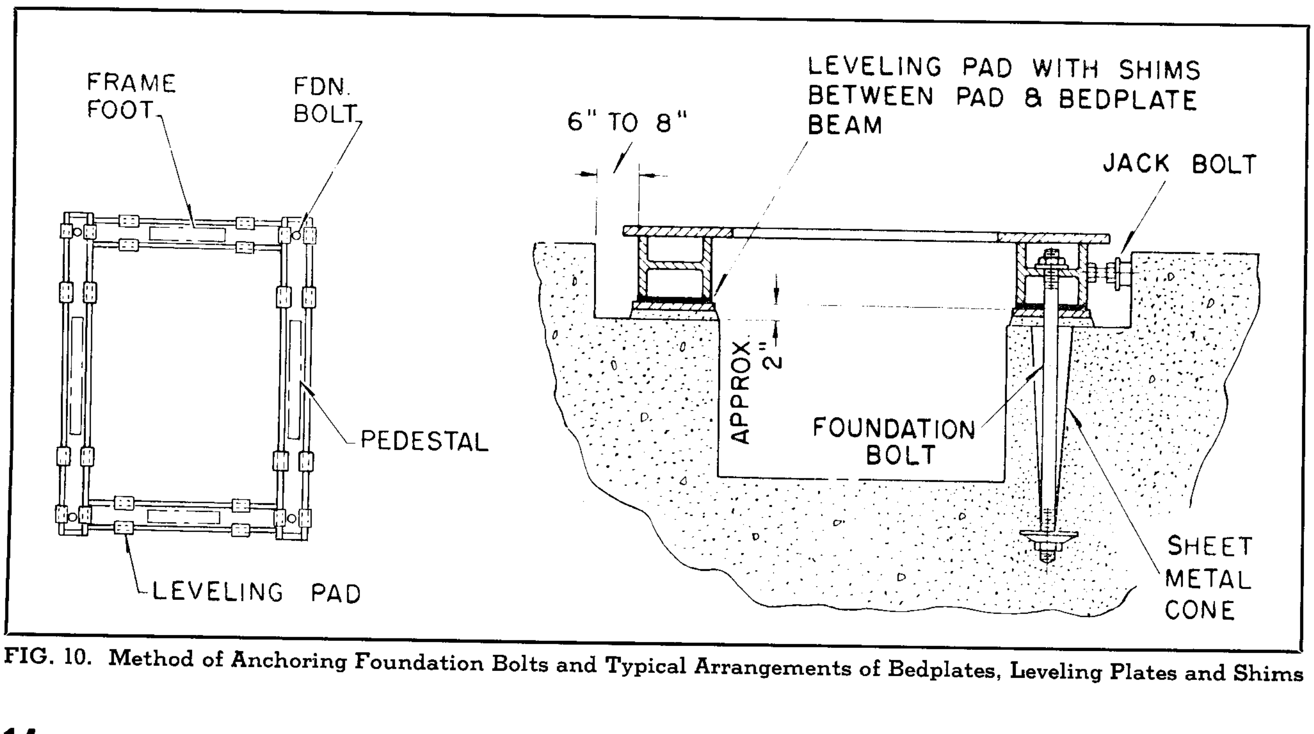


FIG. 10. Method of Anchoring Foundation Bolts and Typical Arrangements of Bedplates, Leveling Plates and Shims

shims on the pad. All shims used should be straight and clean.

A transit survey will establish the correct elevation for the first leveling pad. Adjacent pads can then be set level with the first pad using a leveling bar 6 to 8 feet long and a 12 inch machinist's level. The level and leveling bar are kept together and moved as a unit, end for end, as progress is made around the bedplate pad positions. This procedure compensates for any minor error in the leveling bar and the level. The pads are tapped into the stiff grout to establish the correct elevation while simultaneously being leveled in both directions with small levels.

After the leveling pad grout is cured, the bedplate is cleaned and set in place on the shims and all foundation bolts are tightened. The bedplate is checked for level and adjustments made as required, making certain that all shims are tight. For horizontal alignment, the entire bedplate is easily shifted by using jack bolts which are made with a small section of pipe and a nut and bolt as shown in Fig. 10.

For purposes of description of the erection operation, these machines will be divided into two classes:

(a) Those shipped assembled—Bracket bearing machines and pedestal bearing machines and pedestal bearing machines attached to a bedplate.

(b) Those shipped not assembled—Machines with pedestal bearings and bedplates or soleplates.

For purposes of explanation of the erection, a two bearing machine will be used as an example. It is understood that the principles of lining up a shaft are the same no matter how many bearings are supplied.

Important: 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. 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. Be sure that all connections are clean and tight. This is especially important where machines have fields with parallel circuits.

Erection of Machines Shipped Assembled. Bracket bearing machines and pedestal bearing machines shipped assembled are erected in the following manner:

1. Set the assembled machine onto the roughened foundation with the leveling plates in place. The foundation should be of such elevation that the bedplate, feet or slide rails, may rest on the leveling plates which are placed so that they will carry the weight of the machine without distortion.

2. The machine is then brought into final level and elevated by means of micrometer thickness shim stock of approximately the same area as the steel leveling plates and are placed between them and the bottom of the bedplate. Most satisfactory results in leveling horizontal electrical apparatus are usually secured by using a very accurate spirit level on the shaft.

3. Align as under "Coupling Alignment and Allowances".

4. Run slowly, if possible, after making tests and adjustment under "Preparing for Use" page 21.

5. Recheck alignment after foundation bolts are tight.

6. Grout in bedplate as under "Grouting".

7. Connect permanent wiring.

8. Check pedestal insulation, if used, to make sure it is effective. See page 18.

Coupling Alignment and Allowances. The machine is aligned by the use of a thickness gauge between coupling faces at top, bottom and sides.

Then rotate the shaft in the bearings 180° from the original checking position and recheck the coupling separation at top, bottom and sides to again prove the shaft alignment and truth of the coupling faces. The factory allowable tolerances for such alignment are:

(a) The difference between readings at either side—.001″ for any size flange.

(b) The difference between the readings at top and bottom—not to exceed .002″ per 12″ of flange diameter, but a maximum of .004″ for any diameter flange.

If the openings at the top and bottom of the coupling faces are not uniform the larger opening must always be at the top.

With single bearing units, the couplings should be opened just far enough so that the weight on the coupling end of the shaft is carried by the pilot fits, taking care that the fit in the coupling is not so tight that it affects the alignment measurement.

With two bearing units, the coupling faces should be entirely isolated from each other and the vertical and lateral position of the machine should also be checked in each of the above positions by means of an accurate steel straight edge belt on the edges of the flanges parallel to the shaft.

The longitudinal location should be such that the armature is in the center of the end play allowance at the normal running position.

Flexible couplings should not be forced to accommodate excessive misalignments. This will produce undue wear and can cause vibration and thrust. Flexible type couplings should be aligned by checking between the coupling hub faces with feeler gauges and with dial indicators from one hub cylindrical surface to the other. This will eliminate both offset and angular misalignment. Mount the indicator on one shaft and read radial as well as axial variations between the coupling halves as they are revolved slowly together. Where the two half couplings float axially with respect to each other, it is necessary to use two indicators mounted 180° apart and obtain the difference in the two axial readings in order to check the angular alignment. If the coupling manufacturer supplies specific instructions on alignment, they should be followed as those given here are a summary of general practices.

Grouting the Bedplate. When the alignment is satisfactory with the foundation bolts drawn up tight, the bedplate may be grouted in accordance with Fig. 10.

A wooden form is the best method of retaining the grout inside and outside the bedplate. The grout is mixed in the proportion of two parts clean sand to one part Portland cement. Add water until the mixture is thin enough to be tamped thoroughly under the base. The outline drawing gives minimum and recommended grouting dimensions.

The entire operation of mixing and pouring the grout should be completed without interruption and as rapidly as possible.

Erection of Machines Shipped Not Assembled. 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.

Erection of Belted or Coupled Motors and Generators with 2 or More Bearings.

1. Set the bedplate with pedestals on the foundation and adjust between the bedplate and foundation with leveling plates to the approximate correct level and elevation.

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

3. After covering the journals with a film of oil, lower the rotating part into the bearings using rope slings around the shaft taking care that the ropes do not touch the windings at the back end of the armature—never support the armature wholly or in part by the commutator. Fill the bearings with oil to the proper level. See page 35 for type of oil to use. Place the bearing caps in position and tighten the bolts.

4. Clean the contact surfaces of both halves of the frame. Set the upper half in position and bolt it to the lower half. Tighten the commutating pole bolts first and the frame lug bolts second. Set the upper half of the rocker ring in place and, after bolting the halves together, see that it moves easily in its seat.

5. Bring the assembled machine to the correct elevation and level by using shims under the bedplate (See 1 above).

6. Accurately align the shaft with the driving or driven device. See "Coupling Alignment and Allowances", page 15, for coupled machines. For belt driven machines, the shafts must be parallel and the center lines of the pulleys directly opposite.

7. Set the foundation bolts solidly.

8. Check to see if the air gaps are even by feeler gauge measurements between main poles and armature at both front and rear of the machine. Adjust, if necessary, horizontally by shifting the frame and vertically by means of steel liners placed under the frame feet.

9. Reconnect the armature leads and the field wiring connections inside of the machine. Check to see if brush alignment, spacing and position are correct. See page 25 for details. Grind the brushes to a perfect seat using sandpaper only. See Fig. 27 on page 37. See that brushes move freely in the holder and are held under an equal pressure, usually 2 to 2½ pounds per square inch of the cross-sectional area. Make other tests and adjustments as in "Preparing For Use", pages 21-28.

10. If possible run slowly, and recheck alignment and level. Then grout as described under "Grouting", page 16.

11. Finish assembly by installing permanent wiring and endbells, covers, etc.

12. Check pedestal insulation, if used, to make sure it is effective. See page 18.

13. Note: All frames and pedestals are located by doweling at the factory.

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 pedestal so that the center of the bearing is 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. Never support the armature wholly or in part by 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 described in "Coupling Alignment and Allowances" 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. See page 35 for type of oil to use. 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 upper half in position and bolt to the lower half. Tighten the commutating pole bolts first and the frame lug bolts second. Set the upper half of the rocker ring in place and, after bolting the halves together, see that it moves easily in its seat.

7. Set the foundation bolts tightly.

8. Check to see if the air gaps are even by feeler gauge measurement between main poles and armature at both front and rear of machine. Adjust horizontally by shifting the frame and vertically by means of steel liners placed under the frame feet.

9. Reconnect the armature leads and the field connections inside of the machine. Check to see if brush alignment, spacing and position are correct. See page 25 for details. Grind the brushes to a perfect seat using sandpaper only. See Fig. 27 page 37. See that brushes move freely in the holder and are held under an equal pressure, usually 2 to 2½ pounds per square inch of cross-sectional area. Make other tests and adjustments as in "Preparing for Use", pages 21-28.

10. If possible, run slowly and then recheck alignment and level. Then grout bedplate or soleplate as described under "Grouting", page 16.

11. Finish assembly by installing permanent wiring, endbells, covers, etc.

12. Check pedestal insulation, if used, to make sure that it is effective. See page 18.

Erection of Engine-Type Machines.

1. Set the soleplates, if any, in place and level up to the 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 frame and rocker ring in position.

3. With machines of large size, the armature must be pressed upon the shaft at the point of installation, if this has not been done at the 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 1/32 of an inch.

Before preceding 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. Care 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. Another method is to set the armature in a cradle cut out of heavy tibmer 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 and after covering the journals with oil, lower it into its bearings using rope slings around the shaft, taking care that the ropes do not touch the windings at the back end of the armature. Never support the armature wholly or in part by the commutator. Do not allow workmen to stand on the commutator.

Fill the bearings with oil to the proper level. See page 35 for type of oil to use. Place the bearing caps in position and tighten the bolts.

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 upper half in position and bolt it to the lower half. Tighten the commutating pole bolt first and the frame lug bolts second. Set the upper half of the rocker ring in place and, after bolting the halves together, see that it moves easily in its seat.

7. Set the soleplate bolts solidly.

8. Check to see if the air gaps are even by feeler gauge measurement between main poles and armature at both front and rear of machine. Adjust horizontally by shifting the frame and vertically by means of steel liners placed under the frame feet.

9. Reconnect the armature leads and the field connections inside of the machine. Check to see if brush alignment, spacing and position are correct. See page 25 for details. Grind the brushes to a perfect seat using sandpaper only. See Fig. 27, on page 37. See that brushes move freely in the holder and are held under an equal pressure, usually 2 to 2½ pounds per square inch of cross-sectional area. Make other tests and adjustments as in "Preparing for Use", pages 21-28.

10. If possible, run slowly, and then recheck alignment and level. Then grout the soleplate as described under "Grouting", page 16.

11. Finish assembly by installing permanent wiring, endbells, covers, etc.

12. Check pedestal insulation, if used, to make sure that it is effective. See page 18.

Special Design Considerations. Engine-driven generators are designed with a special allowance made in their rotors for torsional vibrations set up by reciprocating engine prime movers. The total rotational inertia of the generator is so adjusted to avoid resonance with any engine mechanical parts and also to avoid resonance with the electrical system from any impulse either in the engine driving the generator or from other engines in the station at the time of its installation. This entire torsional study is handled by the engine builder who supplies a flywheel of proper design for elimination of torsional vibration as completely as possible. Therefore, when changing generators from one engine or location to another, it will be necessary to contact the engine builder to make sure that such problems are avoided.

Adjustment of the Air Gaps. After the units have been aligned the gaps should be checked as follows:

Measure the gaps under the two main poles located nearest the vertical centerline, from rear and front where possible. The maximum difference between these two gaps should not exceed .020". Gap adjustment is made by shims under the frame feet as necessary.

Measure the gaps on the two main poles located nearest the horizontal centerline from rear and front where possible. The maximum difference be-

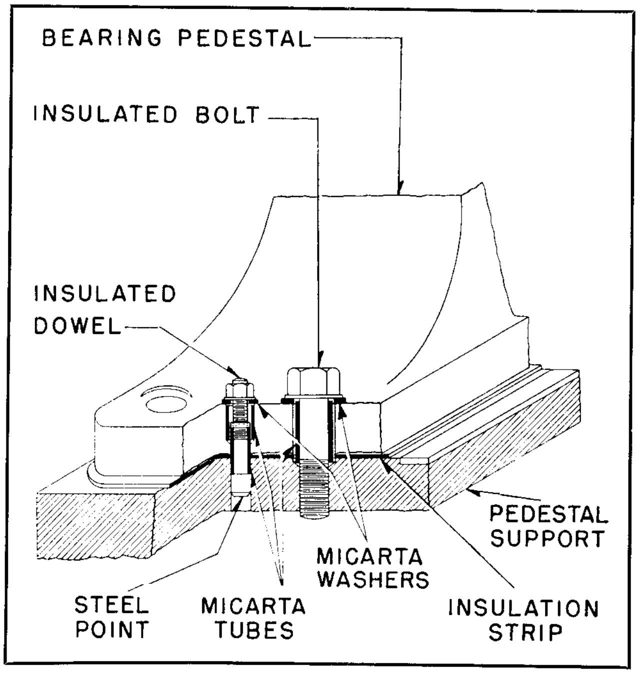


FIG. 11. Method of Insulating Bearing Pedestal from Bedplate

tween these two gaps should not exceed .020". Adjustment is made by shifting the frame horizontally as required.

Pedestal Insulation. Pedestal insulation is provided with certain machines of such a size or using such a combination of pole and punchings that shaft voltages cannot be avoided. This insulation is installed in order to break the circuit of the circulating current through the shaft, bearing and bedplate.

The insulation is usually provided on the outboard end between the pedestal and foundation or between the bearing shell and housing. The insulation consists of micarta sheets and tubes to insulate the pedestal, bolts and dowels from the bedplate in the more common insulated pedestal type of insulation. (See Fig. 11).

Care should be taken to see that there is no metallic connection between an insulated pedestal and the bedplate. If this precaution is not observed, the insulation becomes useless and bearing current is permitted to flow. Such metallic connection may be any of the following:

(a) Piping or conduit which touches both the pedestal and bedplate and which has no insulated union.

(b) Guard rail.

(c) Metal ladder set against the pedestal.

(d) Tools left in contact with both pedestal and bedplate.

(e) Pump or other device geared to the main shaft.

A break in the insulation may occur during erection due to careless handling and it is well to test for this with a bell and battery or with a test lamp. To make this test a section in the shaft-pedestal-bedplate circuit must be free from ground.

CONNECTIONS

Connections for Parallel Operation of D-C Generators. 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 cumulative compound-wound machines, the addition of equalizer connections between the machines is required.

In order to secure proper parallel operation, it is absolutely necessary that the voltage regulation characteristic of a shunt wound generator or of the characteristic of a compound-wound generator when operated as a shunt-wound generator be sufficiently drooping when measured at the point of paralleling or at the point of connection of the equalizer in the case of compound-wound generators. 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 28.

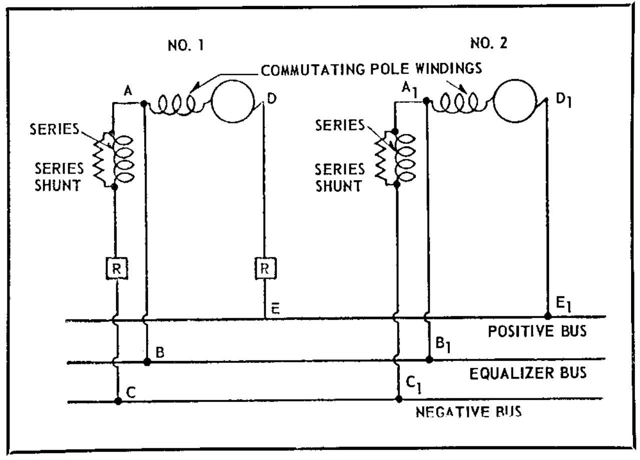


FIG. 12. Diagram Showing Connections of D-C Generators for Parallel Operation

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.

If generators differ in design or size, the difference is 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 percentages of their rated loads but the drop in corresponding sections of the connecting cables of the different machines should also be equal. 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 Fig. 12 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.

Equalizers. 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, (Fig. 12).

The ratio of the resistance of the equalizer connections to the resistance of the series field and its connection, both to the point of paralleling, should be no more than 0.5, but in no case should the cross-sectional area of the longest equalizer lead from a generator be less than the area of that generator's main leads.

The object of the equalizer 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.

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 D-C Generators. A diagram of connections of a balance coil to a three-wire d-c generator is shown in Fig. 13.

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. 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.

Connections for Cross Compounded D-C Generators. A simple and very effective means of paralleling d-c generators is by the use of cross compounded generators.

Each generator has a differential series field connected in series with its own armature circuit and a cumulative series field connected in series with the opposite armature circuits as shown in Fig. 14.

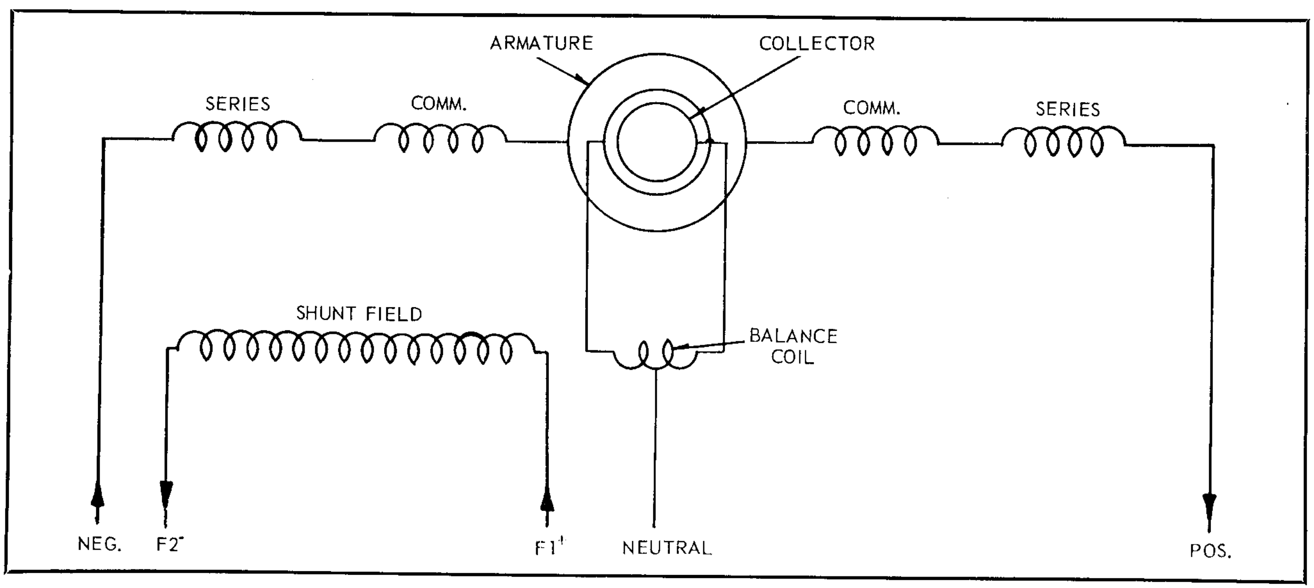


FIG. 13. Diagram Showing Connections of Balance Coil for Three-Wire D-C Generator

Load balance is accomplished by the action of the two series fields. When a machine takes more than its share of the load its voltage is reduced by the action of its differential series field and the voltage of the other machines is raised by the action of its cumulative series field.

Refer to the control diagram for lead markings when connecting cross compounded generators.

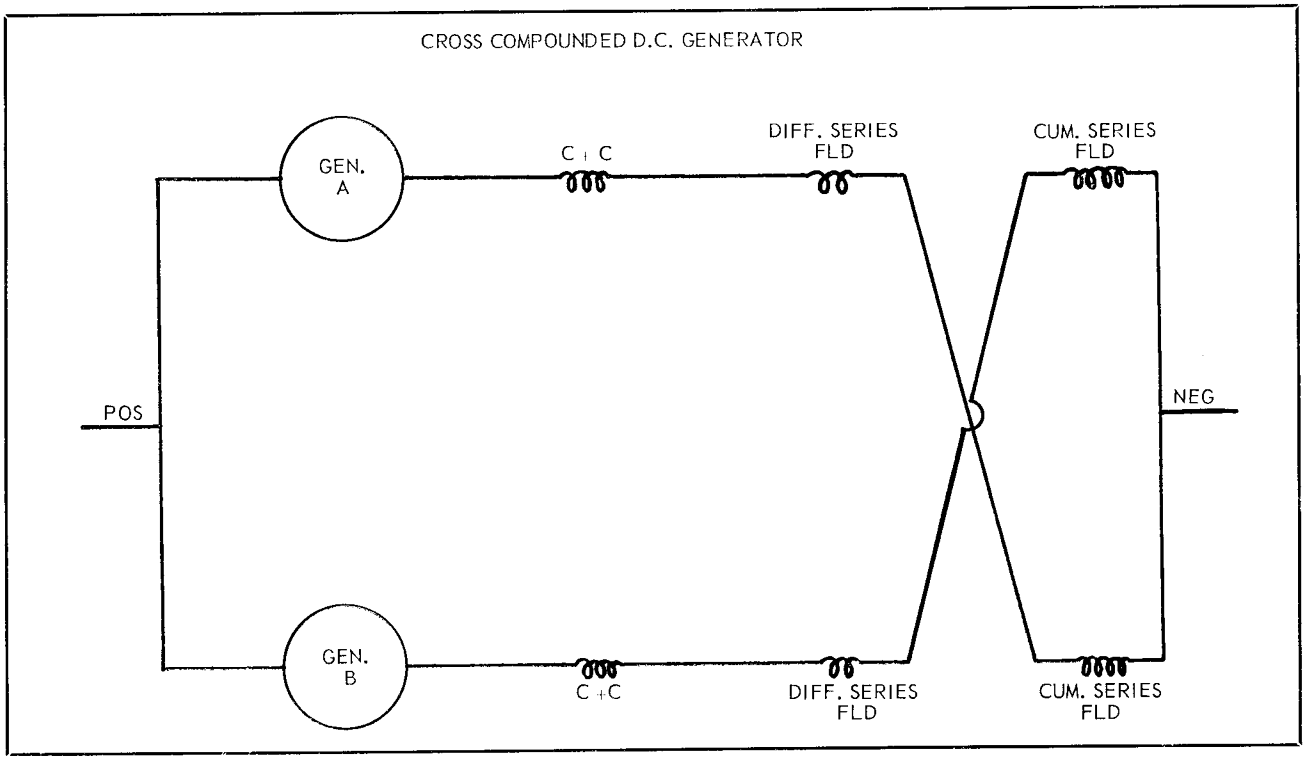


FIG. 14. Connections for Cross Compounded D-C Generators

PART THREE

PREPARING FOR USE

ELECTRICAL TESTS AND ADJUSTMENTS

Insulation Resistance. The insulation resistance of the windings should be measured with a "Megger"* instrument. This measurement gives an indication of the condition of the insulation with regard to moisture and dirt. See Page 33 for details of this test.

