A-C. GENERATORS

Rotating Field Type G—Rotating Armature Type SK With Oil Lubricated Sleeve Bearings

INSTRUCTIONS

General Information

The instructions given apply to salient pole a-c. generators, both rotating field and rotating armature types.

Installation

1. **Inspection**—Unpack the generator and make sure that it was not damaged during shipment. See that the name-plate reading agrees with the voltage frequency, phases, speed and service required.

2. **Mounting**—The generator should be located in a well ventilated, easily accessible place, where the external air temperature (ambient) will not exceed 40°C. or 104°F. The foundations must be rigid enough to prevent excessive vibration.

Protection

The machine should be protected carefully against moisture both before and after erection. Water or steam from leaking pipes, rain, snow or condensation from the atmosphere should be excluded. It is particularly important to keep the windings dry since moisture lowers the insulation resistance and increases the likelihood of a breakdown. If a machine is brought from cold surroundings into a warm room, it should be kept covered until its temperature has risen to room temperature so as to prevent condensation on the windings and other parts.

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

Lifting of the machine by cranes should be done with the greatest care. The stator is usually provided with lifting holes into which the crane hooks may be inserted. The rotor 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 or collector rings.

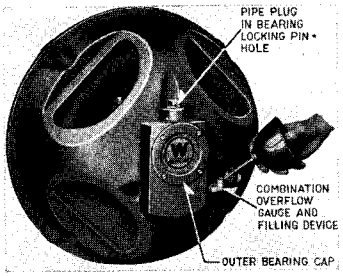


FIG. 1—SEALED SLEEVE BEARING BRACKET SHOWING METHOD OF OILING

For machines that are not assembled at factory use kerosene to remove paint on the journals. In cases where rust is present use an oil stone or emery cloth and finish with an oil stone, depending upon the amount of rust to be removed.

Do not mar or scratch the journals, as any roughness may cut the bearings and cause them to run hot.

Bearings on machines that are assembled at factory do not require cleaning and polishing.

Method of Drive

1. **Belt Drive**—Mount the generator on the slide rails or bedplate, which allows for adjusting the belt tension. Mount the generator pulley close to the bearing housing, allowing sufficient clearance for rotor end play. Align the pulleys so that the belt runs true, and tighten the belt just enough to prevent slippage. Use a belt wide enough to carry the load without excessive tension.

2. **Direct Drive**—The motor shaft and the driven shaft must be in line, except for a slight allowance with flexible couplings. Dowel the generator to the base.

Exciters

An exciter may be mounted on one end of the machine. The exciter frame is usually supported from the end bracket. The exciter armature is mounted on an extension of the main shaft. Vertical machines have the exciter mounted at the top.

Lubrication

Before starting the generator, fill both oil reservoirs through the **combination overflow gauge and filling device** with best quality clean dynamo oil. (See Fig. 1). The oil used should have a viscosity of from 185 to 212 seconds at 40°C. No oil should be poured in the top of the brackets through the pipe plug hole, or the oil ring slot cover inside the bracket. No oil need be added till the oil drops below the full level, which is $\frac{1}{8}$" below the top of the overflow gauge. Do not flood the bearings. After oiling, close the cover of the overflow gauge. If any oil is accidentally spilled on the bracket, it should be wiped off with a rag or waste. This prevents dirt from collecting on the oily surface of the machine. It also eliminates any possibility of oil getting into the windings which in time may mean an expensive repair job.

The construction of the Sealed Sleeve Bearing is such as to require no "flushing out". At intervals of about two years in average service, or during general overhaul periods, remove the bracket and thoroughly wash out the bearing housings, using hot kerosene oil and compressed air if available.

Fans

Fans or blowers are attached to the rotors of most generators to assist in forcing ventilating air through the machines. In most cases these are straight radial vanes good for either direction of rotation.

Bearings

When a machine is started, particular attention should be given to the bearings to see that they are well supplied with lubricant. The oil rings should revolve freely and carry oil to the top of the journals.

Bearings may be operated safely with temperature from 90° to 100°C. if they are in good condition. Usual recommended continuous operating temperature is 80°C. (176°F.). It should be remembered that a bearing may be below this temperature even though it is hot enough to burn the hand when held against the outside.

