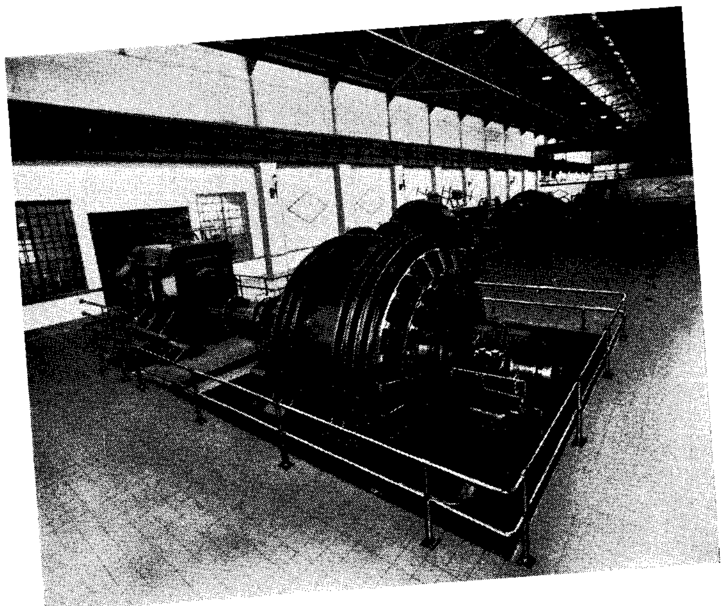
Westinghouse
Main Roll Drives
A-C. and D-C. Motors

Instruction Book 5207



DOUBLE UNIT REVERSING MILL MOTOR

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Pa.

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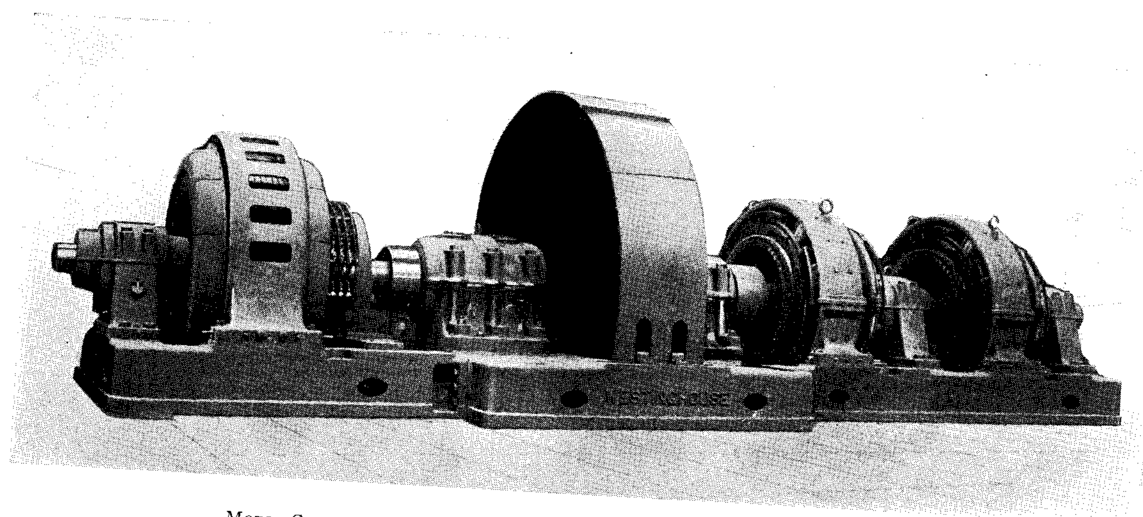
IMPORTANT

Install electrical apparatus in a clean place and keep it clean. The absence of moisture and dirt is the greatest assurance of long life of electrical machinery.

The present design of insulation of generators and motors is the result of exhaustive research work and engineering study: also the development of improved shop methods. The insulation is selected and applied with great precision and its deterioration is slight within the operating capacity of a machine when given reasonable protection and care.

Definite arrangements for the periodic inspection and cleaning of units should be made to prevent undue accumulation of dirt.