The standard value of insulation resistance of a rotating machine is the least value which a winding should have after cleaning and may be evaluated from definitions and formulas from A.I.E.E.** It is recognized that it is possible to operate machines with insulation resistance approximately 1/10 of the standard value; however, the insulation resistance of the armature windings of machines in good condition is usually not less than one megohm.

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. The preferred method is baking in an oven but is often impractical. The windings can be dried out by use of external heat as from space heaters. They are usually dried out by circulating current through the windings. This can be done on field coils by raising the current so as to raise the temperature to 70°C and then adjusted to maintain that temperature until the coils become thoroughly dry. Armatures of generators and motors can be dried out by driving them with a separate motor and short-circuiting the armature leads beyond the ammeter through a fuse with current capacity equal to that of the machine and

* Trademark of James G. Biddle Co., Philadelphia, Pa.
** Report #43 "Recommended Practice for Testing Insulation Resistance of Rotating Machines" (dated April, 1950)

adjusting the field current until sufficient current is circulated to raise the temperature to about 70°C.

Important: **Do not circulate current through an armature while at standstill as localized heating will occur on the commutator and will cause permanent damage to it.**

In general, the drying should proceed slowly at first and the heat gradually increased as the insulation dries. The reason for this is that if vapor is formed from the moisture in the windings more rapidly than it is allowed to escape, the insulation is liable to damage from being ruptured by escaping steam. Keep in mind that insulation is more easily injured by overheating when damp than when dry. The temperature of the hottest observable spot should not be allowed to exceed 70°C total temperature.

Several hours or even days may be required for thoroughly drying out large machines.

During the drying out process the temperature should not be allowed to drop below that of the surrounding air as moisture then condenses on the coil surfaces and the effect of the previous drying would be largely lost.

During the drying out run, readings of the insulation resistance should be taken at regular intervals and plotted as a curve using time for the horizontal scale and resistance for the vertical scale. The drying out should continue until the resistance has begun to increase. If the insulation contains appreciable moisture the resistance will decrease during the first part of the drying out process.

Heating windings by current is more effective than any process of heating from the outside, such as enclosing the machine and heating the air by electric heaters, because in the former method the inside of the coils becomes hotter than the outside and moisture is driven outward. With external heating the reverse is true.

If the apparatus is to be stored before being put in service, consult the nearest Service Department for detail recommendations.

Caution: **Precautions against fire should always be taken when drying insulation. Flammable material should not come in contact with the heaters. Wiring connections should be substantially made and well checked. Fire extinguishers of the CO_2 type should be at hand.**

Brush Position on D-C Generators and Motors. For direct current machines, accurate adjustment of the brush position is necessary in order to obtain satisfactory commutation and regulation. If the brushes are shifted against rotation on a generator, the machine will receive cumulative com-

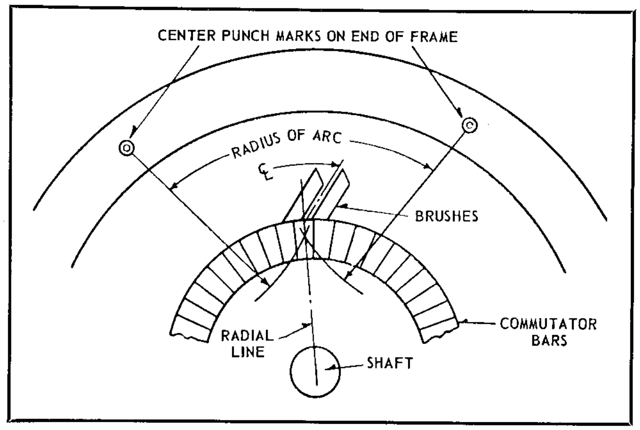


FIG. 15. Method of Locating Factory Brush Position for D-C Generators and Motors

pounding series field effect and reduced commutating pole flux which may cause poor commutation. With the brushes shifted with rotation, a generator will tend to be under-compounded and may not commutate properly. For a motor, a shift against rotation will increase the speed and a shift with rotation will decrease the speed, and less satisfactory commutation may result for both positions.

When the brush position on a 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 Redetermination of Factory Brush Position".

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 relocated so that they are on the original factory setting. The following is the mechanical method for checking the factory brush position. See Fig. 15.

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 arc on the commutator. Due to the angularity of the brush contact on the commutator surface, the midpoint of the brush arc does not

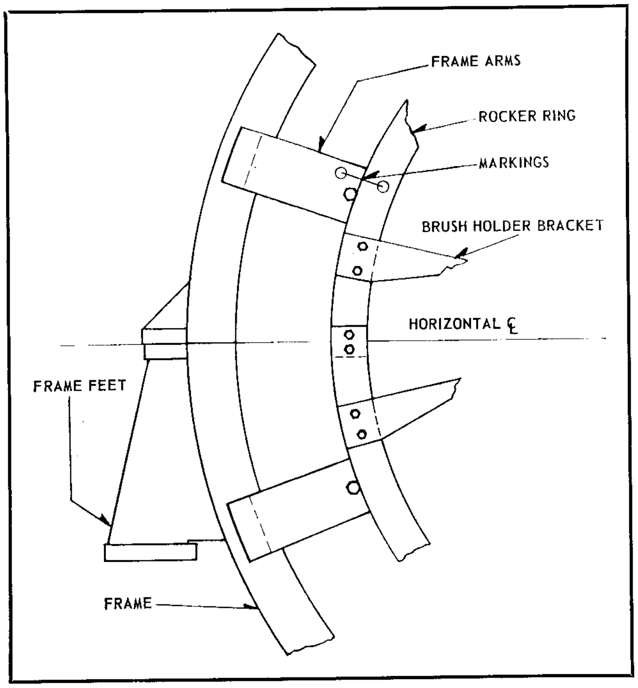


FIG. 16. Locating Brush Position by Rocker-Ring and Frame Arm Markings on Standard D-C Generators and Motors

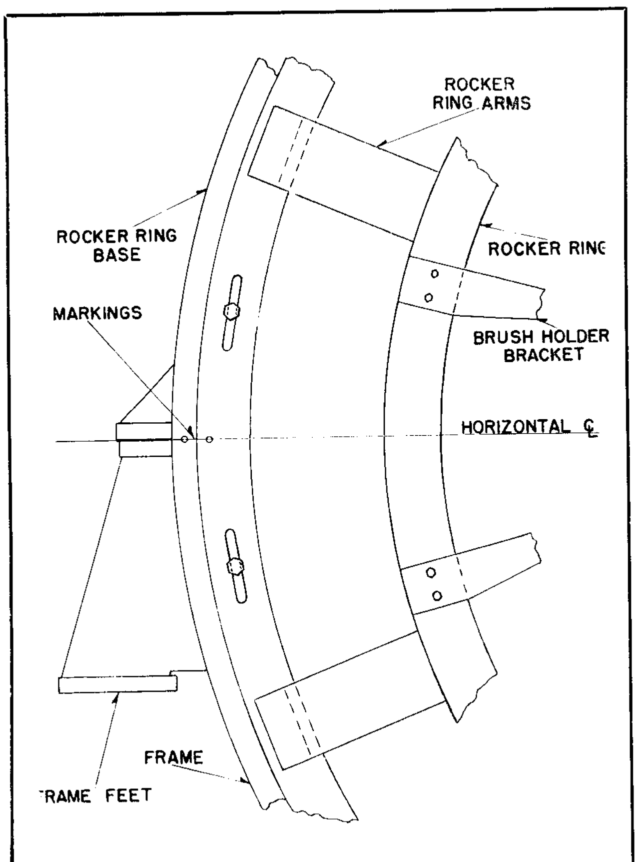


FIG. 17 Locating Brush Position by Rocker-Ring Base and Frame Markings on Large Reversing Type D-C Mill Motors

coincide with the centerline of the brush. Therefore, the midpoint of the arc periphery of the brush contact must be selected. Note that in the case where the brushes are staggered circumferentially, the midpoint of the effective arc must be used. 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.

On new installations another method may be used to locate the brush position, providing the brush-holder brackets have not been disturbed from their original position on the rocker ring.

Located on left side of the machine on or just above the horizontal center line, a chisel mark is on the frame arm and rocker ring. Aligning the chisel marks locates the correct brush position. The chisel marks are identified by a center punch mark with a circle around them located at the outer end of each chisel mark. See Fig. 16.

In the event the brushholder brackets have been moved on the rocker ring then it will be necessary to locate brush position as illustrated by Fig. 15.

The chisel marks locating correct brush position on a reversing mill type motor are placed as shown in Fig. 17. Here the rocker ring base, rocker ring arms and the rocker ring are an integral part of the rocker ring assembly. Aligning the chisel mark on the rocker ring base and the split at the left side of the frame locates the correct brush position.

Locating the Electrical Kick Neutral. Where it is necessaty to locate the electrical neutral position on a direct current machine in the field, it may be correctly and simply located by the electrical "kick" method if due care is exercised.

With the machine at standstill, raise all brushes. Determine the number of electrical bars. In a few high current, low voltage machines, there are two mechanical bars joined together by the commutator risers or "necks" to form one electrical bar. Treat each pair as one electrical bar in this case. Otherwise, the number of electrical bars is equal to the total number of bars in the commutator.

Determine the number of main poles and proceed as follows:

Number of Bars Evenly Divisible. If the number of bars is evenly divisible by the number of poles, then determine the throw. For example, if the machine has 20 bars per pole, such as with 160 bars and 8 poles, the throw would be bar 1 to bar 21. Then use a d-c voltmeter, preferably one having .5, 1.5 and 15 volt scales and place the voltmeter points on bars 1 and 21 in the approximate neutral zone. See Fig. 18.

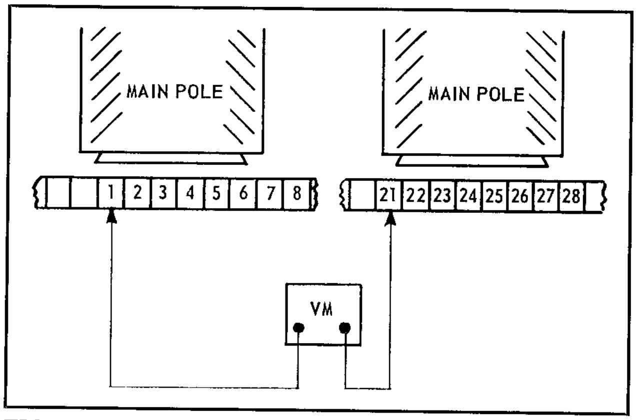


FIG. 18. Instrument Connections for Reading Voltage Induced in D-C Armature

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 as the switch is opened 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.

When the value of field current that is satisfactory is found, then move the voltmeter points to bars 2 and 22 and read deflection as the field is opened. If possible, 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.

Shift the rocker ring so the center line of the brush arc is over the correct neutral point. If the machine has double brushholders, be sure the center of the total brush arc is placed on the neutral. With machines with brushes staggered circumferentially, locate the midpoint of the total brush arc (distance from front of leading brushholder to rear of lagging holder) on the neutral mark.

After the rocker ring has been located on kick neutral, this in no way implies that it is the final brush position. The original factory brush position must be ascertained in respect to kick neutral and the rocker ring shifted the proper amount in the prescribed direction.

If the armature cannot be rotated, and the number of bars is evenly divisible by the number of poles, the neutral can be located by use of a curve or calculation. Proceed as described in previous paragraphs to adjust the field current. When the value field current that is satisfactory is found, then read induced voltages between 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, and plot these induced voltages as ordinates and the numbers of commutator bars as abscissae, using first number in each pair. Keep in mind that the number indicates the center line of the end of the bar. Determine the point of exact reversal from the plot, mark the relative position on the commutator. This is the correct neutral. Shift the rocker ring so that the center of the brush arc is set over this point as described in the preceding paragraph. See Fig. 19.

Number of Bars Not Evenly Divisible. If the number of bars is not evenly divisible by the number of poles (such as 164 bars and 8 poles which is 20½ bars/pole), then proceed as in the previous method except read the voltage with the voltmeter points on bars 1 and 21 in the approximate neutral zone. Then move the voltmeter points to bars 1 and 22 and read again. If possible, rotate the armature slightly until the two readings are equal but opposite in polarity. This indicates the correct neutral is exactly on the centerline of bar 1 and on the mica between bars 21 and 22. The rocker ring is shifted until the center lines of the

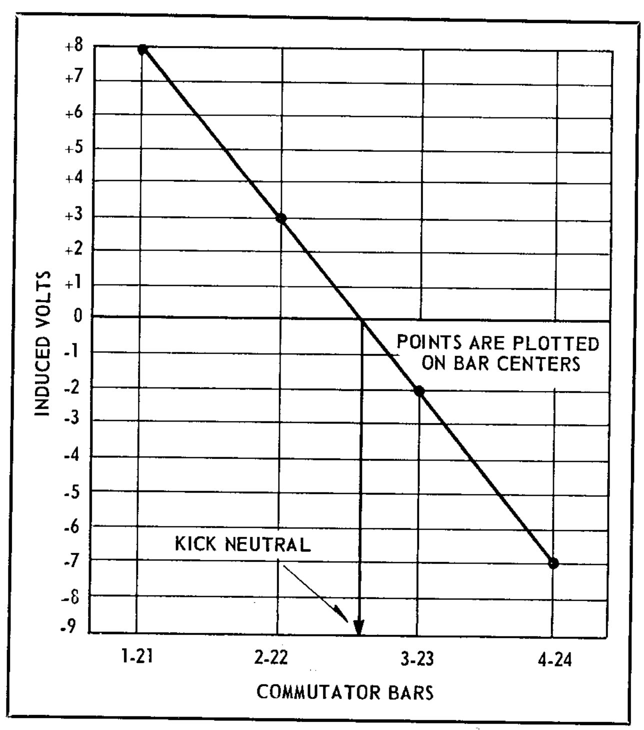


FIG. 19. Curve Method of Determining Neutral Bars Evenly Divisible for D-C Armatures

arc of the brush surfaces are exactly over this position.

If the armature cannot be rotated and the number of bars is not evenly divisible by the number of poles, (such as 20½ bars), then proceed as in the previous paragraphs except read voltages between bars 1 and 21, 2 and 22, 3 and 23, until a point of reversal is reached. Then read between bars 1 and 22, 2 and 23, 3 and 24, etc. Then record four readings for each group of readings, two on either side of each reversing point. Plot each set as in previous paragraph. See Fig. 20. Then the neutral point is the midpoint between the two points of reversal. Mark the commutator and shift the rocker ring as in the previous paragraph.

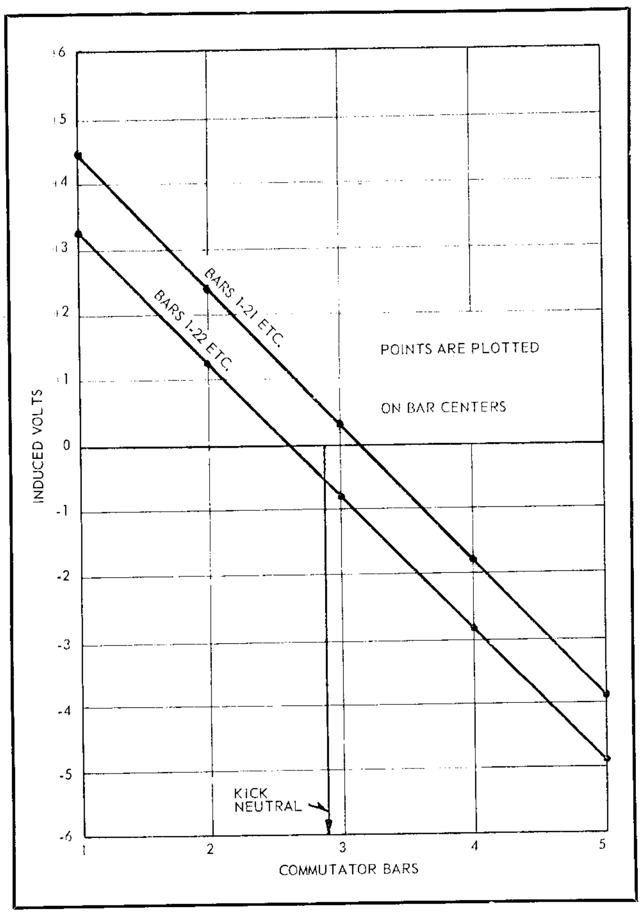


FIG. 20. Curve Method of Determining Neutral Bars not Evenly Divisible for D-C Armatures

Important: 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.

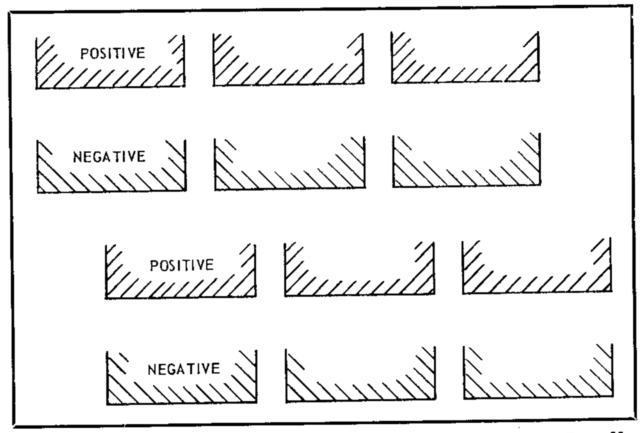


FIG. 21. Correct Method of Staggering Brushes Axially on D-C Generators and Motors.

This being the case, it is best when the brush position has once been disturbed to relocate the brushes so that they will be on the factory setting.

Before taking any readings to determine kick neutral, the commutator should be checked to determine as whether or not there are two mechanical bars for every electrical bar. This is done by taking a reading such as from 1 to 22, 1 to 21, and 1 to 23. If all three readings are different, this will indicate that there is only one mechanical bar for every electrical bar. If any two of these readings would be alike, that would mean there are two mechanical bars for every electrical bar and after the two mechanical bars have been paired off all the way around the commutator, it can be treated as above.

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 two adjacent rows of brushes should be accurate to within ± 1/32″. The best way to secure this spacing is to mark a narrow strip of tough paper or adding machine tape exactly equal in length to the circumference of the commutator. This strip is then marked off into equal parts, corresponding to the number of brusharms, 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.

If any brush arms are respaced check to see that brushes are parallel to commutator bars within ± 1/32″ from back to front.

Staggering Brushes Axially. The brushes are staggered axially 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 3/16" or more. The third pair of brush arms trail the first pair; the fourth, the second, and so on. See Fig. 21. If the brushholder supports are removed from the rocker ring they should be reassembled so that correct staggering is obtained.

Staggering Brushes Circumferentially. On some machines the brushes are staggered circumferentially by placing spacers between the brushholder and brushholder bracket. Spacers are generally put on alternate brushholders and placed on the same brush track in each arm. See Fig. 22.

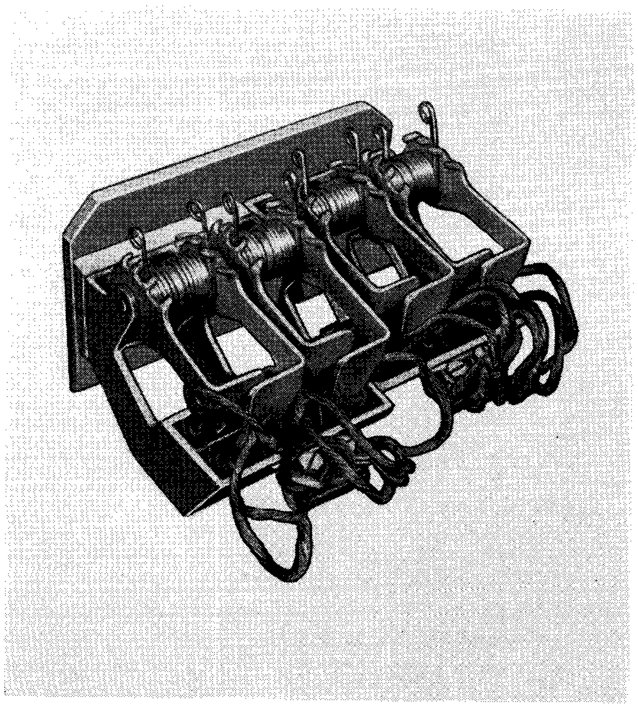


FIG. 22. Staggering Brushes Circumferentially on D-C Generators and Motors

Staggering is beneficial to commutation for the following reasons:

1. Increases the time of commutation, thereby reducing the reactance voltage.

2. At the trailing edge of the brushes where the bar leaves the brush, the cross section of brush in contact with the bar is reduced giving higher resistance which is conducive to good commutation.

3. Where rough or eccentric commutator conditions occur, stagger gives the effect of a wider brush and thus all brushes on a given arm will not be affected simultaneously, thereby having some brush contact on all brush arms at any one instant.

Due to the difference in angle between the staggered brush and the normal brush and the fact that commutating conditions are different between the two brushes, there will be a definite difference in the appearance of the commutator film on the brush tracks corresponding to the staggered brushes and the non-staggered brushes. This difference is perfectly normal and is in no way detrimental to commutation or brush and commutator maintenance.

When placing a machine in service with staggered brushes, see "Mechanical Re-Determination of Factory Brush Position", in the installation section.

D-C Brushes and Brushholders. A careful examination of the brushholders should be made to see that all brushholder fingers move freely and exert the correct pressure on the brush. This pressure should normally be 2 to 2½ pounds per square inch of cross sectional area of the brush. For the correct finger pressure, depending upon the size of the brush, see the tabulation given below:

Brush Size	Pounds per Brush
⅜ x 1¾	1.3 to 1.6
½ x 1¾	1.8 to 2.2
⅝ x 1¾	2.2 to 2.7

The brush shunts should be checked to see that they are properly connected to the brushholder of the machine and are arranged neatly to provide adequate clearance from any other parts of the machine.

The brushholders should clear the commutator by 3/32" to ⅛".

MECHANICAL TEST

Caution: Before starting the unit make absolutely certain there is no foreign or loose material in or on the rotors or air gap spaces. Also check to make sure all ventilating ducts in the rotors and interpolar spaces are clean to preclude any interference with the ventilation of the unit. Any time spent to eliminate foreign material is well spent since any hindrance to the flow of air within the machines may cause overheating and great damage.

Keep the area adjacent to the machines free of all small iron items as they may be drawn magnetically into the air gap spaces of the machines while they are running and cause serious damage.

Checks to be Made. Before the machines are turned over for a mechanical test run, the following items should be checked:

1. Oil level.

2. Oil circulating system (if supplied)

3. Cooling water system (if supplied)

If these are satisfactory, the machines should be jacked over by hand to see that everything is free to rotate.

Before starting, go over all machines thoroughly, testing for loose bolts and nuts that may have been overlooked. Check blower bolts, pole bolts, copper connections, coupling bolts, exciter coupling bolts or belting, foundation bolts and dowels. Make absolutely certain that all parts are in their correct places and are properly tightened down.

Make reference to the drawings. Compare drawings and assembled machines point by point. Check first before it is too late. Then start the machines on a slow roll and gradually bring up to speed. Check operation of oil rings at frequent intervals. The oil rings should revolve freely and smoothly and should carry oil to the tops of the journals.

Bearing Temperature Relays. Separate information is supplied with these devices and reference should be made to it. After the bearings with relays are installed, the covers of the relays should be removed, all parts checked to see if they are tight and in operating order. Their operation should be checked by immersing the bulb in a high flash-point oil and then heating the oil until the contacts operate. This should normally occur at 96°C total temperature.

Bearing Temperature. During this first run, the temperature of the bearings must be watched closely. A thermometer should be placed in the oil ring inspection hole.

Most small and medium sized machines have bearings which are designed for a low temperature rise. These bearings should operate below 70°C (158°F) total temperature. See Page 35 for recommended oils.

In some cases where a higher ambient temperature or other special condition exists bearings may operate at total temperatures as high as 85°C (185°F).