A rapid rise in the temperature of a bearing is usually an indication of trouble and requires prompt attention. The machine should be taken out of service immediately, but, if possible, it should be kept rotating at low speed until the bearing has cooled. Fresh oil should be fed into the bearing and onto the journal through the openings over the oil rings.

The cause of overheating may be any of the following:

Insufficient oil in the reservoir.
Dirty oil or oil of poor quality.
Failure of oil rings to revolve.
Excessive pressure or end thrust caused by poor alignment of the machine.
Bent shaft.
Shaft currents.
Rough bearing surface, which may have been the result of careless handling.

Leads

The arrangement of leads for various types of windings is shown in Fig. 2.

On horizontal generators of the rotating field type, the armature leads are normally brought out through a conduit box on the side of the frame. These leads are equipped with terminals into which the purchasers cables may be inserted. The field leads are brought out through a conduit box on the front bracket or through a ¾ inch squeeze connector located either in the front bracket or on the side of the frame. Outline drawings show locations of both armature and field outlets.

On rotating armature type machines the armature leads are brought out through a conduit box located on the frame of the generator. The field leads are brought out through the conduit box located on the frame.

On machines with a direct connected exciter the exciter leads are brought out through a squeeze connector at the bottom of the exciter on the small sizes

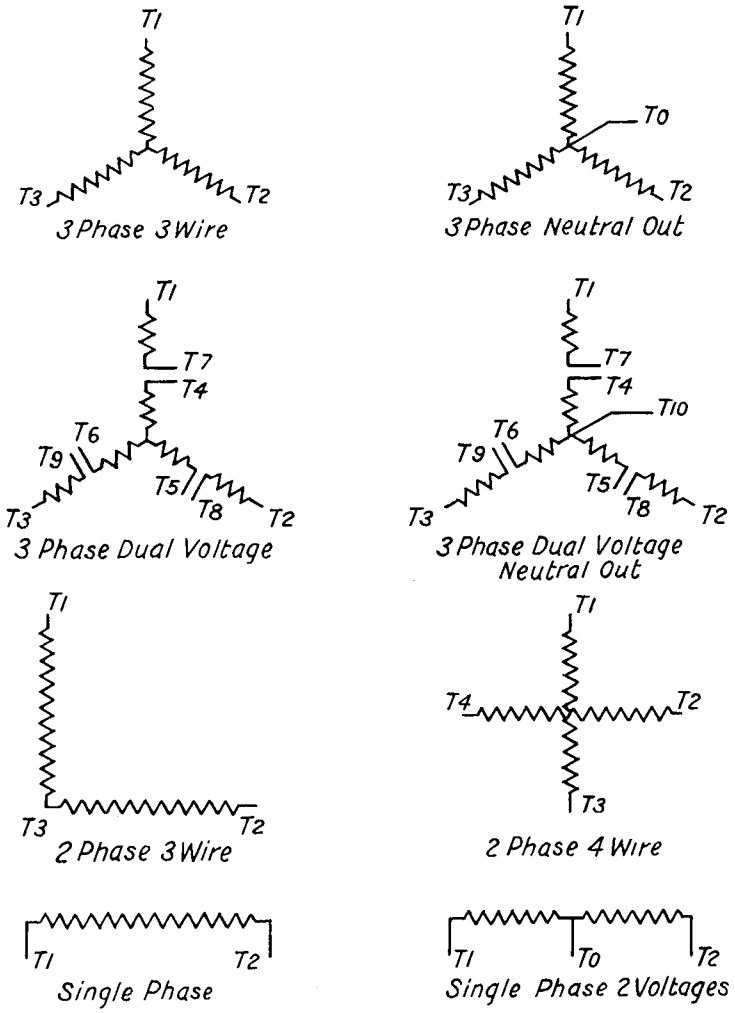


FIG. 2

On rotating armature generators, for single phase, single voltage, the armature is usually wound for 3 phase with three collector rings. Single phase can then be taken from between any two of the three rings.

A simple connection diagram, without meters or regulator is shown in Fig. 4.