Before installing or operating a machine, read all of the following instructions carefully, making note of the points to be observed.



Motor-Generator with Flywheel Equalizer with Two Generators Supplying Power to 12,000 Hp., 3-Unit Motor Driving 35-Inch Reversing Blooming Mill

Westinghouse Main Roll Drives

A-C. and D-C. Motors

General Information

Steel mill motors are practically always located so that they are subject to a large amount of dust and dirt, and the service which they are called upon to withstand is of the most severe character. The precautions discussed in this book apply particularly to the larger motors and their accessories such as those used to drive the main rolls in steel mills. In general the installation and care of this class of machinery is similar to that for other large electrical power apparatus, but on account of the exceptionally severe service and the unfavorable nature of the surroundings, certain features require particular emphasis.

Location—The location of the motor is determined to a large extent by the type of the mill which it is to drive. But in any case it is considered advisable to provide a motor house within the mill to protect the motor and control apparatus from mill dust and gas fumes which attack the insulation and corrode the brass and copper parts. When a motor room is provided, it is easier to keep the apparatus clean, and also to keep the mill men and unauthorized persons away from the electrical equipment. It is very important that the location be wisely chosen, due regard being paid to the rules of the National Board of Fire Underwriters and to state and local regulations. The following considerations should also be carefully observed:

(1) The machine should be located in a cool, dry place, well ventilated and not exposed to moisture. Remember that the room temperature is added to that developed in the machine. The arrangement should be such as to prevent moisture or escaping steam reaching the windings.

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

Ventilation—The machine should be so located as to receive proper ventilation. This is important and means that the air circulation in the room must be such as to carry away the heated