Of more significance than the actual temperature of the bearing is the change and the rate of change of the temperature as the machine is started and

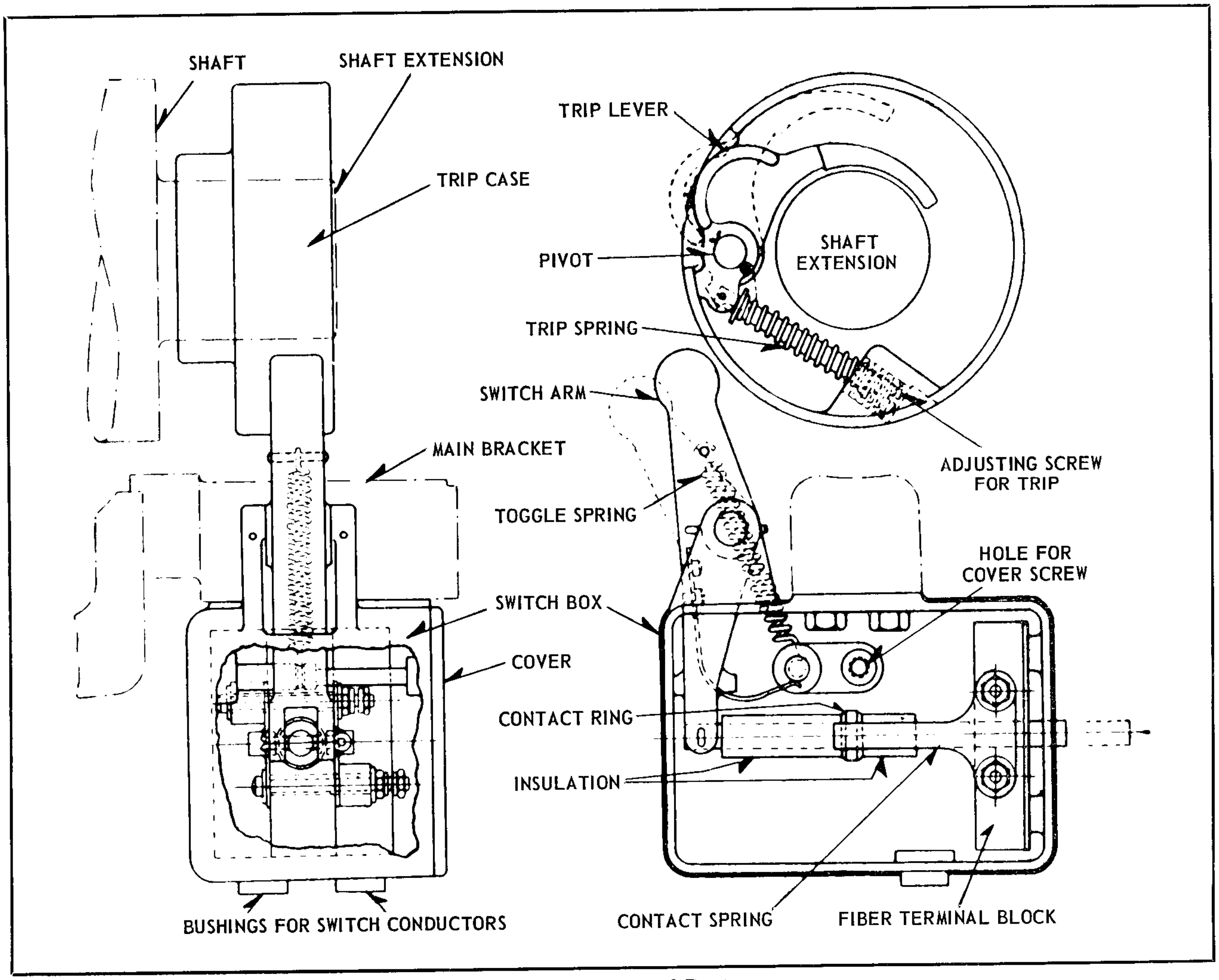


FIG. 23. Overspeed Device

run. When bearings are operated for the first time, their temperature should be periodically checked until they level off at normal temperature.

A rapid rise in the temperature of a bearing is usually an indication of trouble and requires prompt attention.

The causes of overheating of sleeve bearings and actions to be taken are given on Page 36—"Overheating of Bearings."

SPEED LIMIT DEVICE

As a safeguard against overspeeds, a speed-limit device may be attached to many machines. One normally open contact and one normally closed contact is usually supplied. A device with two normally open or two normally closed circuits can be supplied upon request.

The circuits of this device may be used to trip a circuit breaker to prevent the machine from overspeeding, to sound an alarm or operate other protective devices.

To Reset the Switch. Move the switch arm back to the normal position by hand. This can readily be done at any time whether the machine is running or not and without opening the switch box.

Assembly of Speed-Limit Device. All speed-limit devices are set and tested at the factory. The switch box complete is shipped attached to the pedestal. Bolt up parts in place, fasten the trip case to the shaft, next push in the switch arm; there should be at least 1/8 inch between the switch arm and the trip-case. See Fig. 23.

Adjustment of Speed-Limit Device. When checking the overspeed setting the d-c machine can be run as a motor from the d-c bus or it can be belted to a motor. It is important to have complete control of the speed during the test. Use a tachometer or any reliable direct-reading speed indicator, but do not use the ordinary revolving dial indicator.

Then test for overspeed; the switch should trip at about 15 percent above normal speed. Bring the speed up slowly and watch for the tripping speed of governor trip-lever.

Should it be found necessary to reset the governor proceed as follows:

First determine the tripping speed, assemble the governor as shown in Fig. 23. Screw in the adjusting screw even with the governor case, and give the screw about one-half turn inward at each run until it trips at the overspeed. Then tighten the small locking screw on the side of the trip-case.

Before starting each test see that the switch arm is in and pull the trip-lever several times by hand to see that it works freely.

Inspection. Speed limit devices should be tested and lubricated at regular intervals as a part of the routine inspection to insure that all parts are operative and all circuits complete. Failure to maintain the overspeed device and wiring in proper condition may result in the loss of a machine.

PART FOUR

OPERATION

CAUTION

Leave all switches open when the machines are not operating.

Do not work on any machine while it is running. Make sure that all switches are open and that the machines 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.

STARTING D-C 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. If water cooled check the water circulation.

3. With the field circuit open turn in all resistance in the shunt field rheostat.

4. Set the excitation voltage to its specified rating when shunt fields are separately excited.

5. Close the switch applying excitation voltage to the shunt field and note voltmeter reading. If voltmeter reading is reversed consult control diagram for shunt field polarities and correct as necessary.

6. Slowly cut out resistance in the shunt field rheostat until rated voltage is reached on generator.

7. With rated voltage on generator read field current and check value as given in the control manual. The generator is now ready for use.

Note: This description is very general and reference to the instructions furnished with the control should be made before starting the machine.

PARALLELING D-C 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 19).

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 proportions 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.

ADJUSTMENT OF LOAD DIVISION OF SHUNT WOUND D-C 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 overall 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. The increased losses are also objectionable on large machines.

(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 machines can stand some brush shift to secure better paralleling characteristics and still have acceptable commutation.

ADJUSTMENT OF LOAD DIVISION OF COMPOUND WOUND D-C 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.

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 regulating 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 series-field circuits should be checked and changed, when necessary, by changing the resistance of the leads to be 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, and the main lead from the series field to main bus) 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 underloaded generator. However, 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).

ADJUSTMENT OF LOAD DIVISION OF CROSS COMPOUNDED D-C GENERATORS

Cross compounded generators have approximately the same voltage regulation as a shunt wound generator. The addition of the cross series fields, namely the cumulative and differential series field provide a simple and powerful load balancing action.

To adjust the load division it is only necessary to adjust the shunt field rheostats to give load division over the entire range.

If the generators cannot be made to parallel by manipulation of shunt field rheostats check polarities of the cumulative series field. This may be done as follows:

1. Disconnect leads from cumulative series field.

2. Open breakers which connect the generators together.

3. Separately excite the cumulative series field with about ten percent of rated current. The excitation current must be in the direction as indicated by the control diagram.

4. Set the shunt field rheostat to all in position (minimum voltage).

5. Start up the MG set and bring up to its rated speed and note the polarity of the output voltage. If the output voltage is in the same direction as normal operation the series field is correct. If the output voltage is in the opposite direction the series field is incorrect and the connections to the series field must be reversed.

SUCCESSFUL PARALLEL OPERATION OF D-C GENERATORS*

"Successful parallel operation is attained if the load on any generator does not differ more than plus or minus 15 percent of its rated kilowatt load from its proportionate share, based on the generator ratings of the combined load, for any steady-state condition in the combined load between 20 percent and 100 percent of the sum of the rated loads of all the generators."

EXCITATION FAILURE OF SELF EXCITED D-C 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. 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

* ASA Standards C 50.4-1955 Paragraph 4-12.3

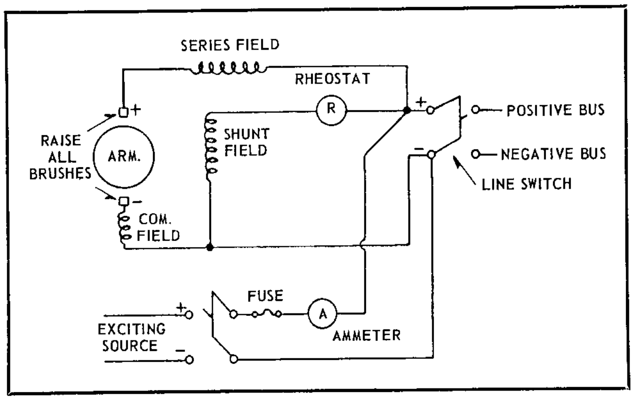


FIG. 24. Connection for Restoration of Residual Magnetism of Generator

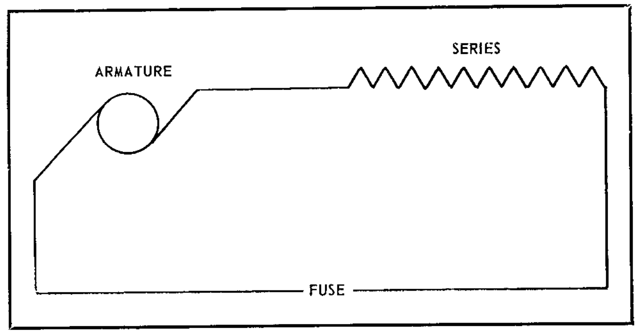


FIG. 25. Convenient Method of Making a Compound-Wound D-C Generator Pick Up Voltage

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 Fig. 24.

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.

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 Fig. 25. 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 D-C 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 D-C 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.

SHUTTING DOWN D-C GENERATOR

1. Decrease the load as much as possible by reducing the output voltage by increasing the resistance of the shunt field rheostat.

2. Remove 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, inspect and clean the machine and put it in good order for the next run.

STARTING D-C MOTOR

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 master switch or controller is in the "off" position and if it is an adjustable speed motor, see that the shunt field rheostat is set for full field (lowest speed).

3. Close the main switch or circuit breaker.

4. Close the field switch and the control switch.

5. Move the master switch 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 the motor is an adjustable speed motor, then after the motor is running on full-line voltage, gradually adjust the shunt field rheostat until the motor is at the desired speed.

Note: This description is very general and reference to the instructions furnished with the control should be made before exciting the generators.

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.

SHUTTING DOWN D-C MOTOR

If adjustable speed motor start with Step 1, otherwise start with Step 2.

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

2. Return the master switch or controller to the "stop" or "off" position.

3. After the motor has come to rest, open the main switch or circuit breaker.

4. Open the field switch and the control switch.

5. Clean the machine thoroughly and put in order for next run.

PERMISSIBLE LOADING

All d-c motors and generators rated 40°C rise are good for a 15% service factor, i.e., 15% overload continuously with safe temperature rise when operating in 40°C ambient.

This overload should not be exceeded continuously as overtemperatures will result which will shorten the insulation life. In addition the brushes will overheat or burn and bad commutation will result.

All d-c motors and generators capable of carrying 125% load for two hours will commutate for one minute a load of 200% of full load amperes without injury. However, this value is for emergency conditions and should not be frequently repeated.

For generators rated 200% full load maximum momentary the maximum permissible frequently applied load is 175% full load.

For motors rated 200% full load maximum momentary the maximum permissible frequently applied load is 175% full load at base speed, 160%

full load at 200% base speed and 140% full load at 300% base speed and above.

These ratings do not apply to d-c motors and generators for reversing hot mill service or to d-c motors and generators with special overload ratings.

Operating above the frequently applied load limits will produce the following results:

1. Increase commutator and brush maintenance.
2. Shorten brush life.
3. Poorer overall commutation for the load cycle.

PART FIVE

INSPECTION AND MAINTENANCE

IMPORTANT

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 from any source is particularly injurious to commutator mica and may result in insulation failure.

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.

See "Cleaning Methods", Page 34 for details.

INSPECTION

DO NOT permit the machines to operate for extended periods of time without a thorough inspection. After the machines are first installed, frequent inspections are recommended to determine the length of time necessary for subsequent periodic checks. Inspections will reveal any minor troubles as they occur and permit their remedying before serious harm has been done.

Do not allow the inspections to become perfunctory! Use a flashlight and a small mirror fastened to the end of a rod so that the entire machine can be inspected—not just the easily observed places.

MEASUREMENT OF INSULATION RESISTANCE

Insulation resistance is useful in determining the presence of moisture or dirt upon the winding surface, and a complete record kept of insulation resistance is useful in determining when cleaning or drying of the windings are necessary. It is suggested that insulation resistance readings be taken at least every six months once in summer and once in winter. Any sudden downward trend of the insulation resistance values will indicate that special maintenance steps need be taken.

Procedure. The method of taking insulation resistance should be definitely controlled and the following routine is suggested:

1. Adopt a definite time of application for taking readings, preferably after 1 minute of voltage application. Make tests immediately after a shutdown when machine is relatively free from moisture.

2. Always use the same voltage instrument.

3. Keep a complete record of date, temperature of winding and ambient temperature, relative humidity and condition of winding. Insulation resistance will vary inversely with the temperature. That is, the insulation resistance will decrease with increase in temperature. Roughly the resistance will be doubled for each 15° drop in temperature. For example, if a certain insulation has a known resistance at 75°C, then at 60°C the resistance should be approximately doubled and at 25°C it should be in the neighborhood of 10 times as great. It must be emphasized that these figures are only approximations and that the rate for individual machines will usually vary.

4. Take readings at machine terminals, being sure other cables, switches, etc. are isolated.

5. Whenever motor driven or electronic instruments are used to take readings over a period of time longer than 1 minute, as in the case of dielectric absorption curves, it is essential that, before a repeat reading of the same part is taken, that the winding be discharged to ground for a time at least equal to the total time of voltage application when readings were first taken.

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, and only to a completely dry machine. 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. Tests of this character should not be made when the insulation resistance is low.

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 relatively clean machine that has been in service should not be subjected to more than 2/3 the voltage specified for a new machine. The dielectric test value is determined by A.I.E.E. rules. Of course, old machines that cannot be properly cleaned must have even the 2/3 figure reduced.

MAINTENANCE OF SATISFACTORY INSULATION RESISTANCE

Prevention of Condensation. Condensation of moisture occurs when the machine parts are cooler than the atmosphere. The humidity of the atmosphere determines the temperature differential at which condensation will occur. At 100% humidity a very small temperature differential will cause condensation whereas a much larger differential is required for condensation if the humidity is very low. Therefore, the temperature of the machine parts must always be kept above the temperature of the surrounding air. This is naturally accomplished as long as the machine is running with some load present.

Heat must be applied to the machine whenever it is shut down. Heaters are supplied on many machines for this purpose and they should be energized as soon as the machine is shut down. These heaters provide enough heat to keep the machine parts a few degrees above the surrounding air temperature, thus preventing condensation.

Condensation will cause low insulation resistance. This is especially true where a salty atmosphere is present since it is possible to have a certain amount of salt present in the condensation.

Thus the importance of preventing condensation cannot be over-emphasized. This applies during the normal use of the machine as well as to the periods the equipment is out of service for extended periods.

Cleaning Methods. The best way to maintain high insulation resistance is to prevent accumulation of foreign materials and moisture in the windings as much as possible. See the previous paragraph on prevention of condensation. There are four acceptable methods of cleaning machines.

1. Compressed Air—This is the most convenient method if there is not an excessive amount of dirt or oil present. Air pressure should be less than 30 lbs. as excessive pressure is capable of injuring the insulation. Use pressure reducing equipment if necessary. Use dry air and 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 machine should be protected from flying dust by a suitable cover or shield.

2. Suction—Cleaning by a vacuum cleaning system is the preferred method as all dirt is carried away from the machines and the danger of blowing dirt into adjacent machines is completely avoided.

3. Wiping—All accessible insulated parts, subject to copper or carbon dust, should be wiped clean with a clean, dry cloth, in addition to cleaning by suction or compressed air.

When wiping, do not neglect such parts as inner surface of end windings, mica vee ring extension, slip ring insulation, etc.

4. Solvents—Water should not be used on d-c machines unless the machine has already been submersed by flood or accident as there is danger of water remaining inside of certain commutators.

The use of solvents should be avoided in so far as practicable and only used whenever it is necessary to remove hard or pasty deposits of grease or oil and other foreign matter.

Before using any solvent, use a clean, dry rag to wipe off as much dirt as possible as mentioned in Paragraph 3. Then use a rag moistened (not dripping) with a petroleum solvent of the "safety type" such as Stoddard Solvent No. 1609-2 or equivalent. If a petroleum solvent has little effect on the dirt, carbon tetrachloride may be used. However, precautions must be taken as carbon tetrachloride is an active solvent and somewhat corrosive in its action. Do not use on leads or other rubber insulation because it has a deteriorating effect on these items. Thorough drying afterwards is essential to avoid damage to the insulation.

Caution: Carbon tetracholride is a non-inflammable compound, but is toxic and must be used intelligently. The chief danger in its use is that the vapor is heavier than air and will accumulate in pits or confined spaces. It should be used only in locations which are adequately ventilated, as prolonged or concentrated exposure to the fumes is dangerous to life and respiratory membranes.

The Mine Safety Appliance Company makes a special nose mask which is recommended as a protection against overexposure to such fumes. As an additional safety measure it is suggested that any cleaning work be done by more than one workman.

Critical areas which when dirty will cause low insulation and which should receive special attention are:

1. The inner surfaces of the armature coils just behind the commutator riser.

2. The insulated creepage surface at the commutator vee ring under the armature coil.

3. The area under the rear coil extension.

These areas should be brushed or scrubbed in the most convenient manner in order to loosen the dirt.

If all these steps do not bring the insulation resistance to an acceptable level, use a solvent sprayed under pressure.

Care should be taken to prevent too much solvent being used where the dirt may be washed from the windings to an inaccessible location between components which would create an area of low resistance to ground which cannot be remedied except by a major repair.

After the windings have been cleaned it is recommended that a coat of recommended insulating varnish be applied to protect the insulation.

FIG. 26.—OIL SPECIFICATION CHART*

OIL SPECIFICATIONS	HORIZONTAL MACHINES	
	200 HP AND UP	200 HP AND UP
	OIL RING LUBRICATED SLEEVE BEARINGS (ALL SPEEDS) CIRCULATING OIL SYSTEM SLEEVE BEARINGS (JOURNAL SPEED) LESS THAN 2800 FT./MIN.) SEE NOTES 1 AND 2	OIL LUBRICATED ANTI-FRICTION BEARINGS (ALL SPEEDS)
Type of Oil	Light Machine Oil	Extra Heavy Turbine Oil
Flash Point, °F Min.	330	425
Saybolt Viscosity	180-250	475-550
Sec. -100°F	..	..
Sec. 212°F Min	.44	..
Viscosity Index, Min	50	85
Carbon Residue, % Max.	.20	.15
Neutralization No. Max.	.10	.10
Pour Point, °F	+25° See Note 3	+15° See Note 3
Rust & Oxidation Inhibitors	See Note 4	Yes

* Where special equipment or unusual operating conditions are involved, manufacturer should be consulted for lubrication specification.

Note 1: In general, for oil ring lubricated bearings the oil viscosity at the operating temperature should not be less than 70 SUV. Accordingly, where oil ring lubricated bearings operate continuously at temperatures above 158°F (70°C), a turbine oil having a viscosity of 300 SUV or more at 100°F may be used. This may cause the bearing to operate with higher losses and at a slightly higher temperature, however, the highly refined turbine oils are more resistant to sludging, and the higher viscosity maintains the desired oil film at elevated temperatures. The operating temperature referred to above is the temperature as measured by a thermometer inserted in the oil ring inspection hole. This temperature is normally 5 to 15°C lower than the temperature indicated by a thermometer imbedded in the bearing shell.

Note 2: 180 to 250 SUV at 100°F represents the most generally used lubrication classification. Where desired, considerable latitude in oil viscosity can be exercised. Temperature rises and losses permitting, heavier oil up to 800 SUV can be used.

Note 3: As a guide for selecting the proper pour points the following table has been reported:

Max. Ambinet Temp. °F	Max. Pour Point Temp. °F
45 or above	35
32 or above	20
20 or above	0
0 or above	-10
Below 0°F	Consult Manufacturer

On some applications rather than using an oil with a very low pour point it may be more practical to provide some heating means to assure the oil temperature will not fall below a certain minimum point.

Note 4: The majority of equipment in this classification will operate satisfactorily without inhibitors. Turbine-type oil containing inhibitors are recommended, however, on equipment operating under high speed, high temperatures or high loading conditions. Oxidation inhibitors retard deterioration of the oil while the rust or water corrosion resistance inhibitors prevent corrosion of parts in contact with oil, particularly in the presence of water. In addition, some rust inhibitors tend to decrease starting friction, a desirable feature for highly loaded equipment. For applications where excessive foaming is a problem, special anti-foaming agents can be obtained.

BEARING MAINTENANCE

Lubrication of Sleeve Bearings. The design of Westinghouse bearings has a background of many years of operating experience and with reasonable maintenance and attention they should give long and trouble-free service. Periodic inspections should be made to be sure the oil level in the bearing pedestal is up to the normal mark on the gauge, and that the oil rings are revolving and carry a plentiful supply of oil to the shaft.

The oil should be sampled at intervals to check its viscosity, cleanliness, and acid content. It is important that the oil be kept clean and free from grit. See "Oil Specification Chart", Fig. 26 for further information.

Openings are provided in the bearing cap over the oil rings for the purpose of adding fresh oil and inspection of the oil rings.

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. 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.

Grease Lubricated Bearings. When grease is used the bearings are packed with grease when assembled in the factory. Only Westinghouse Ball and Roller Bearing Grease is used for lubrication.

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 on a nameplate attached to the machine.

The relief plug is to be replaced after approximately 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.

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 should be flushed and refilled every year. Keep bearings filled to proper oil level with correct grade of oil. See Oil Specification Chart, Fig. 26.

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

Overheating of Bearings. The cause of overheating of a bearing may be any one, or a combination of the following:

1. Insufficient oil in the reservoir to cover the bottom of the oil rings.

2. Dirty oil or oil of poor quality.

3. Failure of oil rings to revolve.

4. Excess end thrust resulting from an installation with the bedplate badly out of level or from the axial magnetic pull resulting from the magnetic center of rotor and stator being out of line.

5. Poor alignment of the machine.

6. Bent shaft.

7. Rough bearing surface due to corrosion or careless handling.

8. Bearing overload due to unequal air gap.

9. Pitting due to bearing currents.

Caution: Bearing currents may flow if tools or other miscellaneous objects fall across the pedestal insulation.

COMMUTATOR & BRUSH MAINTENANCE

Care of Brushes. With the brushes in the proper position as described on Page 22 under "Brush Position", make frequent inspections to see that:

1. Brushes are not sticking in the holders.

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

3. Correct tension is maintained as the brushes wear.

4. 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.

5. Remove any free copper picked up by the face of the brush.

6. When a new brush is installed, be sure it is free in the brushholder.

Seating of Brushes. The ends of all brushes should be fitted to the commutator so that they

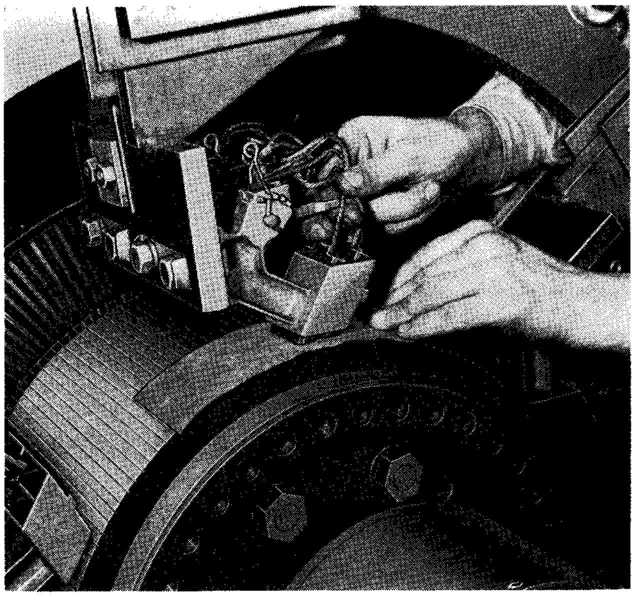


FIG. 27. Method of Seating Brushes on D-C Generators and Motors

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. 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 embedded in the brushes. See Fig. 27.