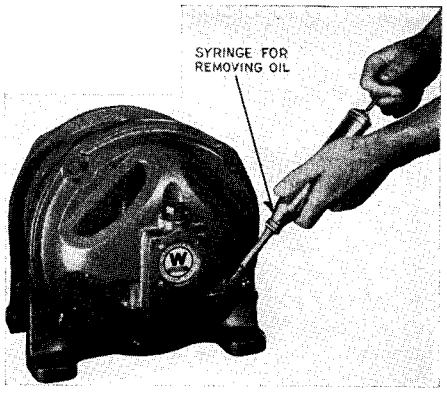


FIG. 3—TO PREVENT THE POSSIBILITY OF LEAKAGE THE DRAIN PLUG HAS PURPOSELY BEEN OMITTED. OIL MAY BE READILY REMOVED FROM THE SEALED SLEEVE BEARING BY MEANS OF AN INEXPENSIVE SYRINGE HAVING THE NOZZLE FITTED WITH A FLEXIBLE RUBBER TUBE ABOUT SIX INCHES LONG AND SMALL ENOUGH TO PASS READILY THROUGH THE STEM OF THE OVERFLOW GAUGE INTO THE INTERIOR OF THE OIL RESERVOIR

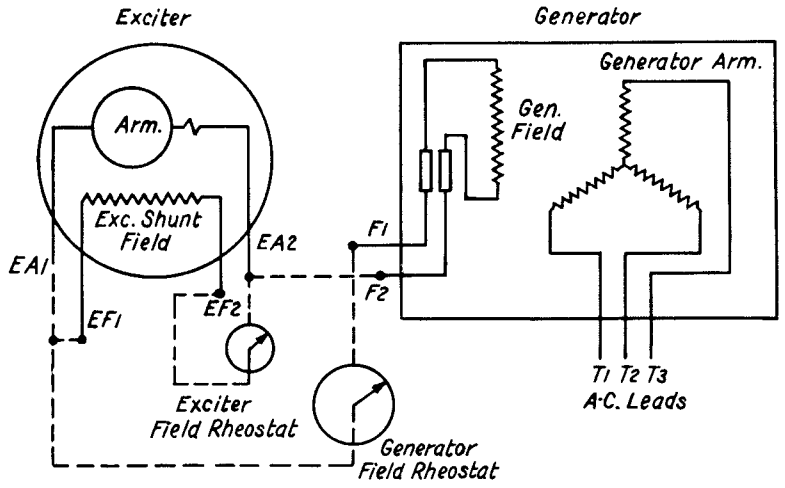


FIG. 4

and through a conduit box on the side of the exciter on the larger sizes.

Electrical Connections

Install all wiring and fusing in accordance with the National Electric Code, and local requirements.

A conduit box is supplied, but conduit and conduit fittings are not furnished with the generator. These items may be purchased from any Electrical Dealer, or Plumber's Supply House.

When the generator is mounted on a bedplate, or on slide rails for belt adjustment, flexible metallic conduit should be used to protect the leads to the generator. In making this connection a squeeze connector should be used for attaching the flexible conduit to the conduit box.

Squeeze connectors may be straight, 45°, or 90°.

In order to connect a squeeze connector to the conduit box first remove the cover of the box. Run a locknut well down the threads of the connector and place the connector in the conduit hole of the conduit box. Screw a conduit bushing over the end of connector, swing the connector to the desired position and draw the locknut up tight against the box. Follow he same procedure with rigid conduit or reducing bushing.

Insulation Resistance

The insulation resistance of windings is measured, usually, with an instrument called a megger.

No new machine should have an insulation resistance of less than 1 megohm.

Insulation resistance of machines in service should be checked periodically to determine possible deterioration of the windings.

This measurement gives an indication of the condition of the insulation particularly with regard to moisture and dirt. The actual value of resistance varies greatly in different machines depending on the size and voltage. The chief value of the measurement therefore, is in the relative values of resistance of the same machine taken at various times. During a drying out run, for example, the insulation resistance rises as the winding dries out although it may fall appreciably at first. When measurements are made at regular intervals, with the machine at the same temperature, as part of the maintenance routine, it is thus possible to detect an abnormal condition of the insulation and take steps to remedy it before a failure occurs.

The insulation resistance of stator windings of machines in good condition is usually not less than the following:

$$\text{Insulation Resistance (in megohms)} = \frac{\text{machine voltage}}{\frac{\text{Rated Kv-a.}}{100}+1000}$$

Synchronizing A-C. Generators

The condition to be fulfilled in order that synchronous apparatus may be connected to a system already in operation, is that the electromotive forces of the incoming machine and of the system to which it is connected shall be approximately the same at each instant. This requires that the frequencies be the same, that the two voltages be equal, as indicated by a voltmeter, and that the two voltages be in phase.