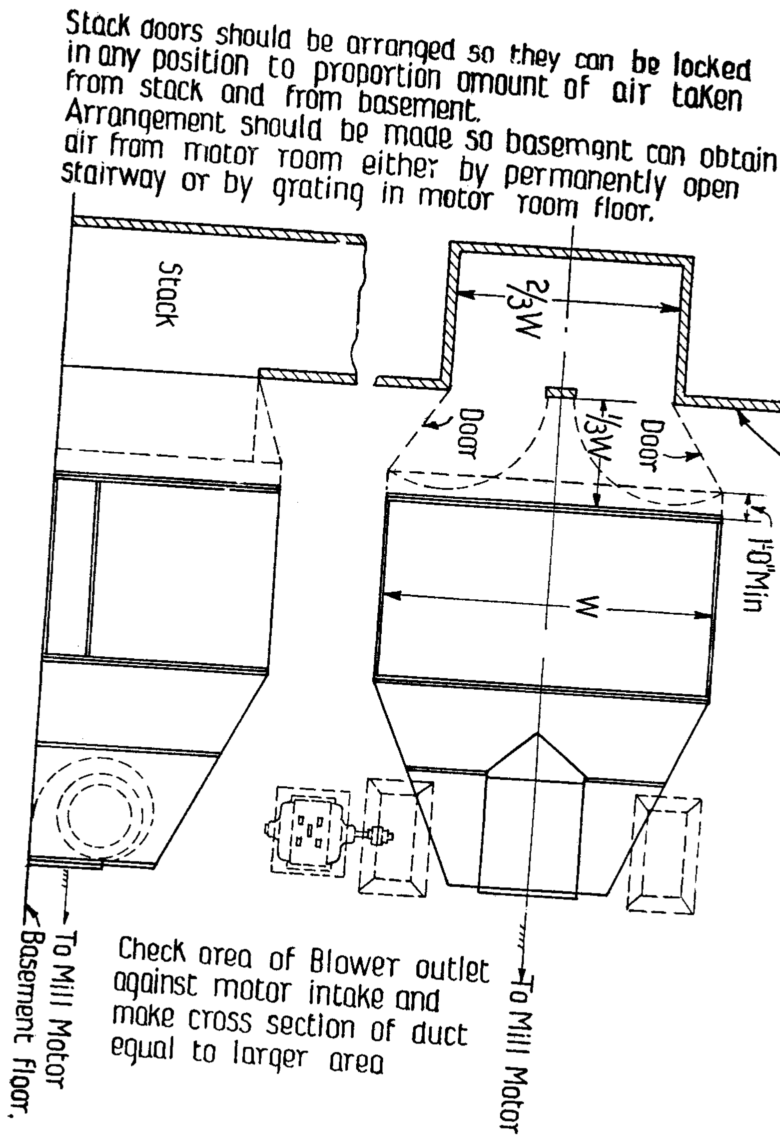

Stack doors should be arranged so they can be locked in any position to proportion amount of air taken from stack and from basement.
Arrangement should be made so basement can obtain air from motor room either by permanently open stairway or by grating in motor room floor.
Stack
2/3W
Door
1/3W
Door
Outside wall
1'0" Min
W
To Mill Motor
Basement floor.
Check area of Blower outlet against motor intake and make cross section of duct equal to larger area
To Mill Motor

FIG. 1

air and supply cool air to the machine. Care should be taken that the air for ventilating purposes is taken from a clean source. In every case the motor room should be completely closed off from the mill, and where clean air is not directly available, an air duct with a blower should be provided.

It is seldom possible to obtain clean air in a steel mill, so that these systems are usually provided with air washers. An arrangement of an air washer is shown in Figure 1, If the washer is placed between the blower and the motor, the washer is subjected to the pressure of the blower, which has a tendency to cause leakage. For this reason, the air should always be drawn through the washer at atmospheric pressure. The amount of air necessary to ventilate a motor depends upon its electrical losses. It is best to have the manufacturer specify the amount of air necessary, but as a general rule about ten cubic feet per rated horsepower per minute will be sufficient.

In laying out ventilating ducts, care should be taken to avoid sharp turns, as these seriously interfere with the passage of air. The ducts should be made as straight as possible and of such dimensions that excessive air velocities will not be encountered. Velocities in the duct of not over 2000 feet per minute have been found most satisfactory for this purpose. This applies to all passages from the source to the motor. The air in the washer, however, should not travel over 600 feet per minute, as otherwise moisture may be carried to the motor.

The air intake should be provided with two openings, one arranged to take air from the inside of the motor room and the other to take air from the outside of the building. This arrangement is necessary, since in the winter the air which is taken from the outside will carry snow and ice into the windings. If an air washer is used, it will become clogged with ice. With the arrangement mentioned above, all or a part of the air can be taken from inside the motor room in winter weather. It is best to proportion the amount of air taken from each source so that the temperature in the duct is never below 50 degrees Fahrenheit. A single door or shutter arrangement should be provided for the two sources, arranged so that in closing one the other is automatically opened. This will prevent the possibility of both sources being closed off at the same time and depriving the motor of its ventilation. This door will serve as a damper for properly proportioning the amount of air taken from each source, the door being fixed in the proper intermediate position.

In the case of forced ventilated machines, the blower should be so interlocked with the control that it is impossible to operate