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 factory test position.

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. See instructions under "Adjustment of Commutating Pole Field Strength" on Page 9.

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, a factory representative should be consulted to remedy the fault.

Brush Chatter. Brush chattering is caused by high friction between the brush and the commutator.

One of the most common causes of high friction between the brush and commutator is light load operation.

Brush friction increases as the current density in the brush is reduced. Brushes which operate with current densities less than 30 Amperes per square

* ASA Standards C 50.4-1955 Paragraph 4-8.9

inch of cross sectional area have a tendency to develop a highly polished glaze on the commutator. The results of this operation are generally

1. Brush chatter.
2. Highly polished brush face.
3. High contact drop between commutator and brush face.
4. Threading of the commutator.
5. Brush finger tip wear.
6. Poor commutation.
7. Brushes chipping or breaking.

Light brush current densities should be avoided. Checks should be made on each application to determine the current density. Brushes should be lifted to obtain a current density between 35 and 65 amperes per square inch of cross sectional area. Peak densities of short duration can be as high as 130 amperes per square inch with no ill effects. With this range of operation, once a machine is put into operation, there should not have to be any changes made in the number of brushes used on a commutator in order to obtain the correct current density. Therefore, the proper procedure is to study the application and lift brushes to get the density up for the major portion of the operating time of the machine. For example: One complete track of brushes around the commutator should be lifted at one time. It is important that the number of brushes lifted be symmetrical in that the same number of brushes on each arm should be used at all times.

Brush vibration which is a result of poor commutator condition or high mica is usually of low frequency compared to chatter caused by light load operation. This type of vibration can be corrected by grinding the commutator as outlined on Page 38.

Streaking or Threading of Commutator Surface. Streaking and threading is caused by the breakdown in paths of the film on the commutator surface. When the film breaks down the current has a tendency to pass through the area where the film has been destroyed. This further aggravates the condition and finally the copper of the commutator bars starts to wear threads or streaks around the periphery of the commutator.

There are a number of different causes for this condition. One is that a very heavy film is built up on the commutator surface, usually due to some atmospheric condition. This heavy film is not a good conductor and to permit passage of current between the commutator and the brush it becomes necessary for the film to break down. This breakdown occurs in just one spot, but it gradually develops into a streak or thread around the periphery of the commutator.

Threading and grooving can also be caused by particles of copper imbedded in the brush face. These particles cut the commutator film and since the copper to copper contact drop is comparatively very low, these areas on the commutator surface carry more than their share of the current which further aggravates the condition.

Selective action, the tendency for one brush or group of brushes to carry more than its share of the load, is also a prime cause for threading and streaking. Streaking in particular can be attributed to selective action.

To prevent threading and streaking due to selective action it is necessary to check the terminal connections, spring pressure, shunt to brush connections, brush freedom in the brushholders, spacing and brush material for symmetry. Any unbalance which will make the electrical resistance in one path different from the other parallel paths in a machine will cause selective action. Mixing several different brush grades on one machine frequently causes selective action.

A common misconception regarding threading is that it is caused by a brush that is too hard. Threading is not a function of brush hardness. The characteristic in a brush material that may cause threading is ash content. The ash particles in a brush material sometimes are extremely hard and unless the type of ash and its quantity are controlled in a brush grade it can contribute to threading or grooving the commutator.

"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.

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 a little attention beyond frequent inspection. If the commutator appears ot be in good condition, leave it alone. Unnecessary grinding or sanding is undesirable and is often an invitation to trouble.

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, causing burnouts.

The commutator will need attention when it becomes 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 machine's ability to satisfactorily handle overloads.

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-thousnadth 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 or sharp pointed stick 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 after grinding and polishing should be concentric within one thousandth of an inch.

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.

The surface of the commutator should be kept smooth. Sometimes a little sandpapering is all that is necessary.

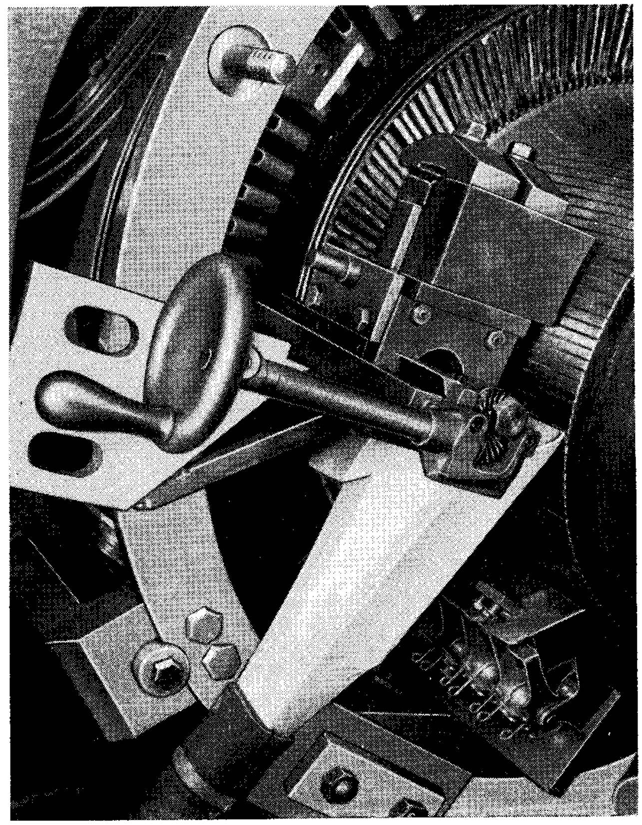


FIG. 28. Grinding Devices for Trueing Commutator

If the commutator becomes badly roughened, it will be necessary to grind the commutator.

Grinding Commutators. All commutator grinding should be done with a grinding rig. A handstone should never be used on a commutator, except on 3600 RPM exciters, to obtain a true surface, because it follows the irregularities in the surface and in some cases may even exaggerate them. The grinding rig consists of an abrasive stone arrangement similar to a lathe tool in a rigging or carriage which may be moved back and forth in an axial direction and is equipped with a radial feed. It should be supported very rigidly so that the stone is subjected to a 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 when the unit operates at 1200 RPM or less. When feasible, higher speed units should be ground at less than rated speed in order to minimize the effects of unbalance and vibration.

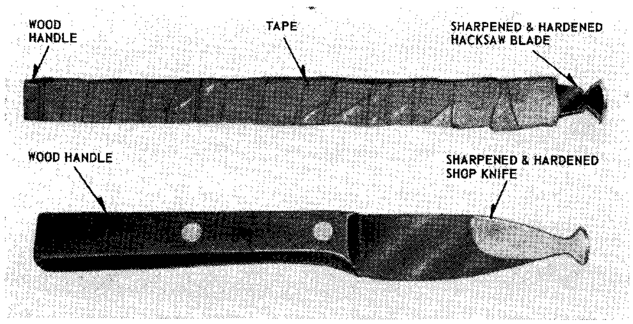


FIG. 29. Tool for Commutator Bar Beveling

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. 28.

In order to rotate the machine, it may be belted to an auxiliary driving motor or in the case of an MG set, it can be run from the machine on opposite end of shaft. If it is impossible to grind a commutator while it is assembled in the motor or generator, the work can be done in a lathe if it is a relatively slow speed machine. This can be done by taking a very fine cut off the surface.

The stones used in grinding commutators may 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, often 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 final finish. The fine stone should have a grit of about 200 mesh.

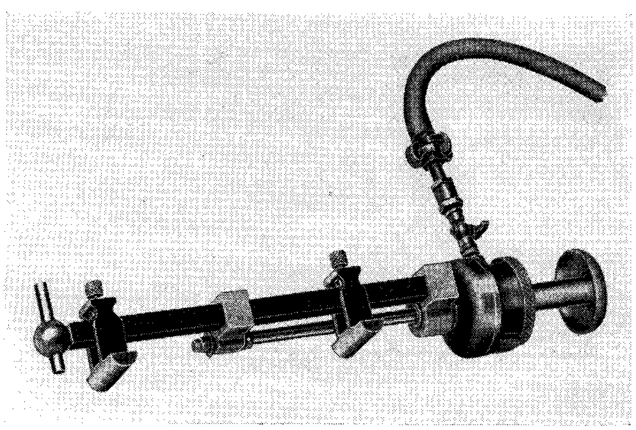


FIG. 30. Tool for Undercutting Mica

Beveling Commutator Bars. 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 eliminating 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. See Fig. 29.

Mica Undercutting. All modern 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 re-undercut 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. 30.

Polishing Commutators. After grinding, undercutting the mica, and beveling the edges of the bars, the commutator surface should be polished at rated speeds. 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 obtained by burnishing the commutator with dense felt or canvas.

Do not attempt to tighten the commutator bolts. All commutators are thoroughly baked and seasoned before leaving the factory and should not require any adjustment. The bolt tension is an important factor in commutator operation and is carefully adjusted by special torque wrenches. Improper tightening can seriously damage the commutator.

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. 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.

Care of Three Wire D-C Generator Collector Rings and Brushes. 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.

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.

REPAIR 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.

RENEWAL PARTS

A recommended list of renewal parts for the motor-generator set is available upon request to the nearest Westinghouse Sales Office.

When ordering renewal parts, give the Stock Order number of the machine and the complete rating as shown on the nameplate. The nameplate is prominently located on the machine frame.

MEMORANDUM

MEMORANDUM

MEMORANDUM

ANACONDA.

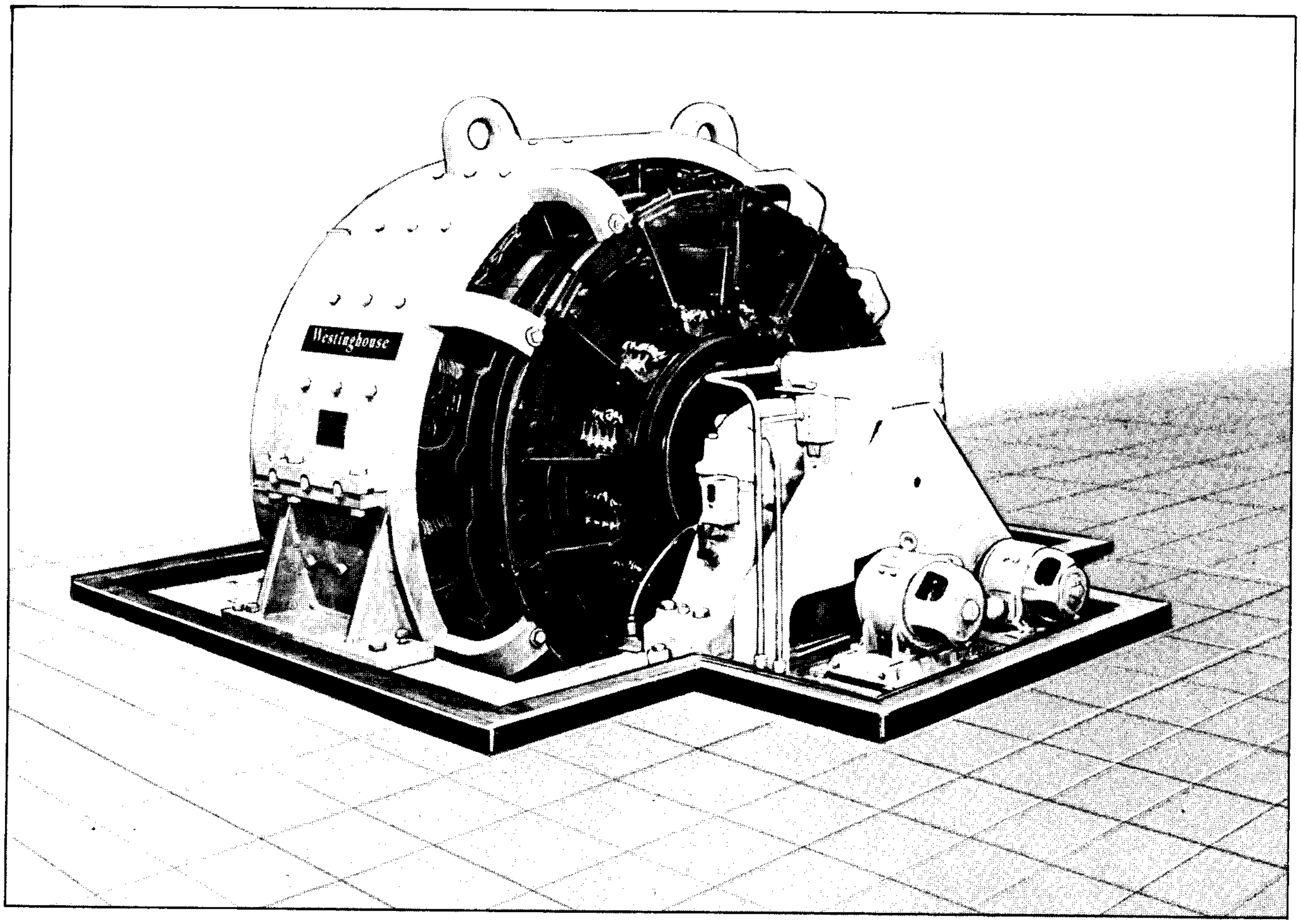
Instructions for Direct Current Generators and Motors

Westinghouse Electric Corporation

Large Rotating Apparatus Division, East Pittsburgh

I.B. 3500-50B, Effective December, 1971, Supersedes I.B. 3500-50A, dated May, 1962

J. Bucich



Installation of a Westinghouse Direct Current Motor

LIST OF ILLUSTRATIONS

Figure **Page**

TABLE OF CONTENTS

Part One | DESCRIPTION | Page

Part Two | INSTALLATION

Part Three **PREPARING FOR USE** **Page**

Part Four **OPERATION**

Part Five **INSPECTION AND MAINTENANCE**

Part Five (Cont'd) **INSPECTION AND MAINTENANCE** **Page**

INTRODUCTION

The rotating machines covered by this Instruction Book include all the larger Direct-Current Generators and Motors.

Long life and minimum outage for your d-c machine can be obtained by following carefully the instructions given in this book for installation, operation and maintenance.

Keep all rotating machines clean. A strict maintenance schedule will pay big dividends in reduced repair bills. By inspection at regular intervals, most troubles will be found and corrected before they can become serious enough to cause a shutdown or hazard to personnel.

Of necessity, this book cannot cover all the details and variations in machine construction, operation and maintenance, but it does give the more important principles which apply to every rotating machine.

Warning: **Small amounts of silicone vapor (as small as 10 parts per million) can cause excessive brush wear and abnormal commutator conditions. Silicone rubber, grease, oil, and varnish may produce silicone vapor. Silicone material should not be used in the area of the commutator or in the path of the air that ventilates the d-c motor or d-c generator.**

Warning: **The commutator and brush rigging may be damaged if current is circulated (for more than a few seconds) in a d-c machine with the armature not rotating.**

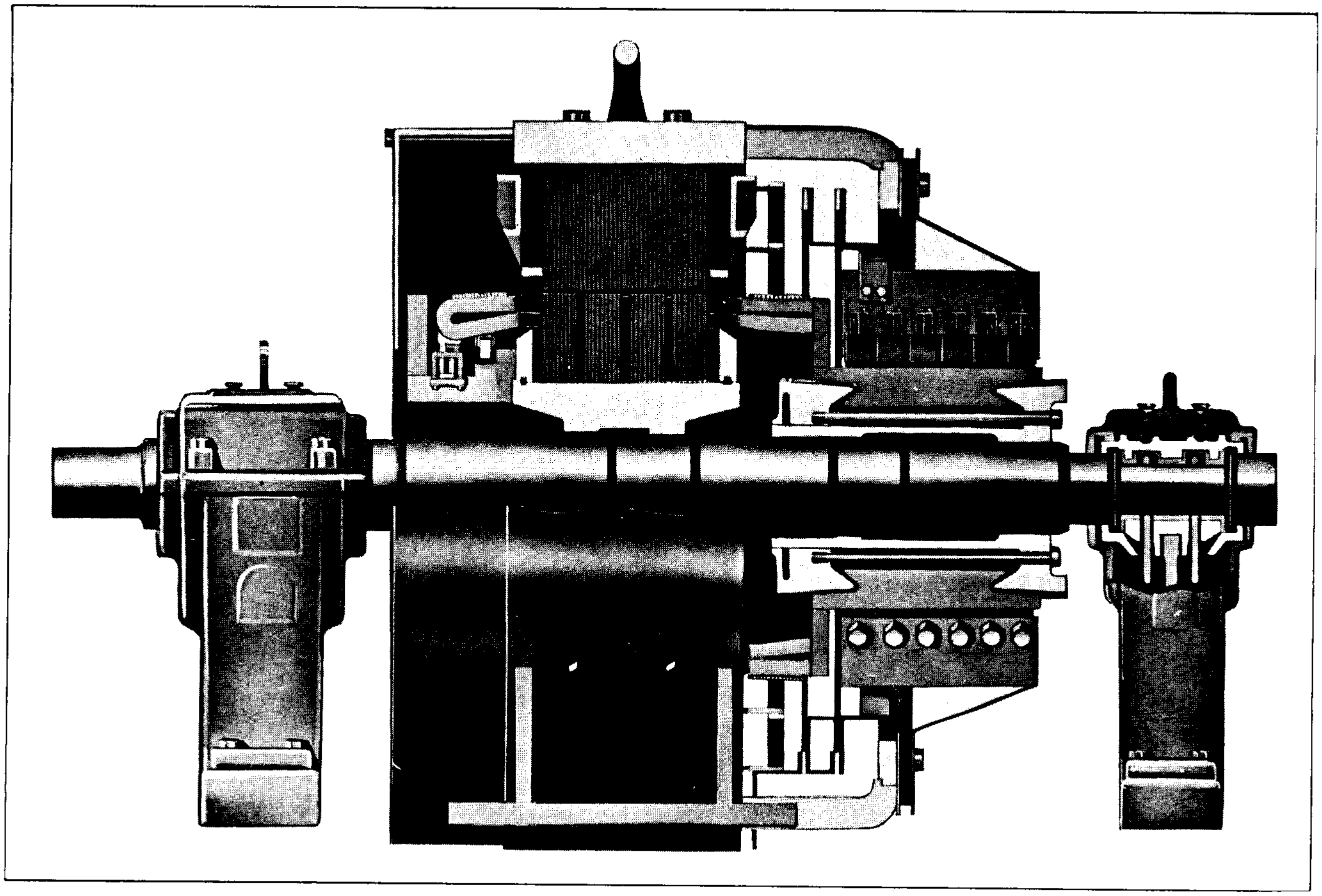


Fig. 1. *Section View of Direct-Current Generator*

Part One: Description of Construction

A general understanding of the construction features of the apparatus is necessary in order that the succeeding chapters on installations, operation and maintenance be the most helpful. Figure 1 shows cross section of typical machine. It is recommended that the reader study the illustrations along with the following description of component parts.

STATOR

Stator Frame

The frame, which is circular in form and constructed of rolled steel, has a rectangular cross section. The inside of the frame is smoothly bored providing a seat for the main and commutating field poles. The frame is accurately drilled for the pole bolts which pass through into the tapped holes of the poles.

Suitable lifting links are provided on the frame for ease in handling. Feet of ample size are electrically welded to the bottom of the frame to insure rigid attachment of the machine to the bedplate or sole-plates. The feet are machined parallel to the shaft and are drilled for the holding down bolts.

Main Poles

The main field poles are built up of steel laminations riveted together under pressure. The poles are held against the frame by bolts which pass through the frame and are threaded into *tapped* holes in the pole.

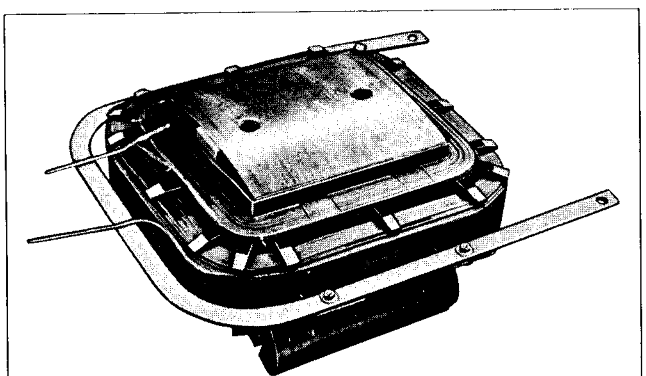


Fig. 2. *D-C Shunt and Separate Series Field*

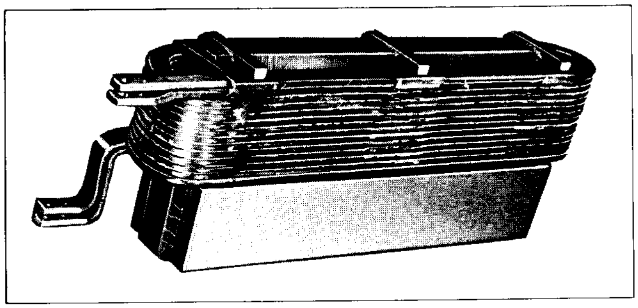


Fig. 3. *Edge Wound D-C Commutating Field Coil and Pole*

Main Pole Windings

The main pole has a shunt field winding and stabilized shunt motors and compound wound generators also have a series field winding. Usually the shunt field winding is wound directly on the pole over insulation. Some are wound in two sections so as to provide the necessary area for proper cooling. The series field winding may be insulated and wound in with the shunt field winding or made of copper bus and supported by hangers wound in with the shunt winding, Fig. 2, depending upon the particular design.

On the larger machines, a compensating winding or "pole face" winding is provided which consists of insulated bars inserted in the face of the main poles.

Commutating Poles

Commutating poles are also attached to the inside of the frame by bolts which pass through the frame and thread into the pole. These poles are symmetrically located midway between the main poles. The ends adjacent to the armature surface are properly beveled to give the correct commutating field form to provide the best commutation.

Commutating Pole Windings

Assembled on the commutating pole is the commutating field winding. These coils may be formed with edge wound copper and assembled on the poles over an insulating cell such as in Fig. 3, or as in the larger machines,

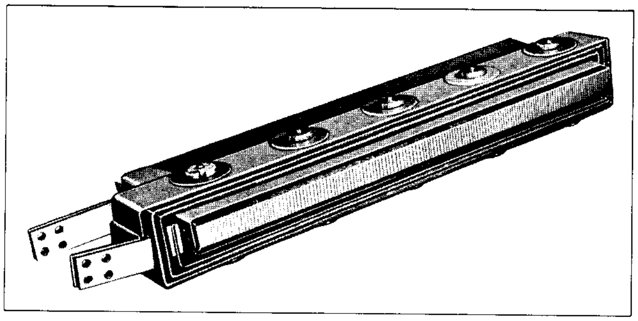


Fig. 4. *Flat Wound D-C Commutating Field Coil and Pole*

the copper may be flat wound and fastened to the poles over an insulating cell by insulated studs and nuts, Fig. 4.

Brush Rigging

The brush rigging is supported by a steel rocker ring which fits into a groove machined into arms welded to the commutator end of the frame. The rocker ring is held in position by a bolt and washer in each supporting arm.

The steel brushholder brackets are supported from the rocker ring by means of insulated bolts and insulating washers.

Double-brush-type brushholders are attached to the brackets. These holders may either be of 2 gang construction as in Fig. 5, or of 3 gang construction as in Fig. 6. Each holder has a finger which presses firmly against the top of the brush by means of a spring, thus insuring uniform pressure between brush and commutator. The brushes have flexible copper shunts that are connected to the brushholder to carry the current and thus the springs and the brushholder box do not conduct current.

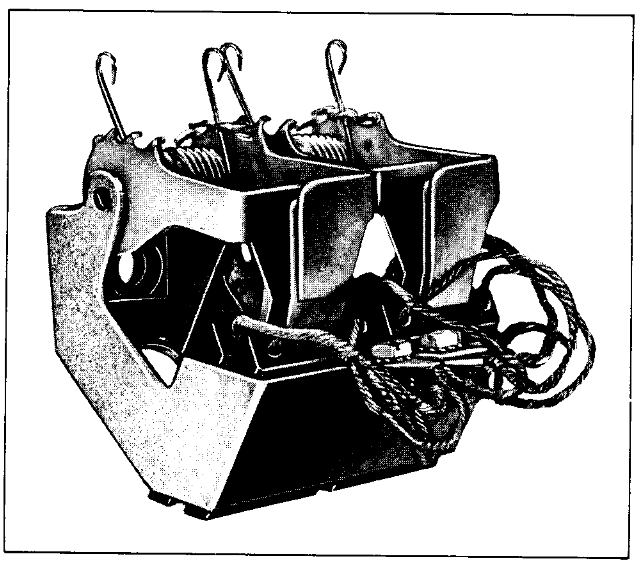


Fig. 5. *Two Gang Brushholder for D-C Generators and Motors*

Covers

Standard open machines are supplied with a rear endbell that directs the natural flow of air through the windings so as to prevent re-circulation of the air around the rear end turns.