The elementary principle employed in determining when generators are at the same frequency and in phase is illustrated by Fig. 5 in which A and B represent two single-phase generators, the leads of which are connected to the bus-bars by switches C and two series of incandescent lamps which are connected as shown. As the electromotive forces change from the condition of phase coincidence to that of phase opposition, the flow of current through the lamps varies from a minimum to a maximum.

When the electromotive forces of the two machines are exactly equal and in phase, the current through the lamps is zero. As the difference in phase increases, the lamps light up and increase to a maximum brilliancy when corresponding phases are in exact opposition. From this condition the lamps will decrease in brilliancy until completely

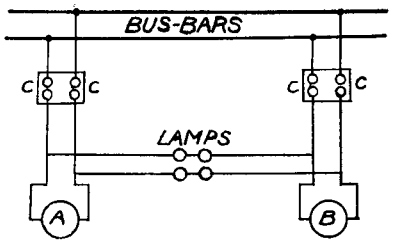


FIG. 5—CONNECTION FOR SYNCHRONIZING LOW VOLTAGE SINGLE-PHASE GENERATORS

dark, indicating that the machines are again in phase. The rate of pulsation of the lamps depends upon the difference in frequency, i. e., upon the relative speeds of the machines.

When the voltage of the system is too high for the synchronizing apparatus, it is usual to place voltage transformers between the main circuits and the synchronizing circuits to reduce the voltage at the switchboard to safe limits, as shown in Fig. 6.

If the connections of either the primary or secondary of either transformer be now reversed from those shown in the diagram, the indications

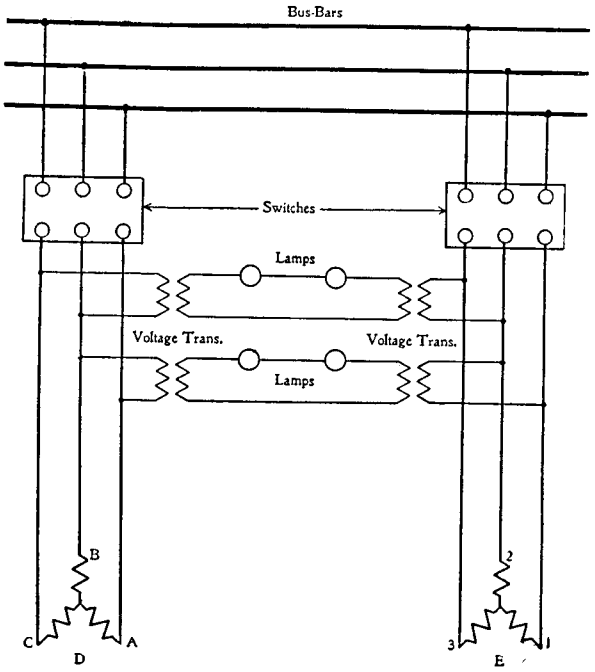


FIG. 6—CONNECTIONS FOR SYNCHRONIZING THREE PHASE GENERATORS

of the lamps will be reversed, i.e., when the generators are in phase, the lamps will burn at maximum brilliancy and vice versa.

In order to make certain that the lamps will be dark instead of bright when the machines are in phase, disconnect the main leads of the first generator at the generator and throw in the main switches of both generators with full voltage on the second generator. Since both machine circuits are then connected to one machine, the lamp indication will be the same as when the main or paralleling switches are open and both machines are in phase. If the lamps burn brightly and it is desired that they be dark for an indication of synchronism, the connections of one of the voltage transformer primaries or one of the secondaries should be reversed. **Dark lamps as an indication of synchronism are recommended.** The lamps should be adapted for the highest voltage which they will receive, i.e., double the normal voltage.

Phase Sequence

In the case of polyphase machines, it is not only necessary that one phase be in synchronism with one phase of another generator but the sequence of maximum values of voltage in the several phases must be the same. The phase sequence must therefore be checked. The necessary connections for two three-phase generators are shown in Fig. 6.