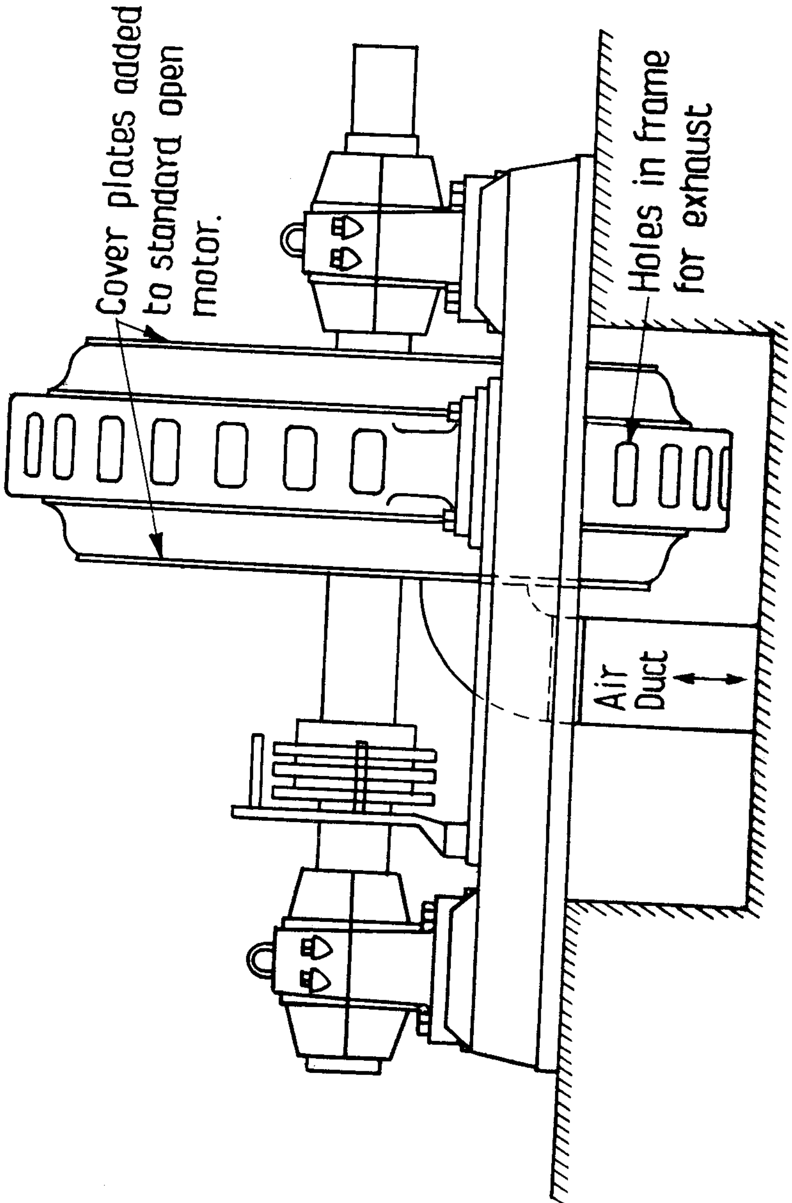

Cover plates added
to standard open
motor.
Holes in frame
for exhaust
Air
Duct

Fig. 2

the machines unless the blower is functioning. In addition, a vane can be located in the air duct which carries a contact in the control circuit, rendering the control inoperative unless the vane is deflected by air passing through the duct.

When ventilating air is forced into a motor room, the room must be designed with sufficient openings to provide free outlet for the air, so that a pressure will not be set up in the room and the influx of air opposed, thus diminishing the amount of air to the machines. The best plan is to install, near the roof, exhaust fans having sufficient capacity to expel the same amount of air as is forced in by the blower.

Sometimes it is not convenient to install a motor house, in which case the motor can be enclosed, as shown in Figure 2, and artificial ventilation provided as described above. The most common instance of this is a hot sheet mill. Motors for this application are invariably located in a pit, where it is difficult to obtain the necessary change of air, and the atmosphere is usually warm and dirty.

Sweating is the result of a difference of temperature between the machines and the surrounding air. If the air is saturated at a certain temperature and is cooled below this point, it gives up some of its moisture. When the temperature of the machine is low enough to reduce the temperature of the air below the dew point, the excess moisture is precipitated upon the machines. This is very injurious to insulation and has a bad effect on the apparatus generally, as it causes rusting of journals and other bright metallic parts and corrosion of the copper and brass. If the room temperature is kept uniform at all times, or if the machines are kept slightly warmer than the surrounding air, sweating will be prevented.

INSTALLATION

General Precautions—Upon receipt of the cases containing the machine or its parts, place them in a dry storeroom. Do not open them, and disturb them as little as possible until everything is finally ready for assembling. If the electrical apparatus is not crated it should be covered up to keep out dust and dirt. This storeroom should have an even temperature to prevent sweating.

Handling—Extreme care should be used while unloading or otherwise handling large electrical apparatus as, from the nature of such apparatus, it is easily damaged by being allowed to slip or bump against anything. If the insulation is once broken, it is practically impossible to repair it so that it is as good as it was originally, and the delay and expense occasioned by even a slight damage is out of all proportion to the extra effort required to "play safe" when handling this class of apparatus. Bear in mind that the armature is liable to damage, since its own weight is sufficient to crush the winding if it is lowered on or swung against a projection.