Many types of enclosures may be supplied such as drip-proof, open, or forced ventilated applications and the equipment is so designed to meet the specifications of the order.

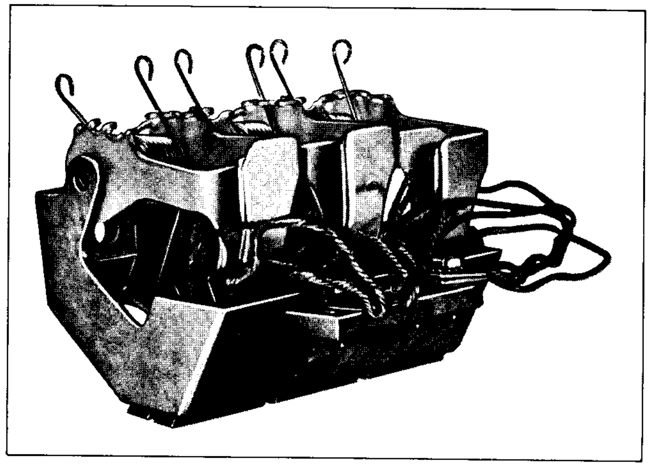


Fig. 6. *Three Gang Brushholder for D-C Generators and Motors*

ARMATURE

Armature Core

The armature core is built up of punched laminations of special electrical sheet steel which is carefully annealed and treated so that the losses will be a minimum. The punchings are keyed to a spider which in turn is bored and keyed to the shaft. In some machines the punchings are assembled directly on a fluted shaft.

Ventilating spaces are formed between the endplates and the end of the core as well as at intervals along the length of the core by means of spacers. These vents permit cooling air to flow radially through the core, thus properly cooling the armature.

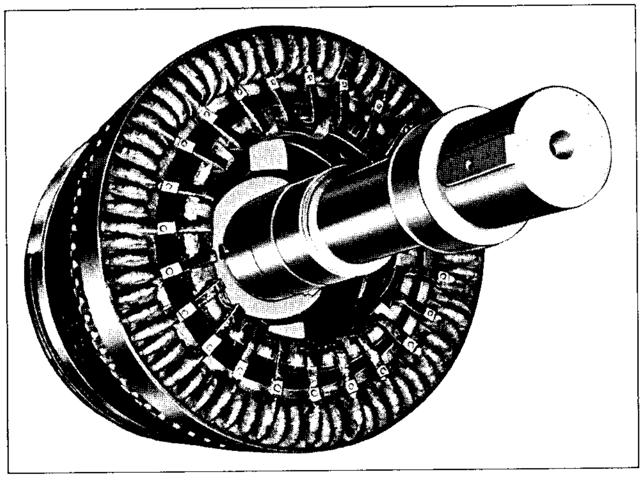


Fig. 7. *D-C Armature Cross Connections*

Armature Windings

The armature coils are form wound. Eddy currents are reduced to a minimum by selection of suitable conductor and strand sizes. The assembled group of insulated wires is impregnated with a solventless thermosetting resin to completely fill all air spaces and to solidify the coil.

Wedges hold the coils in the slot. The armature coils are usually (depending upon type of winding) cross connected in the rear. The front and rear coil extensions are banded securely. See Fig. 7.

Commutator

The commutator is made up of hard drawn copper bars held in position by two steel "V" rings which are part of commutator spider. The two "V" rings are drawn together by steel bolts. The commutator necks are of hard-rolled copper brazed to the bars. The armature conductors are soldered or brazed to the upper portion of the commutator necks. Plate mica formed in V-rings is used to insulate the copper from steel. Mica plate is used for the insulation between bars and is undercut 1/16 of an inch.

Shaft

The shaft is of either axle or forged steel. It is to be noted that in many machines, the commutator spider is fastened to the armature spider so that the shaft can be pressed out without disturbing the windings; however, on some machines the commutator and armature spiders have to be separately mounted on the shaft, or the armature punchings are built directly upon flutes on the shaft, in which

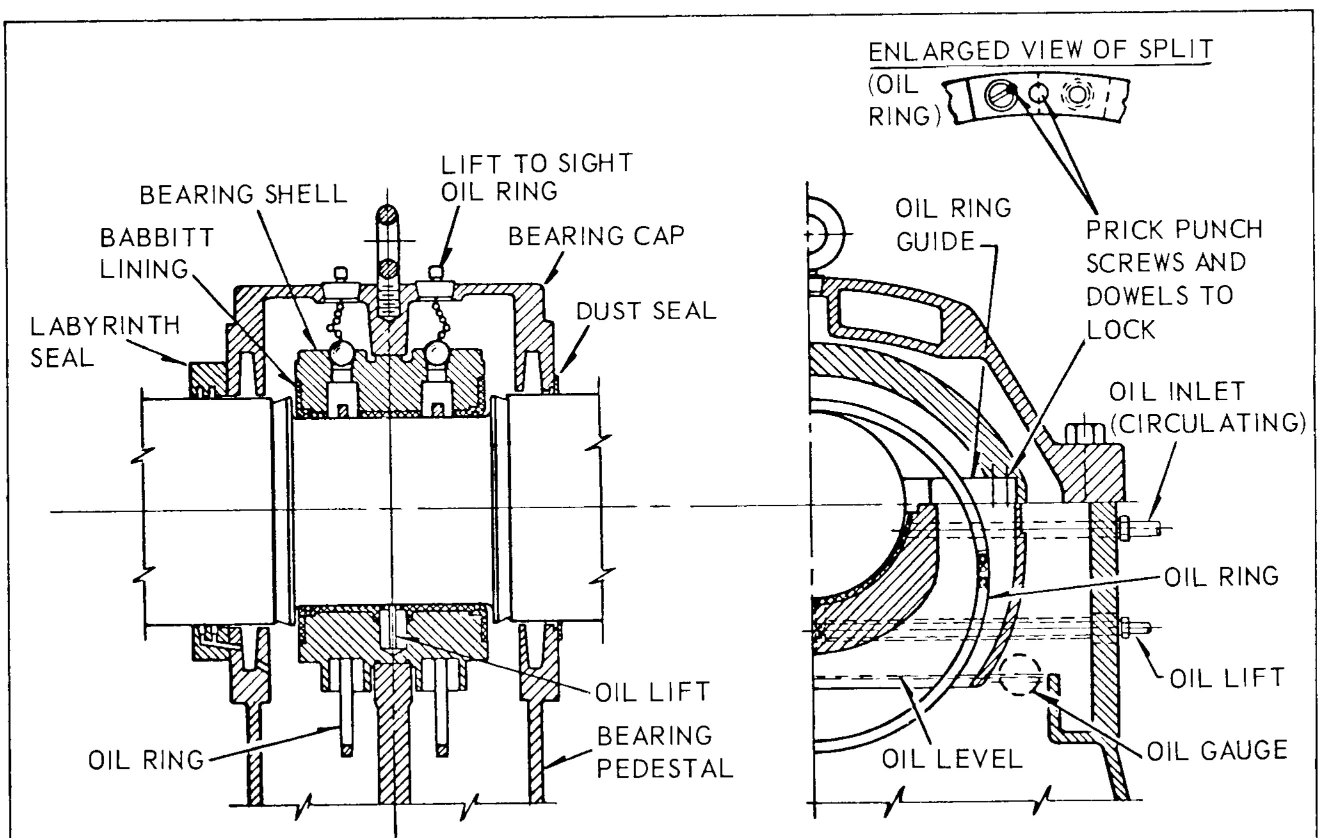


Fig. 8. *Cross-Section of Typical Sleeve Brg. Assy.*

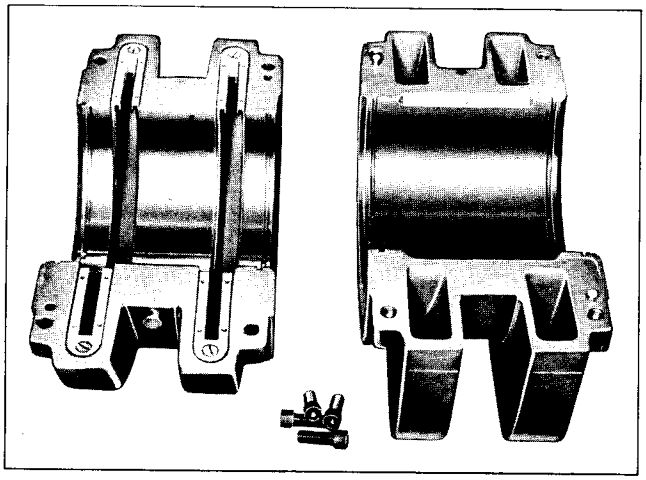


Fig. 9. *Split Section of Sleeve-Bearings*

case the shaft cannot be pressed out as a unit. The factory representative should be contacted to give specific recommendations on the procedure to follow before any attempt is made to remove a shaft.

BEARINGS

There are two general styles of bearings used on these machines, sleeve bearings and anti-friction bearings.

The various anti-friction type bearings are usually grease lubricated at low speeds and oil lubricated at high speeds.

Sleeve bearings are oil ring lubricated. They are provided with oil rings which rotate with the shaft, dipping into a bath of oil in the bearing housing, thus carrying oil up and over the journal. There are openings at the top of the bearing cap for inspection of the oil rings. A glass sight gauge is normally provided on the oil reservoir for determining oil level. There is a drain plug which allows the oil in the reservoir to be removed.

Oil Ring Assembly and Removal

Oil rings used in sleeve bearings are made of brass in two halves, joined and machined all over to close tolerances as a ring to insure balance. For this reason, when removing the oil ring from the shaft, care must be used in opening the ring joints.

After removing the screws, which must be replaced in the same position, use the wooden or plastic handle of a screw driver to alternately and gently tap at the side of the splits to open the ring joint while supporting the ring to prevent distortion.

For assembly of the ring reverse the above procedure. It is only necessary to engage the fit at the ring split and use the screws to pull the split of the ring into position by alternately tightening the screws at each split. Lock screws by prick-punching at the edge of the counterbored hole and lock dowel by prick punching at the center of the dowel on one end only.

Note: **There should be no screws or dowels extending beyond the sides of the ring. The splits of the ring must be smooth on the sides as well as in bore. All burrs must be removed. Ring must be handled carefully to prevent bending or damage at the splits.**

On some large high speed machines the loss in the bearings may become sufficient that the heat cannot be dissipated by the bearings alone at a permissible temperature rise. In such cases, an external means of dissipating the excess loss must be provided.

The standard method is to circulate the oil from the reservoir through external coolers to the bearings by means of a motor driven pump. The rate of oil circulation in the bearing and water circulation in the cooler depends upon the bearing loss. Suitable pipe connections are provided in the bearings to permit the use of oil circulating systems.

Bearing assemblies have only minor differences whether assembled in brackets or on pedestals. Some small sleeve bearings on exciters are not split, the bearing being made to slide out from the bracket axially.

Note: **When replacing bearings alignment is to be checked.**

When bearing temperature detectors are supplied they are mounted on the side of the bearing housing and the

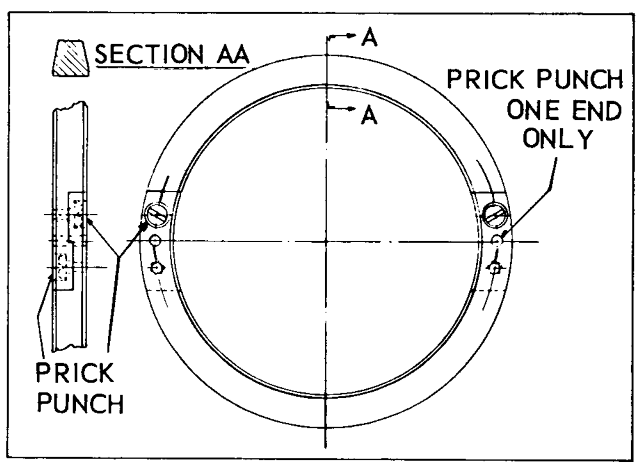


Fig. 10 *Oil Ring Assembly*

sensitive portion of the instrument is embedded in the bearing shell very close to the bearing babbitt.

All sleeve bearings have babbitted oil ring guides to prevent side wear of the oil rings. Pedestal bearings are split horizontally and have a relief at the split to distribute the oil evenly over the entire bearing surface. See Figs. 8 and 9 for a typical sleeve bearing assembly.

Note: **All pedestals are to be assembled using Permatex #2 cement or equivalent on the split between the pedestal cap and the pedestal base. Spread the cement thin on the split.**

When assembling the labyrinth seal, use a very thin coating of Permatex #2 or equivalent on the mating surface of the seal. Labyrinth seal drain holes must not be clogged with the coating material.

Felt seals normally supplied as dust seal should be set within .002 inch of the shaft diameter.

The grain of the felt must be perpendicular to the shaft diameter.

Copper dust seals may be adjusted to "ride" the shaft and should not have more than .002 inch all around the shaft.

Variations in reluctance in the magnetic circuit of rotating machine may cause cyclic changes in the amount of flux which links the shaft. This change in flux may generate sufficient voltage to circulate current through the circuit consisting of shaft, bearings, and bedplate or reinforcing in the concrete. If this current is permitted to flow, it soon has a destructive effect on the shaft journal and bearings.

It is not practicable in the design of all machines to completely avoid the induction of some shaft voltages, therefore, some machines are provided with one or more insulated pedestals. (See Fig. 12.) Pedestal insulation is fully covered on Page 13 of this book.

When shaft grounding brushes are supplied, the shaft track on which the brushes ride must be kept clean for brushes to remain effective.

Bedplates

Bedplates, when provided, are fabricated from standard structural shapes, arranged to obtain the maximum rigidity for the mass of material used. For some machines, soleplates are supplied, which consist of separate side rails and end rails for the bearings. These rails are not joined at the corners but are mounted separately on the foundation

Part Two: Installation

General

The following instructions and precautions are intended to aid in the installation of d-c motors and generators. In many cases the instructions are of a very general nature since the wide variety of types and sizes and the numerous special features that may be included make it difficult to give detailed instructions that are applicable to all units. The service of an experienced erection engineer is invaluable and must be relied upon for a great many of the details of installation.

RECEIVING

Before shipment, all machines are inspected, and tested to eliminate electrical and mechanical defects. If the crate or wrapping appears damaged upon receipt, the machine should be unpacked at once, in the presence of a claim adjuster, and all apparent injuries and breakage reported to the carrier.

If there is an impact meter on the car, this meter should be checked with the claim adjuster and forwarded immediately to the E. Pgh. Works per directions attached to the meter.

Important: **When writing to the Westinghouse Electric Corporation concerning the machine, always give the serial number which appears on the nameplate and on the end of the shaft.**

Storing

Apparatus which cannot be installed as soon as received should be unpacked, examined, and stored in a room which is clean and dry and where temperature variations are small and slow. It is very important to keep the windings dry since moisture tends to lower the insulation resistance and increase likelihood of insulation breakdown. If possible the machine should be kept warmer than the room air by heaters. Heaters must be such that the products of combustion do not condense on the electrical parts or form a fire hazard. Electric heaters are most suitable for this purpose.

If nothing else is available, it will be possible in some cases to keep the machine dry and warm by placing a number of large light bulbs with the machine in a tarpaulin enclosure. The tarpaulin should allow a small amount of air circulation. Metal surfaces not covered by rust resisting coating should be so covered.

Handling

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

Lifting of machines should be done with the greatest of care. The stators are provided with lifting eyes 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 rotors should be lifted preferably with rope slings looped around the shafts. In no case should the ropes or chains be allowed to exert pressure on the windings, commutator, collector rings or journals.

Reference to the outline drawing will indicate whether the assembled machine can be lifted as a unit.

The armature and stator may be lifted as a unit in machines whose armature diameters are 45 inches or less.

LOCATION

It is important that the location of the machines meet the requirements of the National Board of Fire Underwriters and all local regulations. The following additional considerations should also govern the location:

1. Install the machines so that they are well ventilated and easily accessible for cleaning, inspection and assembly.

2. Avoid exposure to mill and coal dust or any other injurious substances.

3. Protect the machines from moisture and chemical or oil fumes.

The motor room must be well ventilated so that the hot air can escape and will not be recirculated through the machine. Unless the room is large and well ventilated, natural ventilation will not be sufficient. If the machine is designed to take air from the pit, suitable ducts must be provided in the foundation. The outline drawing shows the recommended minimum size of the pit and location of ducts.

FOUNDATION

The foundation should consist preferably of solid concrete walls or piers and should be carried down far enough to rest on a solid sub-base. A competent consulting engineer who is familiar with foundation design should design and supervise this part of the installation.

If it is necessary to support the bedplate on steel girders instead of concrete, the girders should be well braced and supported by adequate columns so as to prevent vibration. A rigid foundation is essential so that vibration and misalignment during operation will be reduced to a minimum.

The pit beneath the machines, if required, should be deep enough to give ample working space for connecting the leads which are normally brought out below the machine.

Foundation bolts should be accurately and firmly located in proper location.

PROCEDURE BEFORE ERECTION

The erection or "setting up" of the d-c machine is a matter requiring great care and attention to detail, for the subsequent successful performance of the machine will depend to a great extent on its line-up and rigidity with respect to the foundation. Before beginning to erect the machine, the following points should be checked to avoid trouble once the operation has begun:

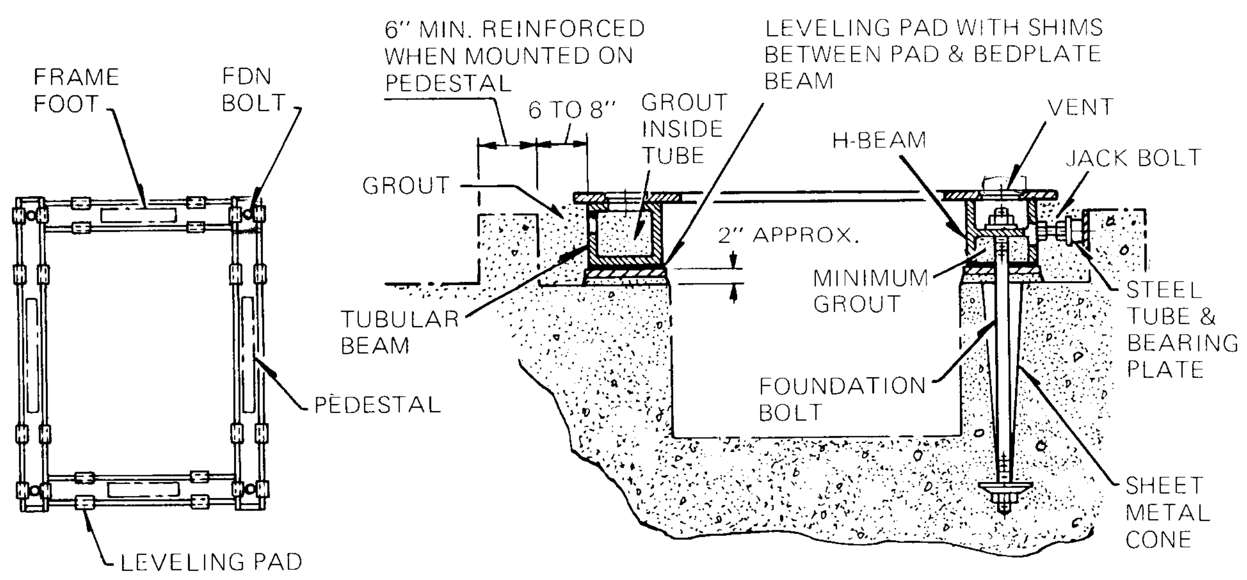
1. Check all items at the site of the erection against the manufacturer's shipping report. If all the equipment cannot be accounted for, the shortage should be reported at once to avoid undue delay in erection. Likewise, any damaged equipment should be reported as soon as discovered.

2. Locate foundation bench marks to permit establishing the centerline of the unit and the elevation of the foundation surface.

3. Check the foundation against the outline drawing of the machine to be sure that the pit, if any, and any cable, bus or ventilating ducts that may be indicated have been provided in their proper locations and are of suitable dimensions to permit correct assembly of the unit and its accessory equipment.

4. Check the size, location and elevation of the top of the foundation bolts against the outline drawing.

5. Refer to schematic arrangement shown in Fig. 11. The forms for the rough concrete foundation should provide



Note: Foundation bolt for tubular beam similar to foundation bolt for H-beam. Jack-bolts when used may remain when grouting bedplate.

Fig. 11. *Method of Anchoring Foundation Bolts and Typical Arrangements of Bedplates, Leveling Plates and Shims*

about 6 inches space at all sides of the bedplate and 2 inches space below the bedplate when unit is to be grouted in place. Foundation bolts can be set with clearance pipe or galvanized sheet metal cones as shown in Fig. 11. A tight fit is required at the bottom to the bolt and at the top to the form to prevent leakage of concrete into the clearance area. The top cone diameter may be 2 inches larger in diameter than the bolt.

Leveling pad locations may be determined from the outline drawing. These pads must be located on each side of and adjacent to each foundation bolt. At points of heavy load or at wide spans such as below the motor pedestal support section, additional pads should be placed as shown in Fig. 11. These leveling pads may be cut from 1/2 inch by 2 inches hot-rolled steel bars and the length will vary from 6 inches up, depending on the size of the bedplate. The pads must be straight and free from burrs on the top side. The pads should be set in a stiff grout and must be leveled to the correct elevation. Small forms for the pad grouting may be made from either sheet metal or wood. The sides of the forms should be tapered to allow easy removal. The pad elevation should be selected so that a shim may be used at every pad for preliminary alignment in case lowering of the bedplate elevation is necessary. It is good practice to use 1/16 inch shims on the pad. All shims used should be straight and clean.

A transit survey will establish the correct elevation for the first leveling pad. Adjacent pads can then be set level with the first pad using a leveling bar 6 to 8 feet long and a 12 inch machinist's level. The level and leveling bar are kept together and moved as a unit, end for end, as progress is made around the bedplate pad positions. This procedure compensates for any minor error in the leveling bar and the level. The pads are tapped into the stiff grout to establish the correct elevation while simultaneously being leveled in both directions with small levels.

After the leveling pad grout is cured, the bedplate is cleaned and set in place on the shims and all foundation bolts are tightened. The bedplate is checked for level and adjustments made as required, making certain that all shims are tight. For horizontal alignment, the entire bedplate is easily shifted by using jack bolts which are made with a small section of pipe and a nut and bolt as shown in Fig. 11.

For purposes of description of the erection operation, these machines will be divided into two classes:

(a) Those shipped assembled–Bracket bearing machines and pedestal bearing machines and pedestal bearing machines attached to a bedplate.

(b) Those shipped not assembled–Machines with pedestal bearings and bedplates or soleplates.

For purposes of explanation of the erection, a two bearing machine will be used as an example. It is understood that the principles of lining up a shaft are the same no matter how many bearings are supplied.

Important: **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. 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. Be sure that all connections are clean and tight. This is especially important where machines have fields with parallel circuits.**

Erection of Machines Shipped Assembled

Bracket bearing machines and pedestal bearing machines shipped assembled are erected in the following manner:

1. Set the assembled machine onto the roughened foundation with the leveling plates in place. The foundation should be of such elevation that the bedplate, feet or slide rails, may rest on the leveling plates which are placed so that they will carry the weight of the machine without distortion.

2. Remove bearing housing cap and bearing cap at both ends of machine. Place an accurate spirit level on the bearing housing split and bring machine to level and elevation by means of shim stock of approximately the same area as the steel leveling plates and placed between them and the bottom of the bedplate. Also check level using the spirit level on the journal. Check for longitudinal clearance at the bearings with the shaft end play all out in both directions. Apply thin coat of Permatex between bearing housing and cap at assembly.

3. Align as under "Coupling Alignment and Allowances".

4. Run slowly, if possible, after making tests and adjustment under "Preparing for Use" page 16. Check oil ring rotation.

5. Recheck alignment after foundation bolts are tight.

6. Grout in bedplate as under "Grouting".

7. Connect permanent wiring.

8. Check pedestal insulation, if used, to make sure it is effective. See page 13.

Coupling Alignment and Allowances

The machine is aligned by the use of a thickness gauge between coupling faces at top, bottom and sides.

Then rotate the shaft in the bearings 180° from the original checking position and recheck the coupling separation at top, bottom and sides to again prove the shaft alignment and truth of the coupling faces. The factory allowable tolerances for such alignment are:

(a) The difference between readings at either side—.001" for any size flange.

(b) The difference between the readings at top and bottom—not to exceed .002" per 12" of flange diameter, but a maximum of .004" for any diameter flange.

If the openings at the top and bottom of the coupling faces are not uniform the larger opening must always be at the bottom.