Connect the generators temporarily to their switches, but with the switches open, so that the phases of D will be in parallel with those of E. Connect synchronizing apparatus in any two phases. Test out the synchronizing connections with machine D running at normal speed and voltage, the leads disconnected from E at the generator and the paralleling switches closed. Having changed the synchronizing connections, if necessary, so that both sets of lamps will be the same when indicating synchronism, open the paralleling switches, re-connect the leads of machine E and bring it up to normal speed and voltage. Then observe the two sets of synchronizing lamps. If their pulsations come together, i.e., if both sets are dark and both are bright at the same time, the phase rotation of the two generators is the same, and the connections are correct for paralleling the generators when the lamps are dark. If, however, the pulsations of the lamps alternate, i.e., if one is dark when the other is bright, reverse any two leads of one machine and test out the synchronizing connections again, changing them if necessary so that they are the same when indicating synchronism. The lamps will now be found to pulsate together and the generators may be thrown in parallel at the proper indication. Synchronizing apparatus in one phase only is sufficient for paralleling the generators after the first time.

The procedure in synchronizing a generator with an existing power system is the same, the phase rotation of the generator being changed, if necessary, to agree with that of the system.

The paralleling of two-phase generators is accomplished in a similar manner. In case of incorrect rotation the two leads belonging to either phase must be reversed instead of any two leads.

Synchronoscope

A synchronoscope, Fig. 7 is an instrument that indicates the difference in phase between two electromotive forces at every instant. By its aid the operator can see whether the incoming machine is running fast or slow, what the difference in speed is, and the exact instant when it is in synchronism. These conditions cannot be observed with certainty by the use of lamps alone.

The synchronoscope has a pointer which shows the phase angle between the incoming and running machines. This angle is always equal to the angle between the pointer and the vertical position marked on the dial of the instrument. When the frequencies of the two machines are equal, the pointer stops at some position on the scale and when the machines are in phase, the pointer coincides with the marker at the top of the scale.

In order to check the synchronoscope connections, proceed in the same manner

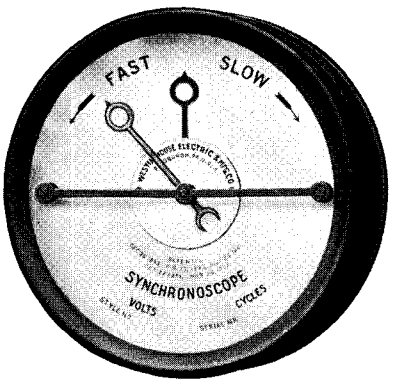


FIG. 7—SYNCHRONOSCOPE

as previously described for determining whether lamps will be bright or dark for a given synchronizing connection. If the synchronoscope pointer stops at the bottom, reverse the leads at the upper terminals. If it stops in the same position, the connections to the upper terminals are made to the wrong phase.

Operation
Starting an A-C. Generator

Bring the generator up to speed and synchronize it with the line according to instructions in previous paragraphs.

Adjust the prime mover so that it tends to speed up, thus causing the generator to take part of the kilowatt load of the system.

Adjust the field current in line with instructions given under "Adjustment of Field Current".

Adjustment of Field Current

Single Generator—When a generator operates alone, without being paralleled with other generators, the field current is adjusted for each change in load so as to maintain rated voltage. The adjustment can be made by hand, but it is preferable to use a voltage regulator which can keep the voltage constant even though the load varies rapidly.

Generator Operated in Parallel—A generator operated in parallel with one or more other generators may have its excitation varied through a fairly wide range while delivering the same kilowatt output at rated voltage. A change in field current under these conditions changes the power factor of the generator. The field current may be set at its rated full load value for all loads or it may be varied depending upon the need for reactive kv-a. If the field current is increased, the generator furnishes reactive kv-a. to the system and thus relieves the other generators of part of their burden. No change in kilowatt output can be effected by variation of the field current. This can be accomplished only by a change of governor of the prine mover.

Operation with field current lower than the value which gives 100 per cent power factor should usually be avoided since this imposes additional load in reactive kv-a. on the other generators. In addition it reduces the ability of the machine to stay in step with the system and may result in its being pulled out during periods of heavy load. A generator is pulled out of step with other machines and is forced above synchronous speed when its prime mover attempts to deliver more power than the generator is capable of delivering to the electrical system.

In the case of a generator connected to a long transmission line which is lightly loaded, it may be necessary to operate with very low values of field current in order to prevent a rise in terminal voltage due to the charging current of the line.