Rope or cable slings should be used when lifting rotors with cranes, and these should be so placed and separated with spacers that no pressure is exerted on the windings. In case wire slings are used for handling a rotor, the shaft should be well lagged under the slings to prevent scarring or cutting same.

The rotor must not be lifted by slinging around the commutator, and care should be exercised that no pressure is applied to the commutator by the slings during lifting. When possible a rotor should be supported from its shaft or spider. If it is necessary to place it on the floor, it should be set on a board not wider than the active iron. It should be borne in mind that a scar or dent in the laminations short-circuits them and partly nullifies the effect of the laminated construction. Eddy currents will be set up in the laminations so short-circuited which will cause a hot spot, and endanger the insulation at this point.

FOUNDATIONS

The general purpose of constructing a foundation is to form a sufficient and solid base for the load to be supported, so that no movement will take place after its erection. Since it has been found that almost all of our soils will compress under heavy loads, it is natural to expect most foundations to settle to some extent, regardless of the materials used. The main object of the engineer, then, should be to limit this settlement and guard against unevenness of settlement.

Bearing Value of Soils—Before the bearing value of any soil can be determined and before any important foundation structure is erected, the engineer should make a thorough test of the soil, either by drilling or digging test holes. Where excavating is not necessary tests may be made by loading 1 foot square pedestals up to the bearing capacity required. This type of testing should be done at several placed to see if the soil is uniform. In making a test of this kind a permanent bench mark should be determined before the load is applied and accurate levels taken with an engineer's level as the load is increased, until the settlement reaches the maximum set. The working load is generally taken at one-fifth of the load necessary to produce the maximum settlement giving a factor safety of five.

Where marshy and wet soils are encountered, it is very difficult to spread the footer foundation on footing course sufficiently to carry the load, and concrete or wood piles are used. Formulas for safe bearing powers of piles are simply aids to judgment and should not be followed blindly.

ERECTION

When placing machines on the foundations, particular care should be taken to line up all bearings correctly and see that they are clean. Journals should be examined for rough or rusty places and gone over carefully to see that they are in perfect condition before being placed in the bearings. The air gap should be checked after the machine is set, and all bolts gone over to see that they are tight. Machines should be realigned regardless of shop alignment, due to stresses which may be received or set up during handling or shipment.

With machines of large size, the armature must be pressed upon the shaft at the point of installation. 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 surface to be fitted, as it may have received injury during transportation. File down any roughness of this sort and smooth with an emery cloth. See that the key has a good bearing on its sides and clears on top about $\frac{1}{32}$ of an inch.

Before proceeding further with the operation, the surfaces on the shaft and in 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 pressure required to force 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 pressure 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 and one at the end of the shaft, and draw the armature in place by means of two bolts which pass through the yokes and spider close to the hub. Care should be taken to tighten up evenly on the bolts, otherwise the hub will twist and bind on the shaft. Once started, this operation should be carried to completion as quickly as possible, as, if the armature is allowed to set several hours when only part way on the shaft, it may require from 25 to 50 per cent more pressure than was previously used to start it again.

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

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

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

After the machine has been carefully aligned and leveled the bedplate should be grouted. After the grout is settled and hardened all wedges should be removed and the foundation bolts gone over and tightened.

In setting up any machine in which the bearings are independent of the frame, great care must be exercised in the adjustment of the air-gap, between the rotor core and pole faces, as any inequality in this gap may cause unnecessary friction and heating of the bearings and unequal heating of the armature iron. Adjust the air-gap horizontally by shifting the frame, and vertically by means of thin sheet steel liners between the bedplate and the yoke. During this operation gauge the gap at different points on the front and back of the machines. The rotor should then be revolved 180 degrees and these values checked in the new position.