With single bearing units, the couplings should be opened just far enough so that the weight on the coupling end of the shaft is carried by the pilot fits, taking care that the fit in the coupling is not so tight that it affects the alignment measurement. Remove housing and bearing caps to check shaft to bearing alignment.

With two bearing units, the coupling faces should be entirely isolated from each other and the vertical and lateral position of the machine should also be checked in each of the above positions by means of an accurate steel straight edge held on the edges of the flanges parallel to the shaft.

The longitudinal location should be such that the armature is in the center of the end play allowance at the normal running position.

Flexible couplings should not be forced to accommodate excessive misalignments. This will produce undue wear and can cause vibration and thrust. Flexible type couplings should be aligned by checking between the coupling hub faces with feeler gauges and with dial indicators from one hub cylindrical surface to the other. This will eliminate both offset and angular misalignment. Mount the indicator on one shaft and read radial as well as axial variations between the coupling halves as they are revolved slowly together. Where the two half couplings float axially with respect to each other, it is necessary to use two indicators mounted 180° apart and obtain the difference in the two axial readings in order to check the angular alignment. If the coupling manufacturer supplies specific instructions on alignment, they should be followed as those given here are a summary of general practices.

Grouting the Bedplate

When the alignment is satisfactory with the foundation bolts drawn up tight, the bedplate may be grouted in accordance with Fig. 11.

A wooden form is the best method of retaining the grout inside and outside the bedplate. The grout is mixed in the proportion of two parts clean sand to one part Portland cement. A stiff grout should be tamped tightly under the base of the bedplate. The outline drawing gives minimum and recommended grouting dimensions.

The entire operation of mixing and pouring the grout should be completed without interruption and as rapidly as possible.

Erection of Machines Shipped Not Assembled

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.

Erection of Belted or Coupled Motors and Generators with 2 or More Bearings

1. Set the bedplate with pedestals on the foundation and adjust between the bedplate and foundation with leveling plates to the approximate correct level and elevation.

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

3. After covering the journals with a film of oil, lower the rotating part into the bearings using rope slings around the shaft taking care that the ropes do not touch the windings at the back end of the armature—never support the armature wholly or in part by the commutator. Fill the bearings with oil to the proper level. See page 33 for

type of oil to use. Place the bearing caps in position and tighten the bolts.

4. Clean the contact surfaces of both halves of the frame. Set the upper half in position and bolt it to the lower half. Tighten the commutating pole bolts first and the frame lug bolts second. Set the upper half of the rocker ring in place and, after bolting the halves together, see that it moves easily in its seat.

5. With bearing housing caps and bearing caps removed, place an accurate spirit level on the bearing housing splits and bring the assembled machine to level and elevation by means of shim stock of approximately the same area as the steel leveling plates and placed between them and the bottom of the bedplate. Check for longitudinal clearance at the bearings with the shaft end play all out in both directions. Back-check level using the spirit level on the journals.

6. Accurately align the shaft with the driving or driven device. See "Coupling Alignment and Allowances", page 9, for coupled machines. For belt driven machines, the shafts must be parallel and the center lines of the pulleys directly opposite.

7. Set the foundation bolts solidly.

8. Check to see if the air gaps are even by feeler gauge measurements between main poles and armature at both front and rear of the machine. Adjust, if necessary, horizontally by shifting the frame and vertically by means of steel liners placed under the frame feet.

9. Reconnect the armature leads and the field wiring connections inside of the machine. Check to see if brush alignment, spacing and position are correct. See page 20 for details. Grind the brushes to a perfect seat using sandpaper only. See Fig. 28 on page 34. See that brushes move freely in the holder and are held under an equal pressure, usually 2 to 2-1/2 pounds per square inch of the cross-sectional area. Make other tests and adjustments as in "Preparing For Use", pages 16-23.

10. If possible run slowly, and recheck alignment and level. Check oil ring rotation. Then grout as described under "Grouting", page 9.

11. Finish assembly by installing permanent wiring and endbells, covers, assemble bearing and housing caps, etc. Use a thin coating of Permatex #2 or equivalent between bearing housing and cap.

12. Check pedestal insulation, if used, to make sure it is effective. See page 13.

13. Note: All frames and pedestals are located by doweling at the factory.

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. With the bearing housing and cap not assembled, check alignment of shaft to bearing.

3. Locate the bearing pedestal so that the center of the bearing is on the horizontal axis through the connecting shaft.

4. 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. Never support the armature wholly or in part by 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.

When 2 or more motors are coupled together, refer to outline for an alignment drawing and coupling bolt assembly and tightening information. If no alignment Dwg. is shown on outline, proceed with alignment in par. 5 below.

5. Adjust the bearing pedestals to obtain correct coupling alignment, as described in "Coupling Alignment and Allowances" 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. See page 33 for type of oil to use. Assemble bearing housing cap and bearing cap. Apply a thin coat of Permatex #2 or equivalent to the split surface of the pedestal before replacing bearing housing cap.

6. 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).

7. Clean the contact surfaces of both halves of the frame. Place the upper half in position and bolt to the lower half. Tighten the commutating pole bolts first and the frame lug bolts second. Set the upper half of the rocker ring in place and, after bolting the halves together, see that it moves easily in its seat.

8. Set the foundation bolts tightly.

9. Check to see if the air gaps are even by feeler gauge measurement between main poles and armature at both front and rear of machine. Adjust horizontally by shifting the frame and vertically by means of steel liners placed under the frame feet.

10. Reconnect the armature leads and the field connections inside of the machine. Check to see if brush alignment, spacing and position are correct. See page 20 for details. Grind the brushes to a perfect seat using sandpaper only. See Fig. 28 page 34. See that brushes move freely in the holder and are held under an equal pressure, usually 2 to 2-1/2 pounds per square inch of cross-sectional area. Make other tests and adjustments as in "Preparing for Use", pages 16-23.

11. If possible, run slowly and then recheck alignment and level. Check oil ring rotation. Then grout bedplate or soleplate as described under "Grouting" page 9.

12. Finish assembly by installing permanent wiring, endbells, covers, etc.

13. Check pedestal insulation, if used, to make sure that it is effective. See page 13.

Erection of Engine-Type Machines

1. Set the soleplates, if any, in place and level up to the 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 frame and rocker ring in position.

3. With machines of large size, the armature must be pressed upon the shaft at the point of installation, if this has not been done at the 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 1/32 of an inch.

Before preceding 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. Care 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. Another method is to set the armature 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 and after covering the journals with oil, lower it into its bearings using rope slings around the shaft, taking care that the ropes do not touch the windings at the back end of the armature. Never support the armature wholly or in part by the commutator. Do not allow workmen to stand on the commutator.

Fill the bearings with oil to the proper level. See page 33 for type of oil to use. Place the bearing caps in position and tighten the bolts.

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 upper half in position and bolt it to the lower half. Tighten the commutating pole bolt first and the frame lug bolts second. Set the upper half of the rocker ring in place and, after bolting the halves together, see that it moves easily in its seat.

7. Set the soleplate bolts solidly.

8. Check to see if the air gaps are even by feeler gauge measurement between main poles and armature at both front and rear of machine. Adjust horizontally by shifting the frame and vertically by means of steel liners placed under the frame feet.

9. Reconnect the armature leads and the field connections inside of the machine. Check to see if brush alignment, spacing and position are correct. See page 20 for details. Grind the brushes to a perfect seat using sandpaper only. See Fig. 28, on page 34. See that brushes move freely in the holder and are held under an equal pressure, usually 2 to 2-1/2 pounds per square inch of cross-sectional area. Make other tests and adjustments as in "Preparing for Use", pages 16-23.

10. If possible, run slowly, and then recheck alignment and level. Then grout the soleplate as described under "Grouting", page 9.

11. Finish assembly by installing permanent wiring, endbells, covers, etc.

12. Check pedestal insulation, if used, to make sure that it is effective. See page 13.

Special Design Considerations

Engine-driven generators are designed with a special allowance made in their rotors for torsional vibrations set up by reciprocating engine prime movers. The total rotational inertia of the generator is so adjusted to avoid resonance with any engine mechanical parts and also to avoid resonance with the electrical system from any impulse either in the engine driving the generator or from other engines in the station at the time of its installation. This entire torsional study is handled by the engine builder who supplies a flywheel of proper design for elimination of torsional vibration as completely as possible. Therefore, when changing generators from one engine or location to another, it will be necessary to contact the engine builder to make sure that such problems are avoided.

Adjustment of the Air Gaps

After the units have been aligned the gaps should be checked as follows:

Measure the gaps under the two main poles located nearest the vertical centerline, from rear and front where possible. The maximum difference between these two gaps should not exceed .020". Gap adjustment is made by shims under the frame feet as necessary.

Measure the gaps on the two main poles located nearest the horizontal centerline from rear and front where possible. The maximum difference between these two gaps should not exceed .020". Adjustment is made by shifting the frame horizontally as required.

The air gap adjustment should include centering the commutator in the brushrigging. The final adjustment should give the best average centering for the armature in

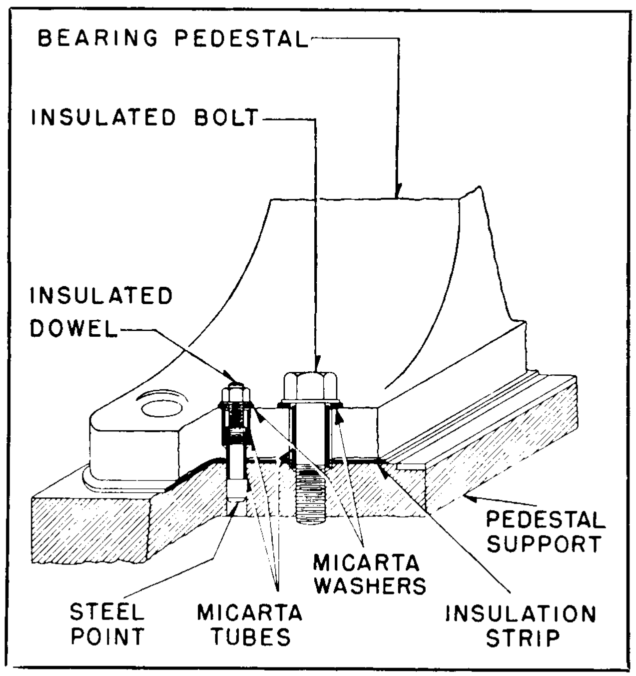


Fig. 12. *Method of Insulating Bearing Pedestal from Bedplate*

the main poles and the commutator in the brushrigging. Changes in individual pole air gaps and changes in individual brush arms should not be necessary since the machines were assembled and run at the factory.

Pedestal Insulation

Pedestal insulation is provided with certain machines of such a size or using such a combination of pole and punchings that shaft voltages cannot be avoided. This insulation is installed in order to break the circuit of the circulating current through the shaft, bearing and bedplate.

The insulation is usually provided on the outboard end between the pedestal and foundation or between the bearing shell and housing. The insulation consists of micarta sheets and tubes to insulate the pedestal, bolts and dowels from the bedplate in the more common insulated pedestal type of insulation. (See Fig. 12).

Care should be taken to see that there is no metallic connection between an insulated pedestal and the bedplate. If this precaution is not observed, the insulation becomes useless and bearing current is permitted to flow. Such metallic connection may be any of the following:

(a) Piping or conduit which touches both the pedestal and bedplate and which has no insulated union.

(b) Guard rail.

(c) Metal ladder set against the pedestal.

(d) Tools left in contact with both pedestal and bedplate.

(e) Pump or other device geared to the main shaft.

(f) Bearing temperature thermostat or relay etc. Connected to a grounded recorder instrument.

(j) Insulated dowel steel point may be bridging across insulation strip.

(h) Insulated tube or washer of insulated bolt may be cracked permitting creepage to ground.

(i) Insulation strip may be cracked or damaged permitting creepage to ground. A minimum of 1/4 inch of insulation strip must extend all around sides of pedestal.

A break in the insulation may occur during erection due to careless handling and it is well to test for this with a bell and battery or with a test lamp. To make this test a section in the shaft-pedestal-bedplate circuit must be free from ground.

CONNECTIONS

Connections for Parallel Operation of D-C Generators

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 cumulative compound-wound machines, the addition of equalizer connections between the machines is required.

In order to secure proper parallel operation, it is absolutely necessary that the voltage regulation characteristic of a shunt wound generator or of the characteristic of a compound-wound generator when operated as a shunt-wound generator be sufficiently drooping when

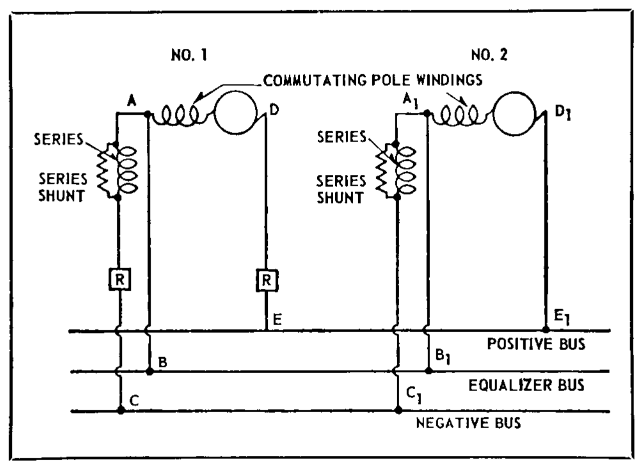


Fig. 13. *Diagram Showing Connections of D-C Generators for Parallel Operation*

measured at the point of paralleling or at the point of connection of the equalizer in the case of compound-wound generators. 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 24.

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

Part Three: Preparing for Use

ELECTRICAL TESTS AND ADJUSTMENTS

Insulation Resistance

The insulation resistance of the windings should be measured with a "Megger"* instrument. This measurement gives an indication of the condition of the insulation with regard to moisture and dirt. See Page 30 for details of this test.

The standard value of insulation resistance of a rotating machine is the least value which a winding should have after cleaning and may be evaluated from definitions and formulas from A.I.E.E.** It is recognized that it is possible to operate machines with insulation resistance approximately 1/10 of the standard value; however, the insulation resistance of the armature windings of machines in good condition is usually not less than one megohm.

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. The preferred method is baking in an oven but is often impractical. The windings can be dried out by use of external heat as from space heaters. They are usually dried out by circulating current through the windings. This can be done on field coils by raising the current so as to raise the tempature to 70°C and then adjusted to maintain that temperature until the coils become thoroughly dry. Armatures of generators and motors can be dried out by driving them with a separate motor and 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.

Important: **Do not circulate current through an armature while at standstill as localized heating will occur on the commutator and will cause permanent damage to it.**

In general, the drying should proceed slowly at first and the heat gradually increased as the insulation dries. The reason for this is that if vapor is formed from the moisture in the windings more rapidly than it is allowed to escape, the insulation is liable to damage from being ruptured by escaping steam. Keep in mind that insulation is more easily injured by overheating when damp than when dry. The temperature of the hottest observable spot should not be allowed to exceed 70°C total temperature.

Several hours or even days may be required for thoroughly drying out large machines.

During the drying out process the temperature should not be allowed to drop below that of the surrounding air as moisture then condenses on the coil surfaces and the effect of the previous drying would be largely lost.

During the drying out run, readings of the insulation resistance should be taken at regular intervals and plotted as a curve using time for the horizontal scale and resistance for the vertical scale. The drying out should continue until the resistance has begun to increase. If the insulation contains appreciable moisture the resistance will decrease during the first part of the drying out process.

Heating windings by current is more effective than any process of heating from the outside, such as enclosing the machine and heating the air by electric heaters, because in the former method the inside of the coils becomes hotter than the outside and moisture is driven outward. With external heating the reverse is true.

If the apparatus is to be stored before being put in service, consult the nearest Service Department for detail recommendations.

Caution: **Precautions against fire should always be taken when drying insulation. Flammable material should not come in contact with the heaters. Wiring connections should be substantially made and well checked. Fire extinguishers of the CO_2 type should be at hand.**

Brush Position on D-C Generators and Motors

For direct current machines, accurate adjustment of the brush position is necessary in order to obtain satisfactory commutation and regulation. If the brushes are shifted against rotation on a generator, the machine will receive cumulative compounding series field effect and reduced commutating pole flux which may cause poor commutation. With the brushes shifted with rotation, a generator will tend to be under-compounded and may not commutate properly. For a motor, a shift against rotation will increase the speed and a shift with rotation will decrease the speed, and less satisfactory commutation may result for both positions.

When the brush position on a machine has once been properly located, no shifting is afterwards required or

*Trademark of James G. Biddle Co., Philadelphia, Pa.

**Report #43 "Recommended Practice for Testing Insulation Resistance of Rotating Machines" (dated April, 1950)

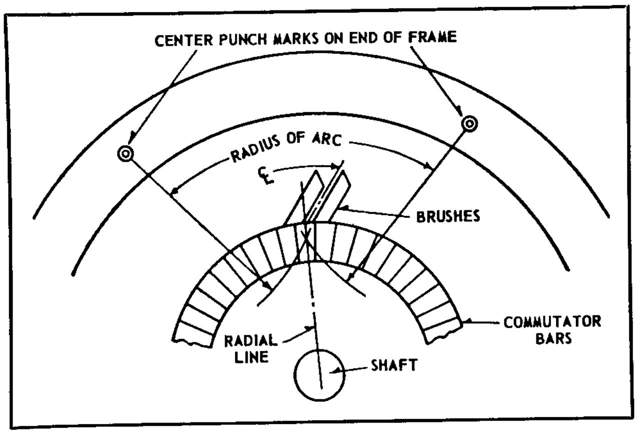


Fig. 16. *Method of Locating Factory Brush Position for D-C Generators and Motors*

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 Redetermination of Factory Brush Position".

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.

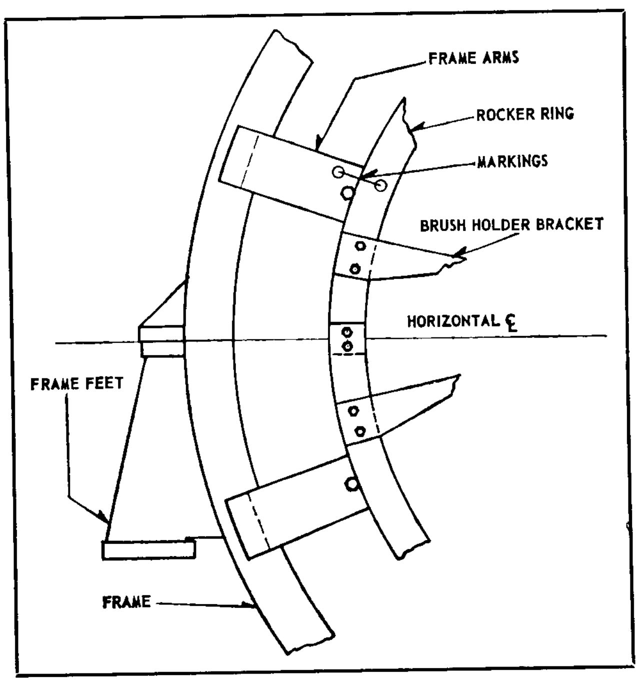


Fig. 17. *Locating Brush Position by Rocker-Ring and Frame Arm Markings on Standard D-C Generators and Motors*

Mechanical Re-Determination of Factory Brush Position

In the event that the brush position has been disturbed, the brushes should be relocated so that they are on the original factory setting. The following is the mechanical method for checking the factory brush position. See Fig. 16.

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 arc on the commutator. Due to the angularity of the brush contact on the commutator surface, the midpoint of the brush arc does not coincide with the centerline of the brush. Therefore, the midpoint of the arc periphery of the brush contact must be selected. Note that in the case where the brushes are staggered circumferentially, the midpoint of the effective arc must be used. 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.

On new installations another method may be used to locate the brush position, providing the brushholder brackets have not been disturbed from their original position on the rocker ring.

Located on left side of the machine on or just above the horizontal center line, a chisel mark is on the frame arm and rocker ring. Aligning the chisel marks locates the correct brush position. The chisel marks are identified by a center punch mark with a circle around them located at the outer end of each chisel mark. See Fig. 17.

In the event the brushholder brackets have been moved on the rocker ring then it will be necessary to locate brush position as illustrated by Fig. 16.

The chisel marks locating correct brush position on a reversing mill type motor are placed as shown in Fig. 18. Here the rocker ring base, rocker ring arms and the rocker ring are an integral part of the rocker ring assembly. Aligning the chisel mark on the rocker ring base and the split at the left side of the frame locates the correct brush position.

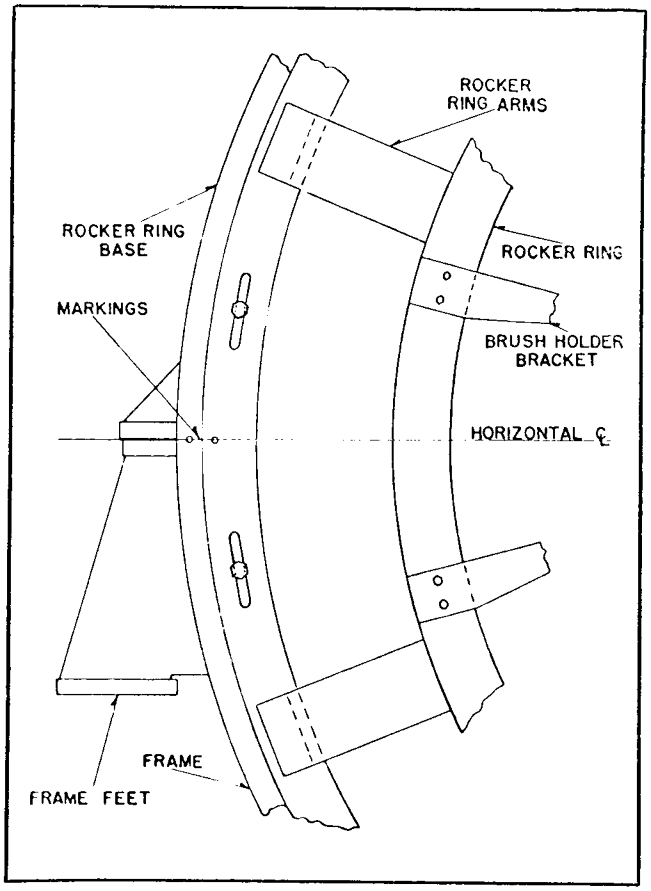


Fig. 18. *Locating Brush Position by Rocker-Ring Base and Frame Markings on Large Reversing Type D-C Mill Motors*

Locating the Electrical Kick Neutral

Where it is necessary to locate the electrical neutral position on a direct current machine in the field, it may be correctly and simply located by the electrical "kick" method if due care is exercised.

With the machine at standstill, raise all brushes. Determine the number of electrical bars. In a few high current, low voltage machines, there are two mechanical bars joined together by the commutator risers or "necks" to form one electrical bar. Treat each pair as one electrical bar in this case. Otherwise, the number of electrical bars is equal to the total number of bars in the commutator.

Determine the number of main poles and proceed as follows:

Number of Bars Evenly Divisible

If the number of bars is evenly divisible by the number of poles, then determine the throw. For example, if the machine has 20 bars per pole, such as with 160 bars and 8 poles, the throw would be bar 1 to bar 21. Then use a d-c voltmeter, preferably one having .5, 1.5 and 15 volt scales and place the voltmeter points on bars 1 and 21 in the approximate neutral zone. See Fig. 19.

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 as the switch is opened 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.

When the value of field current that is satisfactory is found, then move the voltmeter points to bars 2 and 22 and read deflection as the field is opened. If possible, 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.

Shift the rocker ring so the center line of the brush arc is over the correct neutral point. If the machine has double brushholders, be sure the center of the total brush arc is placed on the neutral. With machines with brushes staggered circumferentially, locate the midpoint of the total brush arc (distance from front of leading brushholder to rear of lagging holder) on the neutral mark.