Parallel Operation

The requirements for successful parallel operation are:

1. The speed regulation of the prime movers should be alike. That is, the per cent drop in speed for a given per cent increase in load, should be the same on both, or all, units. The drop in speed from no-load to full-load may be only 2 per cent or less but if it is the same on all units which are in parallel, the total load will divide between them in proportion to their ratings.

2. The governors of the engines or turbines should be free from hunting and should bring the machines to a steady speed without delay. Any oscillation of the governors will result in a transfer of load back and forth between machines and a fluctuation of the voltages.

3. Engine-driven machines should have sufficient flywheel effect to prevent wide fluctuations in speed which arise from the regular pulsations in torque inherent in reciprocating machines.

4. The wave form of the generators should be alike. If this condition is not fulfilled, there will be harmonics in the current wave which produce additional losses in the machines. In modern machines the wave forms are usually close enough to sine waves to prevent any trouble from this source.

Unbalanced Voltage and Single Phase Operation

The ability of a generator to operate on unbalanced voltage or, in the extreme case, to operate single phase, depends largely on the design of the amortisseur or damper winding. Single phase operation produces heavy currents in the damper winding, if there is one, which may cause overheating in a machine not designed for such operation. If there is no damper winding, the field current required for a given load is increased to such an extent that the output is seriously limited. Operation with unbalanced load has the same effect as single phase operation but in a less degree.

For machines not designed for single-phase operation, 20 to 30 per cent of normal current single-phase is usually safe. Higher values may be permissible if the damper winding is liberal. The degree of unbalanced polyphase operation that is permissible depends likewise on the design of the individual machine. In any case of unbalancing of more than five per cent at full load, it is advisable to watch the temperatures of all parts closely.

Starting Squirrel Cage A-C. Motors on Single Generator

When a generator operates alone, the starting of squirrel cage motor becomes a major problem. The starting current on normal squirrel cage motors is approximately six times full load current. Thus if generator full load current is less than six times the full load current of the motor to be started the generator is overloaded when the motor is thrown on the line, with a resulting drop in voltage. If there are other motors already operating from this generator, this drop in voltage may cause them to stall.

As a general rule generator full load current should be approximately five times the full load current of the motor to be started. If motor is started with a compensator (65% voltage) the generator full load current should be approximately three times the full load current of the motor.

Collector Rings and Brushes.

a. Sparking.

If sparking between the brushes and the collector rings occur, the following points should be checked:

1. Brush pressure.

   It may be that the pressure on the brushes is insufficient to make them follow the ring surface.

2. Brush holder vibration.
3. Brush chatter.
4. Oil vapor.
5. Collector ring truth.
6. Spotted rings.
   This has been cured in certain cases by the use of a more abrasive brush.

b. Selective action between brushes.

This is generally aggravated by any of the causes of sparking at the brushes and if the same remedies are applied, it can generally be improved.

Since there is always an electrolytic action on the surface of an iron ring, the collector operation is improved by occasionally reversing the polarity of the rings. Sometimes trouble will occur on one ring only and by reversing the polarity every day or so, the trouble will entirely disappear.

The Rings—Should be maintained smooth and true. Grind or turn them if necessary to restore a smooth and true surface.

Occasionally ring trouble will arise from a ring not being of uniform hardness, so that it wears unevenly. Such a ring should be replaced.

Collector ring trouble is seldom due to high current density as the maximum current density, 40 amperes per square inch or less, is well below the maximum density specified for the brushes.

The brushes used should be light in weight, with a fairly high current capacity and should contain a slight amount of abrasive material. A suitable grade is furnished with the machine, and for the best results this grade should always be used.

The Brushes—Should make good contact with the slip rings along the whole face of the brush. If necessary grind new brushes in with fine sandpaper. Maintain a free sliding fit between the brushes and the brush holder by cleaning both thoroughly when necessary.