Note: **After the rocker ring has been located on kick neutral, this in no way implies that it is the final brush position. The original factory brush position must be**

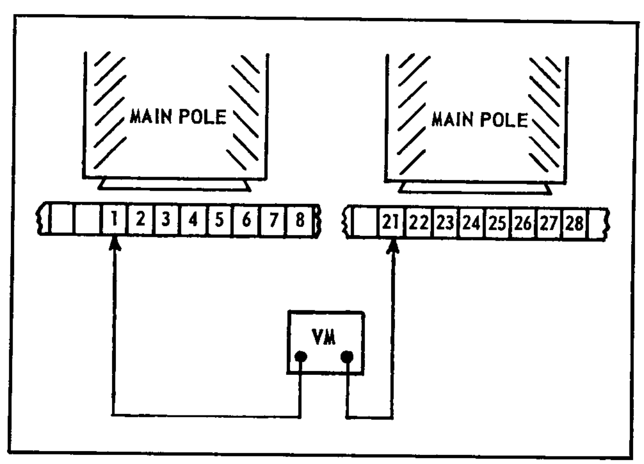


Fig. 19. *Instrument Connections for Reading Voltage Induced in D-C Armature*

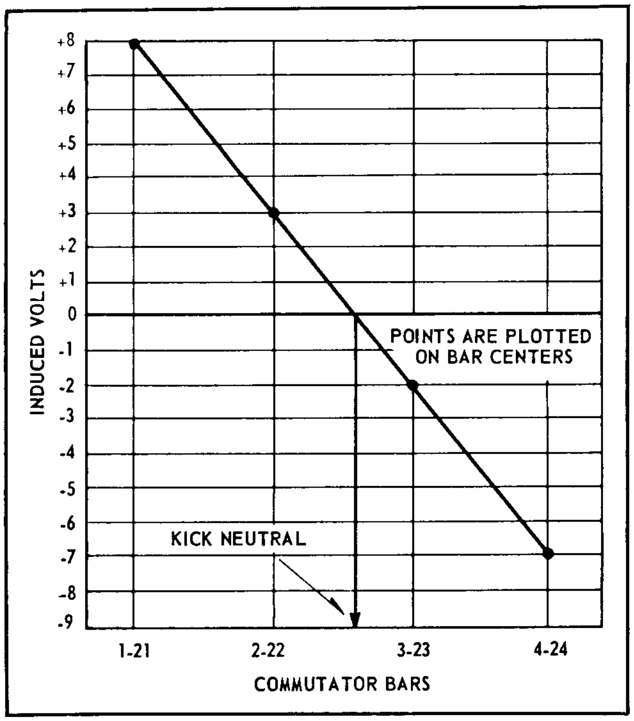


Fig. 20. *Curve Method of Determining Neutral Bars Evenly Divisible for D-C Armatures*

ascertained in respect to kick neutral and the rocker ring shifted the proper amount in the prescribed direction.

If the armature cannot be rotated, and the number of bars is evenly divisible by the number of poles, the neutral can be located by use of a curve or calculation. Proceed as described in previous paragraphs to adjust the field current. When the value field current that is satisfactory is found, then read induced voltages between 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, and plot these induced voltages as ordinates and the numbers of commutator bars as abscissae, using first number in each pair. Keep in mind that the number indicates the center line of the end of the bar. Determine the point of exact reversal from the plot, mark the relative position on the commutator. This is the correct neutral. Shift the rocker ring so that the center of the brush arc is set over this point as described in the preceding paragraph. See Fig. 20.

Number of Bars Not Evenly Divisible

If the number of bars is not evenly divisible by the number of poles (such as 164 bars and 8 poles which is 20-1/2 bars/pole), then proceed as in the previous method except read the voltage with the voltmeter points on bars 1 and 21 in the approximate neutral zone. Then move the voltmeter points to bars 1 and 22 and read again. If possible, rotate the armature slightly until the two readings are equal but opposite in polarity. This indicates the correct neutral is exactly on the centerline 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 this position.

If the armature cannot be rotated and the number of bars is not evenly divisible by the number of poles, (such as 20-1/2 bars), then proceed as in the previous paragraphs except read voltages between bars 1 and 21, 2 and 22, 3 and 23, until a point of reversal is reached. Then read between bars 1 and 22, 2 and 23, 3 and 24, etc. Then record four readings for each group of readings, two on either side of each reversing point. Plot each set as in previous paragraph. See Fig. 21. Then the neutral point is the midpoint between the two points of reversal. Mark the commutator and shift the rocker ring as in the previous paragraph.

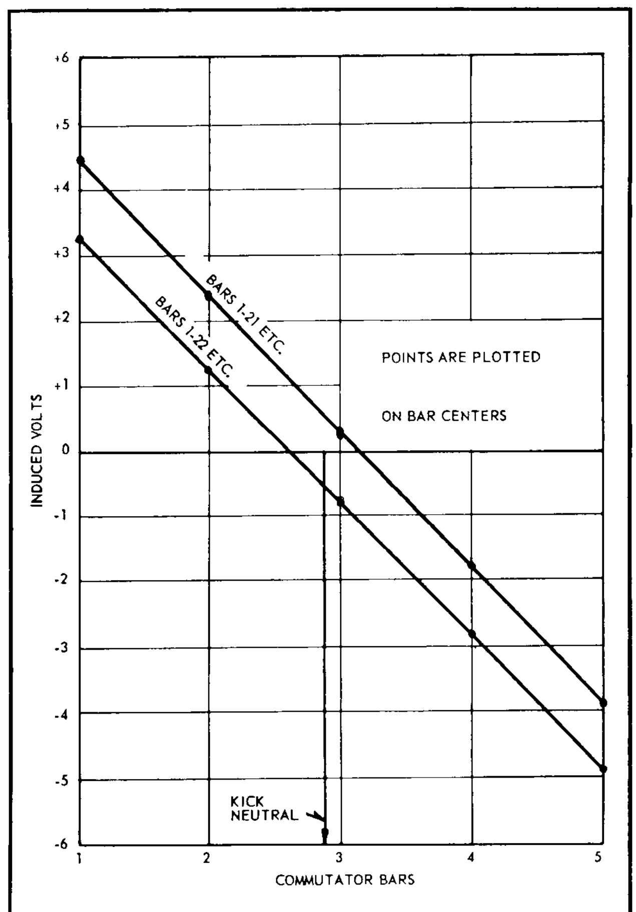


Fig. 21. *Curve Method of Determining Neutral Bars not Evenly Divisible for D-C Armatures*

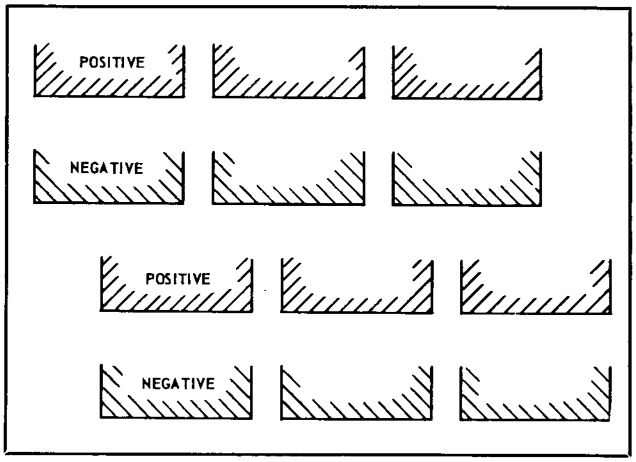


Fig. 22. *Correct Method of Staggering Brushes Axially on D-C Generators and Motors*

Important: **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 once been disturbed to relocate the brushes so that they will be on the factory setting.

Before taking any readings to determine kick neutral, the commutator should be checked to determine as whether or not there are two mechanical bars for every electrical bar. This is done by taking a reading such as from 1 to 22, 1 to 21, and 1 to 23. If all three readings are different, this will indicate that there is only one mechanical bar for every electrical bar. If any two of these readings would be alike, that would mean there are two mechanical bars for every electrical bar and after the two mechanical bars have been paired off all the way around the commutator, it can be treated as above.

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 two adjacent rows of brushes should be accurate to within ±1/32″. The best way to secure this spacing is to mark a narrow strip of tough paper or adding machine tape exactly equal in length to the circumference of the commutator. This strip is then marked off into equal parts, corresponding to the number of brusharms, 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.

If any brush arms are respaced check to see that brushes are parallel to commutator bars within ±1/32″ from back to front.

Staggering Brushes Axially

The brushes are staggered axially 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 3/16″ or more. The third pair of brush arms trail the first pair; the fourth, the second, and so on. See Fig. 22. If the brushholder supports are removed from the rocker ring they should be reassembled so that correct staggering is obtained.

Staggering Brushes Circumferentially

On some machines the brushes are staggered circumferentially by placing spacers between the brushholder and brushholder bracket. Spacers are generally put on alternate brushholders and placed on the same brush track in each arm. See Fig. 23.

Staggering is beneficial to commutation for the following reasons:

1. Increases the time of commutation, thereby reducing the reactance voltage.

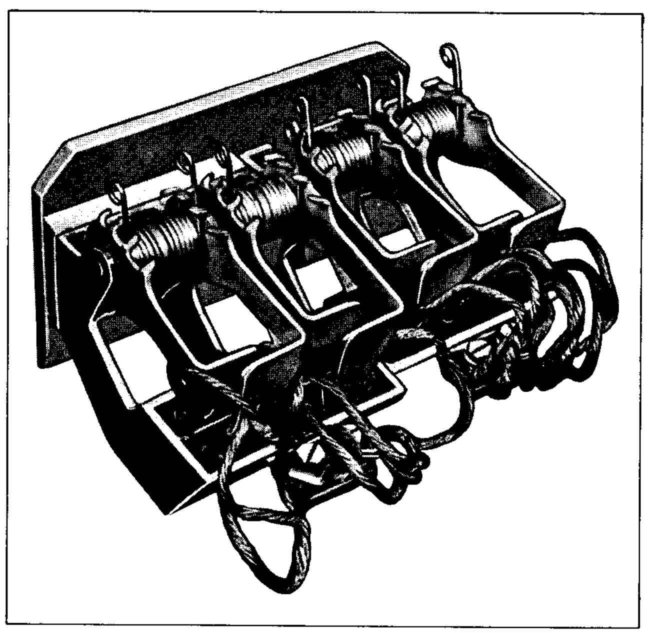


Fig. 23. *Staggering Brushes Circumferentially on D-C Generators and Motors*

2. At the trailing edge of the brushes where the bar leaves the brush, the cross section of brush in contact with the bar is reduced giving higher resistance which is conducive to good commutation.

3. Where rough or eccentric commutator conditions occur, stagger gives the effect of a wider brush and thus all brushes on a given arm will not be affected simultaneously, thereby having some brush contact on all brush arms at any on instant.

Due to the difference in angle between the staggered brush and the normal brush and the fact that commutating conditions are different between the two brushes, there will be a definite difference in the appearance of the commutator film on the brush tracks corresponding to the staggered brushes and the non-staggered brushes. This difference is perfectly normal and is in no way detrimental to commutation or brush and commutator maintenance.

When placing a machine in service with staggered brushes, see "Mechanical Re-Determination of Factory Brush Position", in the installation section, on Page 17.

D-C Brushes and Brushholders

A careful examination of the brushholders should be made to see that all brushholder fingers move freely and exert the correct pressure on the brush. This pressure should normally be 2 to 2-1/2 pounds per square inch of cross sectional area of the brush. For the correct finger pressure, depending upon the size of the brush, see the tabulation given below:

Brush Size	Pounds per Brush
3/8 x 1-3/4	1.3 to 1.6
1/2 x 1-3/4	1.8 to 2.2
5/8 x 1-3/4	2.2 to 2.7

The brush shunts should be checked to see that they are properly connected to the brushholder of the machine and are arranged neatly to provide adequate clearance from any other parts of the machine.

The brushholders should clear the commutator by 3/32" to 1/8".

MECHANICAL TEST

Caution: **Before starting the unit make absolutely certain there is no foreign or loose material in or on the rotors or air gap spaces. Also check to make sure all ventilating ducts in the rotors and interpolar spaces are clean to preclude any interference with the ventilation of the unit. Any time spent to eliminate foreign material is well spent since any hindrance to the flow of air within the machines may cause overheating and great damage.**

Keep the area adjacent to the machines free of all small iron items as they may be drawn magnetically into the air gap spaces of the machines while they are running and cause serious damage.

Checks to be Made

Before the machines are turned over for a mechanical test run, the following items should be checked:

1. Oil level.
2. Oil circulating system (if supplied)
3. Cooling water system (if supplied)

If these are satisfactory, the machines should be jacked over by hand to see that everything is free to rotate.

Before starting, go over all machines thoroughly, testing for loose bolts and nuts that may have been overlooked. Check blower bolts, pole bolts, copper connections, coupling bolts, exciter coupling bolts or belting, foundation bolts and dowels. Make absolutely certain that all parts are in their correct places and are properly tightened down.

Make reference to the drawings. Compare drawings and assembled machines point by point. Check first before it is too late. Then start the machines on a slow roll and gradually bring up to speed. Check operation of oil rings at frequent intervals. The oil rings should revolve freely and smoothly and should carry oil to the tops of the journals.

Bearing Temperature Relays

Separate information is supplied with these devices and reference should be made to it. After the bearings with relays are installed, the covers of the relays should be removed, all parts checked to see if they are tight and in operating order. Their operation should be checked by immersing the bulb in a high flash-point oil and then heating the oil until the contacts operate. This should normally occur at 96°C total temperature.

Bearing Temperature

During this first run, the temperature of the bearings must be watched closely. A thermometer should be placed in the oil ring inspection hole.

Most small and medium sized machines have bearings which are designed for a low temperature rise. These bearings should operate below 70°C (158°F) total temperature. See Page 33 for recommended oils.

In some cases where a higher ambient temperature or other special condition exists bearings may operate at total temperatures as high as 85°C (185°F).

Of more significance than the actual temperature of the bearing is the change and the rate of change of the temperature as the machine is started and run. When bearings are operated for the first time, their temperature should be periodically checked until they level off at normal temperature.

A rapid rise in the temperature of a bearing is usually an indication of trouble and requires prompt attention.

The causes of overheating of sleeve bearings and actions to be taken are given on Page 34—"Overheating of Bearings."

SPEED LIMIT DEVICE

As a safeguard against overspeeds, a speed-limit device may be attached to many machines. One normally open contact and one normally closed contact is usually supplied. A device with two normally open or two normally closed circuits can be supplied upon request.

The circuits of this device may be used to trip a circuit breaker to prevent the machine from overspeeding, to sound an alarm or operate other protective devices.

To Reset the Switch

Move the switch arm back to the normal position by hand. This can readily be done at any time whether the machine is running or not and without opening the switch box.

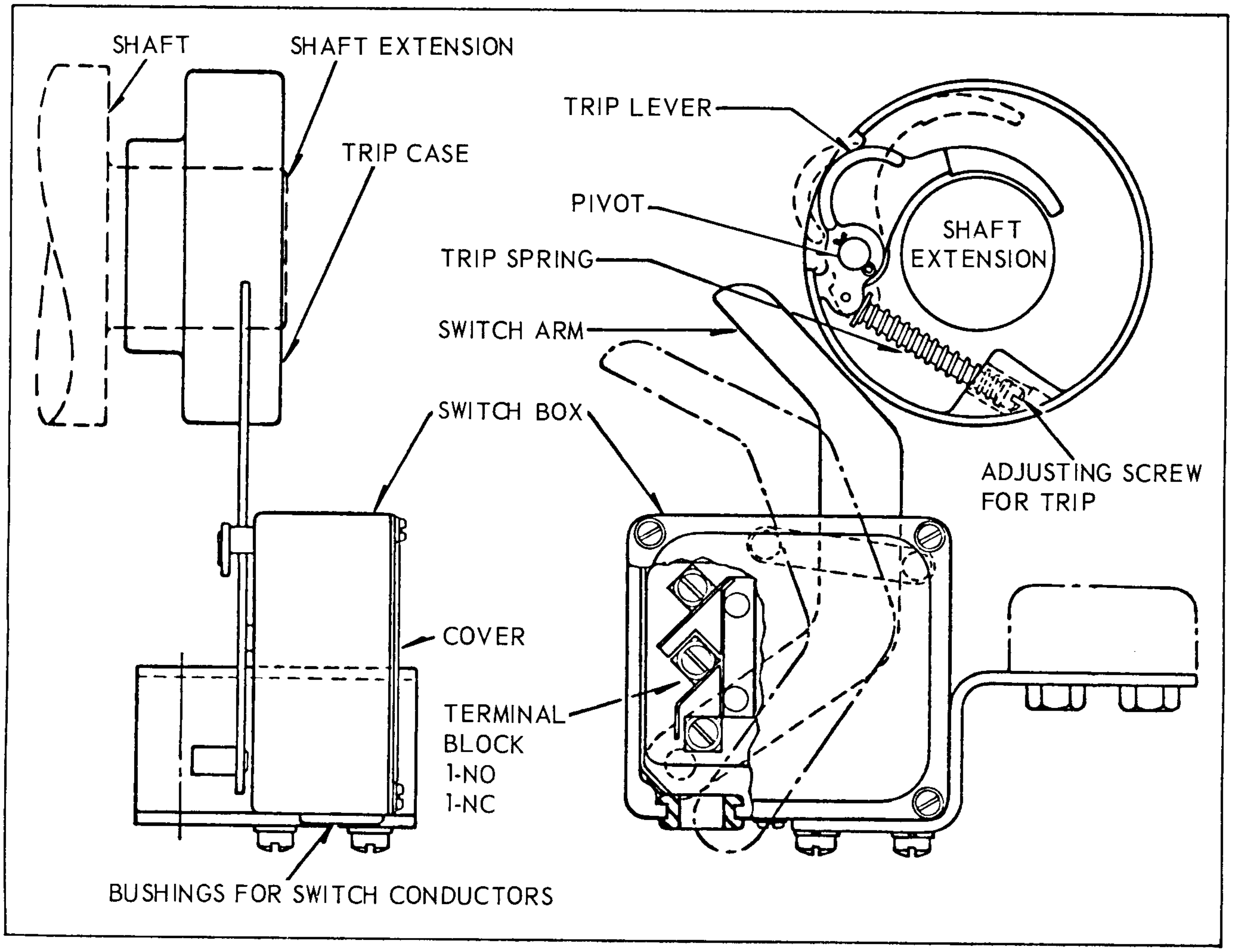


Fig. 24. *Overspeed Device*

Assembly of Speed-Limit Device

All speed-limit devices are set and tested at the factory. The switch box complete is attached to the pedestal. Bolt up parts in place, fasten the trip case to the shaft, next push in the switch arm; there should be at least 1/8 inch between the switch arm and the trip-case. See Fig. 24.

Adjustment of Speed-Limit Device

When checking the overspeed setting the d-c machine can be run as a motor from the d-c bus. It is important to have complete control of the speed during the test. Use a tachometer or any reliable direct-reading speed indicator, but do not use the ordinary revolving dial indicator.

Then test for overspeed; the switch should trip at about 15 percent above normal speed. Bring the speed up slowly and watch for the tripping speed of governor trip-lever.

Should it be found necessary to reset the governor proceed as follows:

First determine the tripping speed, and be sure the unit is assembled as shown in Fig. 24. Screw in the adjusting screw even with the governor case, and give the screw about one-half turn inward at each run until it trips at the overspeed. Then tighten the small locking screw on the side of the trip-case.

Before starting each test see that the switch arm is in and pull the trip-lever several times by hand to see that it works freely.

Inspection

Speed limit devices should be tested and lubricated at regular intervals as a part of the routine inspection to insure that all parts are operative and all circuits complete. Failure to maintain the overspeed device and wiring in proper condition may result in the loss of a machine.

Part Four: Operation

Caution: **Leave all switches open when the machines are not operating.**

Do not work on any machine while it is running. Make sure that all switches are open and that the machines 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.

VENTILATION

The ventilation system must be in operation whenever the d-c machine is in operation.

Integral ventilated machines (totally enclosed with air to water heat exchanger) require proper cooling water during operation. The cooling water should be shut off when the d-c machine is stopped for an appreciable period of time. Condensation may occur (within the machine) if the water continues to flow while the d-c machine is shutdown. Condensation may also occur during operation if excessively cold water is used with respect to the load on the d-c machine.

STARTING D-C 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. If water cooled check the water circulation.

3. With the field circuit open turn in all resistance in the shunt field rheostat.

4. Set the excitation voltage to its specified rating when shunt fields are separately excited.

5. Close the switch applying excitation voltage to the shunt field and note voltmeter reading. If voltmeter reading is reversed consult control diagram for shunt field polarities and correct as necessary.

6. Slowly cut out resistance in the shunt field rheostat until rated voltage is reached on generator.

7. With rated voltage on generator read field current and check value as given in the control manual. The generator is now ready for use.

Note: **This description is very general and reference to the instructions furnished with the control should be made before starting the machine.**

PARALLELING D-C 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 proportions 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.

ADJUSTMENT OF LOAD DIVISION OF SHUNT WOUND D-C 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 overall 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. The increased losses are also objectionable on large machines.

(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 machines can stand some brush shift to secure better paralleling characteristics and still have acceptable commutation.

ADJUSTMENT OF LOAD DIVISION OF COMPOUND WOUND D-C 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.

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 regulating 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 series-field circuits should be checked and changed, when necessary, by changing the resistance of the leads to be 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, and the main lead from the series field to main bus) 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 underloaded generator. However, 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).

ADJUSTMENT OF LOAD DIVISION OF CROSS COMPOUNDED D-C GENERATORS

Cross compounded generators have approximately the same voltage regulation as a shunt wound generator. The addition of the cross series fields, namely the cumulative and differential series field provide a simple and powerful load balancing action.

To adjust the load division it is only necessary to adjust the shunt field rheostats to give load division over the entire range.

If the generators cannot be made to parallel by manipulation of shunt field rheostats check polarities of the cumulative series field. This may be done as follows:

1. Disconnect leads from cumulative series field.

2. Open breakers which connect the generators together.

3. Separately excite the cumulative series field with about ten percent of rated current. The excitation current must be in the direction as indicated by the control diagram.

4. Set the shunt field rheostat to all in position (minimum voltage).

5. Start up the MG set and bring up to its rated speed and note the polarity of the output voltage. If the output voltage is in the same direction as normal operation the series field is correct. If the output voltage is in the opposite direction the series field is incorrect and the connections to the series field must be reversed.

SUCCESSFUL PARALLEL OPERATION OF D-C GENERATORS*

"Successful parallel operation is attained if the load on any generator does not differ more than plus or minus 15 percent of its rated kilowatt load from its proportionate share, based on the generator ratings of the combined load, for any steady-state condition in the combined load between 20 percent and 100 percent of the sum of the rated loads of all the generators."

*ASA Standards C 50.4-1955 Paragraph 4-12.3

EXCITATION FAILURE OF SELF EXCITED D-C 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. 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 Fig. 25.

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

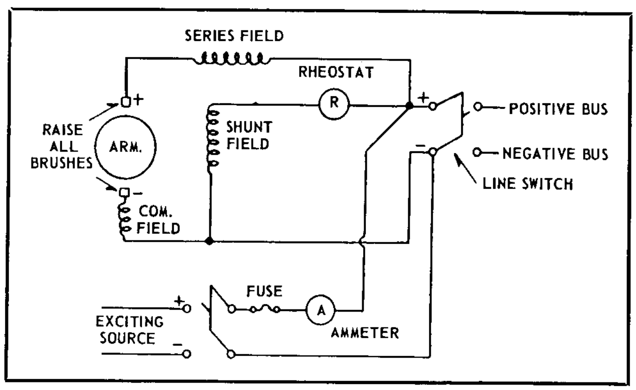


Fig. 25. *Connection for Restoration of Residual Magnetism of Generator*

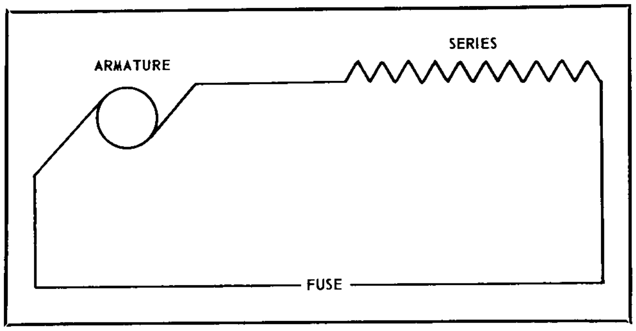


Fig. 26. *Convenient Method of Making a Compound-Wound D-C Generator Pick Up Voltage*

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.

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 Fig. 26. 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 D-C 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 D-C 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.

SHUTTING DOWN D-C GENERATOR

1. Decrease the load as much as possible by reducing the output voltage by increasing the resistance of the shunt field rheostat.

2. Remove 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, inspect and clean the machine and put it in good order for the next run.

STARTING D-C MOTOR

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 master switch or controller is in the "off" position and if it is an adjustable speed motor, see that the shunt field rheostat is set for full field (lowest speed).

3. Close the main switch or circuit breaker.

4. Close the field switch and the control switch.

5. Move the master switch 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 the motor is an adjustable speed motor, then after the motor is running on full-line voltage, gradually adjust the shunt field rheostat until the motor is at the desired speed.

Note: **This description is very general and reference to the instructions furnished with the control should be made before exciting the generators.**

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.

SHUTTING DOWN D-C MOTOR

If adjustable speed motor start with Step 1, otherwise start with Step 2.

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

2. Return the master switch or controller to the "stop" or "off" position.

3. After the motor has come to rest, open the main switch or circuit breaker.

4. Open the field switch and the control switch.

5. Clean the machine thoroughly and put in order for next run.

PERMISSIBLE LOADING

All d-c motors and generators rated 40°C rise are good for a 15% service factor, i.e., 15% overload continuously with safe temperature rise when operating in 40°C ambient.

This overload should not be exceeded continuously as overtemperatures will result which will shorten the insulation life. In addition the brushes will overheat or burn and bad commutation will result.

All d-c motors and generators capable of carrying 125% load for two hours will commutate for one minute a load of 200% of full load amperes without injury. However, this value is for emergency conditions and should not be frequently repeated.

For generators rated 200% full load maximum momentary the maximum permissible frequently applied load is 175% full load.

For motors rated 200% full load maximum momentary the maximum permissible frequently applied load is 175% full load at base speed, 160% full load at 200% base speed and 140% full load at 300% base speed and above.

These ratings do not apply to d-c motors and generators for reversing hot mill service or to d-c motors and generators with special overload ratings.

Operating above the frequently applied load limits will produce the following results:

1. Increase commutator and brush maintenance.

2. Shorten brush life.

3. Poorer overall commutation for the load cycle.

Part Five: Inspection and Maintenance

Important: **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 from any source is particularly injurious to commutator mica and may result in insulation failure.

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.

See "Cleaning Methods", Page 31 for details.

INSPECTION

DO NOT permit the machines to operate for extended periods of time without a thorough inspection. After the machines are first installed, frequent inspections are recommended to determine the length of time necessary for subsequent periodic checks. Inspections will reveal any minor troubles as they occur and permit their remedying before serious harm has been done.

Do not allow the inspections to become perfunctory! Use a flashlight and a small mirror fastened to the end of rod so that the entire machine can be inspected—not just the easily observed places.

INTEGRAL VENTILATED D-C MACHINES

An integral ventilated machine is totally enclosed with air filters and air to water heat exchangers. The air filters should be cleaned (or replaced depending on type of filter) at regular intervals to insure efficient filter operation. The heat exchangers should have the tubes cleaned at regular intervals as determined by the quality of cooling water. The heat exchanger assembly may be removed as a unit for convenient maintenance work.

MEASUREMENT OF INSULATION RESISTANCE

Insulation resistance is useful in determining the presence of moisture or dirt upon the winding surface, and a complete record kept of insulation resistance is useful in determining when cleaning or drying of the windings are necessary. It is suggested that insulation resistance readings be taken at least every six months once in summer and once in winter. Any sudden downward trend of the insulation resistance values will indicate that special maintenance steps need be taken.

Procedure

The method of taking insulation resistance should be definitely controlled and the following routine is suggested:

1. Adopt a definite time of application for taking readings, preferably after 1 minute of voltage application. Make tests immediately after a shutdown when machine is relatively free from moisture.

2. Always use the same voltage instrument.

3. Keep a complete record of date, temperature of winding and ambient temperature, relative humidity and condition of winding. Insulation resistance will vary inversely with the temperature. That is, the insulation resistance will decrease with increase in temperature. Roughly the resistance will be doubled for each 15^{o} drop in temperature. For example, if a certain insulation has a known resistance at $75^{o}C$, then at $60^{o}C$ the resistance should be approximately doubled and at $25^{o}C$ it should be in the neighborhood of 10 times as great. It must be emphasized that these figures are only approximations and that the rate for individual machines will usually vary.

4. Take readings at machine terminals, being sure other cables, switches, etc. are isolated.

5. Whenever motor driven or electronic instruments are used to take readings over a period of time longer than 1 minute, as in the case of dielectric absorption curves, it is essential that, before a repeat reading of the same part is taken, that the winding be discharged to ground for a time at least equal to the total time of voltage application when readings were first taken.

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, and only to a completely dry machine. 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. Tests of this character should not be made when the insulation resistance is low.

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 relatively clean machine that has been in service should not be subjected to more than 2/3 the voltage specified for a new machine. The dielectric test value is determined by A.I.E.E. rules. Of course, old machines that cannot be properly cleaned must have even the 2/3 figure reduced.

MAINTENANCE OF SATISFACTORY INSULATION RESISTANCE

Prevention of Condensation

Condensation of moisture occurs when the machine parts are cooler than the atmosphere. The humidity of the atmosphere determines the temperature differential at which condensation will occur. At 100% humidity a very small temperature differential will cause condensation whereas a much larger differential is required for condensation if the humidity is very low. Therefore, the temperature of the machine parts must always be kept above the temperature of the surrounding air. This is naturally accomplished as long as the machine is running with some load present.

Heat must be applied to the machine whenever it is shut down. Heaters are supplied on many machines for this purpose and they should be energized as soon as the machine is shut down. These heaters provide enough heat to keep the machine parts a few degrees above the surrounding air temperature, thus preventing condensation.

Condensation will cause low insulation resistance. This is especially true where a salty atmosphere is present since it is possible to have a certain amount of salt present in the condensation.

Thus the importance of preventing condensation cannot be over-emphasized. This applies during the normal use of the machine as well as to the periods the equipment is out of service for extended periods.

Cleaning Methods

The best way to maintain high insulation resistance is to prevent accumulation of foreign materials and moisture in the windings as much as possible. See the previous paragraph on prevention of condensation. There are four acceptable methods of cleaning machines.

1. Compressed Air–This is the most convenient method if there is not an excessive amount of dirt or oil present. Air pressure should be less than 30 lbs. as excessive pressure is capable of injuring the insulation. Use pressure reducing equipment if necessary. Use dry air and 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 machine should be protected from flying dust by a suitable cover or shield.

2. Suction–Cleaning by a vacuum cleaning system is the preferred method as all dirt is carried away from the machines and the danger of blowing dirt into adjacent machines is completely avoided.

3. Wiping–All accessible insulated parts, subject to copper or carbon dust, should be wiped clean with a clean, dry cloth, in addition to cleaning by suction or compressed air.

When wiping, do not neglect such parts as inner surface of end windings, mica vee ring extension, slip ring insulation, etc.

4. Solvents–Water should not be used on d-c machines unless the machine has already been submersed by flood or accident as there is danger of water remaining inside of certain commutators.

The use of solvents should be avoided in so far as practicable and only used whenever it is necessary to remove hard or pasty deposits of grease or oil and other foreign matter.

Before using any solvent, use a clean, dry rag to wipe off as much dirt as possible as mentioned in Paragraph 3. Then use a rag moistened (not dripping) with a petroleum solvent of the "safety type" such as Stoddard Solvent No. 55812CB or equivalent.

In cases where a low-power petroleum solvent will not provide proper cleaning and a stronger solvent becomes necessary, properly inhibited methyl chloroform such as Westinghouse M#51550FA may be used.

When methyl chloroform is used definite precautions must be taken to prevent breathing air containing excessive concentrations of its vapor. Satisfactory ventilation of the area should always be provided. If this is not practical adequate respiratory protection must be used. Such protective equipment may consist of chemical cartridge respirators or suitable gas masks. If there is any possibility of oxygen deficiency, breathing apparatus with a self-contained air supply, air line respirators, or hose masks should be used. All protective breathing equipment should have the U.S. Bureau of Mines Approval.

However, if parts containing aluminum are to be cleaned even some so-called inhibited methyl chloroform solvents may cause a severe and detrimental reaction with aluminum. Therefore, engineering approval and proper procedure for usage should be obtained even though only approved products of properly inhibited methyl chloroform such as Westinghouse M#51550FA is used.

Critical areas which when dirty will cause low insulation and which should receive special attention are:

1. The inner surfaces of the armature coils just behind the commutator riser.
2. The insulated creepage surface at the commutator vee ring under the armature coil.
3. The area under the rear coil extension.

These areas should be brushed or scrubbed in the most convenient manner in order to loosen the dirt.

If all these steps do not bring the insulation resistance to an acceptable level, use a solvent sprayed under pressure.

Care should be taken to prevent too much solvent being used where the dirt may be washed from the windings to an inaccessible location between components which would create an area of low resistance to ground which cannot be remedied except by a major repair.

After the windings have been cleaned it is recommended that a coat of recommended insulating varnish be applied to protect the insulation.

BEARING MAINTENANCE

Lubrication of Sleeve Bearings

The design of Westinghouse bearings has a background of many years of operating experience and with reasonable maintenance and attention they should give long and trouble-free service. Periodic inspections should be made to be sure the oil level in the bearing pedestal is up to the normal mark on the gauge, and that the oil rings are revolving and carry a plentiful supply of oil to the shaft.

The oil should be sampled at intervals to check its viscosity, cleanliness, and acid content. It is important that the oil be kept clean and free from grit. See "Oil Specification Chart", Fig. 27 for further information.

Openings are provided in the bearing cap over the oil rings for the purpose of adding fresh oil and inspection of the oil rings.

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

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.

Grease Lubricated Bearings

When grease is used the bearings are packed with grease when assembled in the factory. Only Westinghouse Ball and Roller Bearing Grease is used for lubrication.

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 on a nameplate attached to the machine.

The relief plug is to be replaced after approximately 1/2 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.

Dirt is the biggest foe of anti-friction bearings, and one of the most common ways for it to get into the bearings is

FIG. 27.–OIL SPECIFICATION CHART*

OIL SPECIFICATIONS	HORIZONTAL MACHINES 200 HP AND UP OIL RING LUBRICATED SLEEVE BEARINGS (ALL SPEEDS) CIRCULATING OIL SYSTEM SLEEVE BEARINGS (JOURNAL SPEED) LESS THAN 2800 FT./MIN.) SEE NOTES 1 AND 2	HORIZONTAL MACHINES 200 HP AND UP OIL LUBRICATED ANTI-FRICTION BEARINGS (ALL SPEEDS)
Type of Oil	Light Machine Oil	Extra Heavy Turbine Oil
Flash Point, °F Min.	330	425
Saybolt Viscosity	180-250	475-550
Sec. -100°F.	..	..
Sec. 212°F Min.	..	..
Viscosity Index, Min.	50	85
Carbon Residue, % Max.	.20	.15
Neutralization No. Max.	.10	.10
Pour Point, °F.	+25° See Note 3	+15° See Note 3
Rust & Oxidation Inhibitors.	See Note 4	Yes

*Where special equipment or unusual operating conditions are involved, manufacturer should be consulted for lubrication specification.

Note 1: **In general, for oil ring lubricated bearings the oil viscosity at the operating temperature should not be less than 70 SUV. Accordingly, where oil ring lubricated bearings operate continuously at temperatures above 158°F (70°C), a turbine oil having a viscosity of 300 SUV or more at 100°F should be used. This may cause the bearing to operate with higher losses and at a slightly higher temperature, however, the highly refined turbine oils are more resistant to sludging, and the higher viscosity maintains the desired oil film at elevated temperatures. The operating temperature referred to above is the temperature as measured by a thermometer inserted in the oil ring inspection hole. This temperature is normally 5 to 15°C lower than the temperature indicated by a thermometer imbedded in the bearing shell.**

Note 2: **180 to 250 SUV at 100°F represents the most generally used lubrication classification. Where desired, considerable latitude in oil viscosity can be exercised. Temperature rises and losses permitting, heavier oil up to 800 SUV can be used.**

Note 3: **As a guide for selecting the proper pour points the following table has been reported:**

Max. Ambient Temp. °F	Max. Pour Point Temp. °F
45 or above	35
32 or above	20
20 or above	0
0 or above	-10
Below 0°F	Consult Manufacturer

On some applications rather than using an oil with a very low pour point it may be more practical to provide some heating means to assure the oil temperature will not fall below a certain minimum point.

Note 4: **The majority of equipment in this classification will operate satisfactorily without inhibitors. Turbine-type oil containing inhibitors are recommended, however, on equipment operating under high speed, high temperatures or high loading conditions. Oxidation inhibitors retard deterioration of the oil while the rust or water corrosion resistance inhibitors prevent corrosion of parts in contact with oil, particularly in the presence of water. In addition, some rust inhibitors tend to decrease starting friction, a desirable feature for highly loaded equipment. For applications where excessive foaming is a problem, special anti-foaming agents can be obtained.**

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 should be flushed and refilled every year. Keep bearings filled to proper oil level with correct grade of oil. See Oil Specification Chart, Fig. 27.

Excessive amount of oil increases the fluid friction and thus raises the bearing temperature and tends to originate oil leakage through the seals.

Overheating of Bearings

The cause of overheating of a bearing may be any one, or a combination of the following:

1. Insufficient oil in the reservoir to cover the bottom of the oil rings.

2. Dirty oil or oil of poor quality.

3. Failure of oil rings to revolve.

4. Excess end thrust resulting from an installation with the bedplate badly out of level or from the axial magnetic pull resulting from the magnetic center of rotor and stator being out of line.

5. Poor alignment of the machine.

6. Bent shaft.

7. Rough bearing surface due to corrosion or careless handling.

8. Bearing overload due to unequal air gap.

9. Pitting due to bearing currents, see Page 13 "Pedestal Insulation."

Caution: **Bearing currents may flow if tools or other miscellaneous objects fall across the pedestal insulation.**

COMMUTATOR & BRUSH MAINTENANCE

Care of Brushes

With the brushes in the proper position as described on Page 16 under "Brush Position", make frequent inspections to see that:

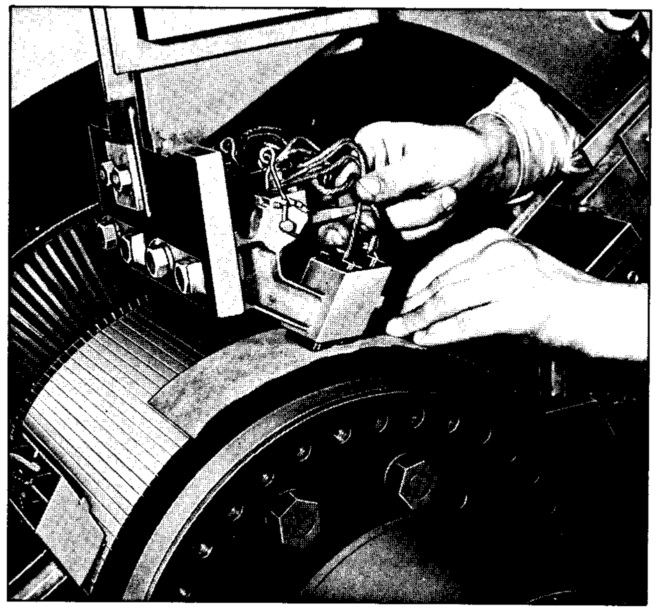


Fig. 28. *Method of Seating Brushes on D-C Generators and Motors*

1. Brushes are not sticking in the holders.

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

3. Correct tension is maintained as the brushes wear.

4. 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.

5. Remove any free copper picked up by the face of the brush.

6. When a new brush is installed, be sure it is free in the brushholder.

Seating of 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. 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 embedded in the brushes. See Fig. 28.

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 factory test position.

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.

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, a factory representative should be consulted to remedy the fault.

Brush Chatter

Brush chattering is caused by high friction between the brush and the commutator.

One of the most common causes of high friction between the brush and commutator is light load operation.

Brush friction increases as the current density in the brush is reduced. Brushes which operate with current densities less than 30 Amperes per square inch of cross sectional area have a tendency to develop a highly polished glaze on the commutator. The results of this operation are generally:

1. Brush chatter.

*ASA Standards C 50.4-1955 Paragraph 4-8.9

2. Highly polished brush face.

3. High contact drop between commutator and brush face.

4. Threading of the commutator.

5. Brush finger tip wear.

6. Poor commutation.

7. Brushes chipping or breaking.

Light brush current densities should be avoided. Checks should be made on each application to determine the current density. Brushes should be lifted to obtain a current density between 35 and 65 amperes per square inch of cross sectional area. Peak densities of short duration can be as high as 130 amperes per square inch with no ill effects. With this range of operation, once a machine is put into operation, there should not have to be any changes made in the number of brushes used on a commutator in order to obtain the correct current density. Therefore, the proper procedure is to study the application and lift brushes to get the density up for the major portion of the operating time of the machine. For example: One complete track of brushes around the commutator should be lifted at one time. It is important that the number of brushes lifted be symmetrical in that the same number of brushes on each arm should be used at all times.

Brush vibration which is a result of poor commutator condition or high mica is usually of low frequency compared to chatter caused by light load operation. This type of vibration can be corrected by grinding the commutator as outlined on Page 37.

Streaking or Threading of Commutator Surface

Streaking and threading is caused by the breakdown in paths of the film on the commutator surface. When the film breaks down the current has a tendency to pass through the area where the film has been destroyed. This further aggravates the condition and finally the copper of the commutator bars starts to wear threads or streaks around the periphery of the commutator.

There are a number of different causes for this condition. One is that a very heavy film is built up on the commutator surface, usually due to some atmospheric condition. This heavy film is not a good conductor and to permit passage of current between the commutator and the brush it becomes necessary for the film to break down. This breakdown occurs in just one spot, but it gradually develops into a streak or thread around the periphery of the commutator.

Threading and grooving can also be caused by particles of copper imbedded in the brush face. These particles cut the commutator film and since the copper to copper contact drop is comparatively very low, these areas on the commutator surface carry more than their share of the current which further aggravates the condition.

Selective action, the tendency for one brush or group of brushes to carry more than its share of the load, is also a prime cause for threading and streaking. Streaking in particular can be attributed to selective action.

To prevent threading and streaking due to selective action it is necessary to check the terminal connections, spring pressure, shunt to brush connections, brush freedom in the brushholders, spacing and brush material for symmetry. Any unbalance which will make the electrical resistance in one path different from the other parallel paths in a machine will cause selective action. Mixing several different brush grades on one machine frequently causes selective action.

A common misconception regarding threading is that it is caused by a brush that is too hard. Threading is not a function of brush hardness. The characteristic in a brush material that may cause threading is ash content. The ash particles in a brush material sometimes are extremely hard and unless the type of ash and its quantity are controlled in a brush grade it can contribute to threading or grooving the commutator.

"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.

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 a little attention beyond frequent inspection. If the commutator appears to be in good condition, leave it alone. Unnecessary grinding or sanding is undesirable and is often an invitation to trouble.

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, causing burnouts.

The commutator will need attention when it becomes 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 machine's ability to satisfactorily handle overloads.

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 or sharp pointed stick 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 after grinding and polishing should be concentric within one thousandth of an inch.

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.

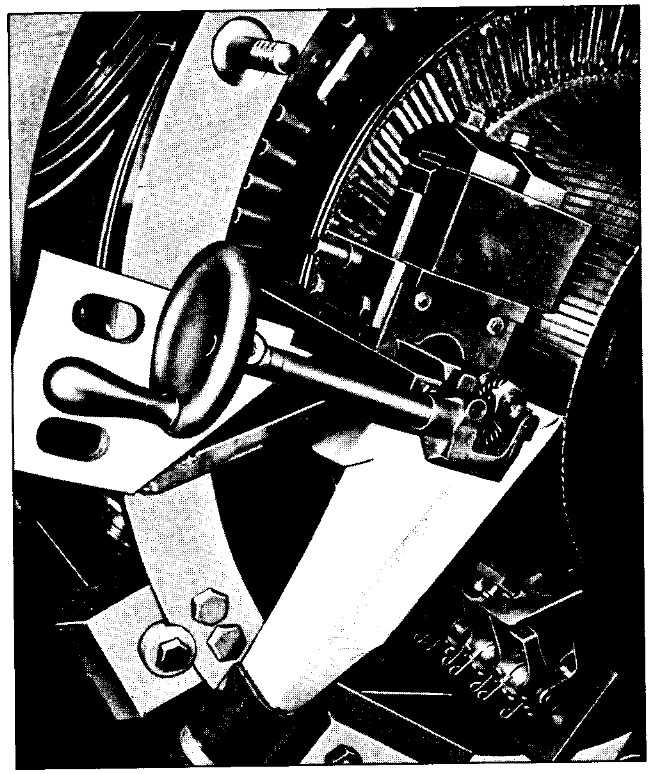


Fig. 29. *Grinding Devices for Trueing Commutator*

The surface of the commutator should be kept smooth. Sometimes a little sandpapering is all that is necessary.

If the commutator becomes badly roughened, it will be necessary to grind the commutator.

Grinding Commutators

All commutator grinding should be done with a grinding rig. A handstone should never be used on a commutator, except on 3600 RPM exciters, to obtain a true surface, because it follows the irregularities in the surface and in some cases may even exaggerate them. The grinding rig consists of an abrasive stone arrangement similar to a lathe tool in a rigging or carriage which may be moved back and forth in an axial direction and is equipped with a radial feed. It should be supported very rigidly so that the stone is subjected to a 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

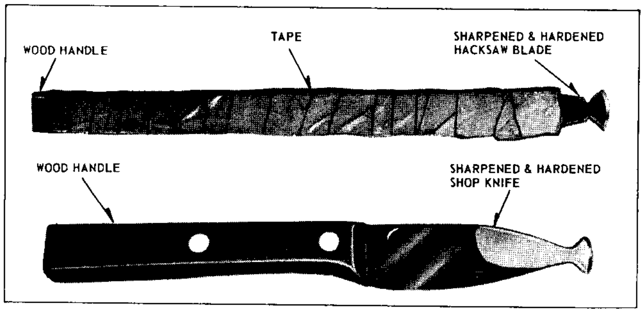


Fig. 30. *Tool for Commutator Bar Beveling*

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 when the unit operates at 1200 RPM or less. When feasible, higher speed units should be ground at less than rated speed in order to minimize the effects of unbalance and vibration.

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. 29.

In order to rotate the machine, it may be belted to an auxiliary driving motor or in the case of an MG set, it can be run from the machine on opposite end of shaft. If it is impossible to grind a commutator while it is assembled in the motor or generator, the work can be done in a lathe if it is a relatively slow speed machine. This can be done by taking a very fine cut off the surface.

The stones used in grinding commutators may 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, often 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 final finish. The fine stone should have a grit of about 200 mesh.

Beveling Commutator Bars

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 eliminating 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. See Fig. 30.

Mica Undercutting

All modern 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 re-undercut 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. 31.

Polishing Commutators

After grinding, undercutting the mica, and beveling the edges of the bars, the commutator surface should be

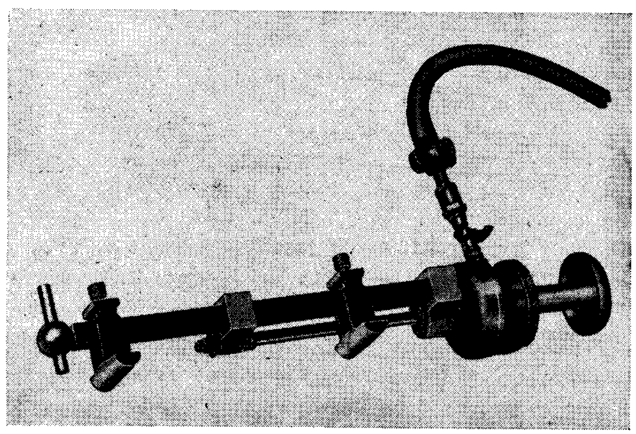


Fig. 31. *Tool for Undercutting Mica*

polished at rated speeds. 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 obtained by burnishing the commutator with dense felt or canvas.

Do not attempt to tighten the commutator bolts. All commutators are thoroughly baked and seasoned before leaving the factory and should not require any adjustment. The bolt tension is an important factor in commutator operation and is carefully adjusted by special torque wrenches. Improper tightening can seriously damage the commutator.

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. 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.

Care of Three Wire D-C Generator Collector Rings and Brushes

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.

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.

REPAIR 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.

The occasion can arise when rewinding a glass polyester banded armature that facilities or a supply of glass polyester banding may not be available. A steel band can be substituted using the following rules of thumb:

1. The steel band should be non-magnetic (AISI 305 cold drawn to 200,000 psi yield).

2. The cross sectional area of the steel band should be not less than 60% of the area of the glass polyester band.

3. The steel band together with the insulation under it should extend over the same location and area of the coil extension as the glass polyester band.

(*Note:* **Check to insure the distance between bare copper and the steel of the band is 3/4″ minimum. On certain special machines such as shovel motors or units using shrink ring commutators, a hooded band may be required. In such cases, the manufacturer should be consulted.)**

4. Use an insulation under the steel band consisting of a minimum of .012″ of flexible mica (exclusive of backing) and one thickness of a varnish treated asbestos or glass of a minimum of .035″ thick. Assemble the mica directly over the coils with the asbestos immediately under the band. The mica should be applied in at least two layers so that any joints will be overlapped. Extend the entire pad 1/4″ on each side of the banding wire. (*Note:* **Silicone treated materials must not be used).**

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.

RENEWAL PARTS

A recommended list of renewal parts for the motor-generator set is available upon request to the nearest Westinghouse Sales Office.

When ordering renewal parts, give the Stock Order number of the machine and the complete rating as shown on the nameplate. The nameplate is prominently located on the machine frame.

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