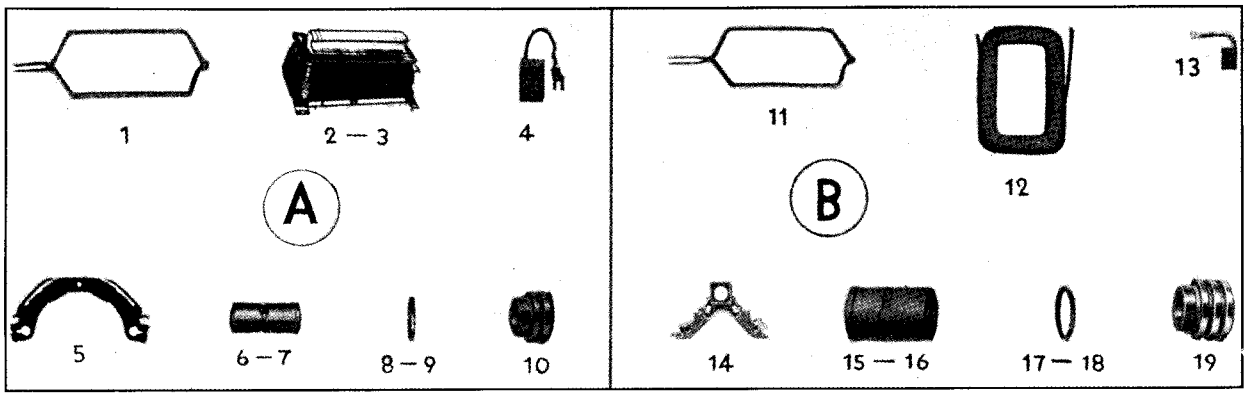
On type G revolving field generators, there are two collector rings made of steel or of bronze alloy. Brushes supplied on these machines are metal graphite and should have a brush pressure of approximately 3 lbs. per square inch. There are two brushes per ring.

On the SK revoling armature generators there are usually three collector rings but for two phase generators and three phase with meutral brought out, four rings are supplied. For single phase generators a standard three ring collector is supplied and single phase output can be taken from any two of the rings. For two voltage single phase the voltage between the outer rings is double that between the center ring and either of the other rings. See sketches of connections on page 3. Brush pressures on rotating armature generators should be 3 lbs. per square inch.

Type G Rotating Field—Type SK Rotating Armature

With Oil Lubricated Sleeve Bearings

RENEWAL PARTS DATA



A—PARTS FOR TYPE G—ROTATING FIELD
B—PARTS FOR TYPE SK—ROTATING ARMATURE

RECOMMENDED STOCK OF RENEWAL PARTS

The following is a list of the Renewal Parts and the quantities of each that we recommend should be stocked by the user of this apparatus to minimize interrupted operation caused by breakdowns. The parts recommended are those most subject to wear in normal operation or those subject to damage or breakage due to possible abnormal conditions. This list of Renewal Parts is given only as a guide. When continuous operation is a primary consideration, additional insurance against shut-downs is desirable. Under such conditions more renewal parts should be carried, the amount depending upon the severity of the service and the time required to secure replacements.

Type G Generators—Rotating Fields

Generators in use		1	5
Ref. No.	Name of Part	No. Per Generator	Recommended For Stock
1	Armature Coil—Stationary	1 set	⅓ set	1 set
x	Cut Winding Insulation	1 set	⅓ set	1 set
2	Revolving Field Coil—Open *	1 set	1	1
3	Revolving Field Coil—Crossed *	1 set	1	1
4	Brush	1 set	1 set	2 sets
5	Brushholder	1 set	½ set	1 set
6	Bearing—Front	1	1	1
7	Bearing—Rear	1	1	1
8	Oil Ring—Front	1	0	1
9	Oil Ring—Rear	1	0	1
10	Collector	1	0	0

Type SK Generators—Rotating Armature

Generators in use		1	5
Ref. No.	Name of Part	No. Per Generator	Recommended For Stock
11	Armature Coil—Rotating	1 set	⅓ set	1 set
x	Cut Winding Insulation	1 set	⅓ set	1 set
12	Stationary Field Coil—Open	1 set	1	1
12	Stationary Field Coil—Crossed	1 set	1	1
13	Brush	1 set	1 set	1 set
14	Brushholder	1 set	⅓ set	1 set
15	Bearing—Front	1	1	1
16	Bearing—Rear	1	1	1
17	Oil Ring—Front	1	0	1
18	Oil Ring—Rear	1	0	1
19	Collector	1	0	0

x Not illustrated.

* These coils are wound directly on poles.

Renewal Parts coils are furnished wound on poles. On 4 pole 20″ and 24″ frame, the rotor is made integral so poles cannot be removed. The field coils are wound directly on the rotor.

ORDERING INSTRUCTIONS

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

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Pa.

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