STARTING

After the machines are completely set up they should be thoroughly dried out before being started. This can be done by applying heat externally or by circulating current in the windings. Drying out externally can be done by placing resistance grids under the machines to dissipate roughly about one kilowatt per

100 horsepower rating of the machines. Care should be taken that no part of the hot grids comes in contact with the windings. The machines should be covered with a tarpaulin and an opening provided at the top to allow the escape of the moisture, otherwise it will condense on the machine again as soon as the heat is discontinued. A thermometer should be kept on the machines, and the temperature not allowed to exceed 90 degrees Centigrade unless it is known positively that the insulation is of such a character that higher temperatures will not be injurious.

The time required to dry out a machine thoroughly will vary from a few days to several weeks, depending on the size of the machine and the condition of the insulation when starting. Insulation resistance should be taken two or three times a day at uniform intervals, during the period of dry out, and a curve plotted using resistance as ordinates and hours as abscissae. This process should be continued until the curve shows that the insulation is thoroughly dry, i. e., until there is no further change in resistance. A high voltage megger is the most convenient method of measuring insulation resistance. Instructions coming with the instrument should be carefully followed or misleading and erratic results may be obtained. All readings should be taken when the insulation is warm.

Insulation Test—It sometimes happens that the insulation of a machine is mechanically injured or exposed to moisture after the factory test but previous to erection. For this reason, insulation tests should be made before the machine is run.

The higher the resistance, the better the general condition of the insulating material. The insulation resistance of the field will be much higher in proportion to the e.m.f. of the exciting current than that of the armature and will in general give little trouble. Since large armatures have much greater areas of insulation, their insulation resistance will be proportionately lower than that of small machines. Even though the material is in exactly the same condition, the insulation resistance of any machine will be much lower when hot than when cool, especially when the machine is rapidly heated. The only feasible way of increasing the insulation resistance when the machine is complete is by "drying out." Armature winding and field coils are dried out by heat; baking in an oven is to be preferred but is often impracticable. They are usually heated by the passage of current. In the case of the armature this may be accomplished by short-circuiting the leads and running the generator with a low field excitation, just sufficient to produce the proper current.

In making the insulation resistance measurements a 500-volt direct-current circuit and a 500-volt direct-current voltmeter may be conveniently used. The method of making a measurement is to first read the voltage of the line, then to connect the resistance to be measured in series with the voltmeter and take a second reading.

The measured resistance can be readily calculated by using

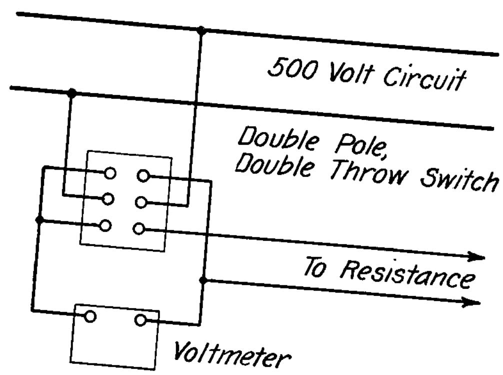


FIG. 3—CONNECTIONS FOR MEASURING INSULATION RESISTANCE

the following formula and the method of connecting the apparatus shown in the diagram Fig. 3.

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

V = voltage of the line.

v = voltage reading with insulation in series with voltmeter.

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

R = resistance of insulation in ohms.

Voltmeters having a resistance of one megohm are made now for this purpose so that, if one of these instruments is used, the calculation is somewhat simplified, since r = 1 and the above formula becomes $R = \frac{V-v}{v} = \frac{V}{v} - 1$ megohms.

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

While it is desirable to use 500 to 700 volts D-C. in making an insulation test, where this is not available 250-volt D-C. may be used.

Machines which have been dried out by applying external heat only may show a very good value of insulation resistance with a megger and still have moisture in the insulation next to the conductor. This is particularly true of high voltage machines where the insulation is heavy and it is very difficult to entirely drive out the moisture. Hence, a much more effective method is to apply the heat internally by circulating current. Machines of 2200 volts or higher can generally be dried by applying 220 volts alternating current, simply by connecting this circuit to the terminals without interposing resistance. This point should, however, be checked with the manufacturer or the machines can be watched very closely at first by observing thermometers placed on the coils to make sure that they do not overheat. The application of current directly to the coils presupposes that the insulation is in good enough condition to withstand this low voltage. If the insulation is in poor condition, external heat should be used until it is safe to apply a low voltage for circulating current. The same process of taking megger readings should be followed as is described above for external heating until the insulation resistance reaches a fixed value. The A. I. E. E. recommendation for insulation resistance is:

$$\text{Megohms} = \frac{\text{Voltage}}{\text{Kva.} + 1000}$$

This value seems to be low, and for some mill apparatus, particularly 2200-volt machines, the machines should show at least one megohm per thousand volts. These values are not given with the understanding that the drying process should be stopped when these values are reached but, in every case, the process should be continued until a constant value is obtained. If this constant value does not equal that given above, the manufacturer of the apparatus should be notified.

Many machines are placed in service after the above precautions have been taken, but on large apparatus where continuity of service is important, many operators give the apparatus the same insulation test as it receives in the factory before shipment. Megger tests, although serving as a measure of precaution, cannot be entirely relied upon, as it is possible to show good resistance values when the insulation is on the verge of a breakdown. The only adequate method of measuring the ability of the insulation to withstand operating voltage is to apply actual potential test on the insulation. This requires a small transformer testing box designed to give a wide range of voltage. The test voltage can be applied for a period of one minute, and if a weak point is found very little damage is done, due to the small capacity of the transformer. On the other hand, if the apparatus is placed in service without discovering this weak point, the apparatus itself may be connected to a power circuit having considerable capacity, and when the breakdown occurs the large amount of power available could damage the machine seriously. Such a breakdown occurs when the mill is in operation and its delay is serious. If a testing transformer is used, this test can be made before the equipment is started up and the repair made before the mill is placed in operation. Before this voltage test is made, the machine should be blown out and all brass and copper parts wiped clean, as the presence of dirt may cause a failure, even when the machine is in good condition.

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

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

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

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

Before starting a motor, it should be thoroughly inspected to see that all bolts are tight, brushes operating freely in their holders, that there is nothing in the air-gap, that the bearings are oiled and, if water cooling is necessary, that the water is turned on. Rotate the machine by means of a bar or crane before actually starting with current to make sure that it turns freely. After the machine is started and before it is brought up to full speed, it should be inspected to see that the oil rings are turning and actually bringing up oil and that no part of the rotor is striking. The bearings should be inspected every few minutes while bringing the machine up to speed and for four or five hours after it is up to speed, to insure that they are not generating excess heat. A thermometer should be placed on any bearing that shows a tendency to generate excess heat. This thermometer should be read at least once every five minutes, and any sudden rise in temperature is the signal to shut down and examine the bearing, as it is probably "cutting," and will need to be scraped, and the alignment verified.

D-C. GENERATORS AND MOTORS

Brush Position—When the brush position on a commutating-pole machine has once been properly fixed, no shifting is afterward required or should be made, and most commutating-pole generators are shipped without any brush shifting device. An arrangement for securely clamping the brushholder ring to the field frame is provided.

Adjusting the Brush Position—In commutating-pole machines accurate adjustment of the brush position is necessary. The correct brush position is on the no-load neutral point, which is located at the factory during test. The following arrangement is employed to enable the erector to obtain the same setting in the field.

The relative positions of the ring which carries the brush-holder arms and the field frame are indicated by a dowel pin.

The dowel pin cannot be put in place until the rocker ring has been located in the correct position. This determines the relative location of the rocker ring and the magnet frame. It is equally important to fix the relative location of the brushholders and the rocker ring. This is accomplished by supplying a fixed brush bracket and bolting the brushholders to the brush brackets, the wear of the commutator being taken up by shifting the brush-holders radially on the brush brackets, which does not change the position of the brushes on the commutator.

The position of one set of brushes having been thus fixed, the others should be set by uniform spacing from the first set. The best way to secure this spacing is to cut a narrow strip of tough paper exactly equal in length to the circumference of the commutator. This strip is then divided into equal parts corresponding to the number of poles, after which it is stretched around the commutator and the brushes spaced accordingly. This method gives far more accurate results than those obtained by depending upon the uniform spacing of the bars.

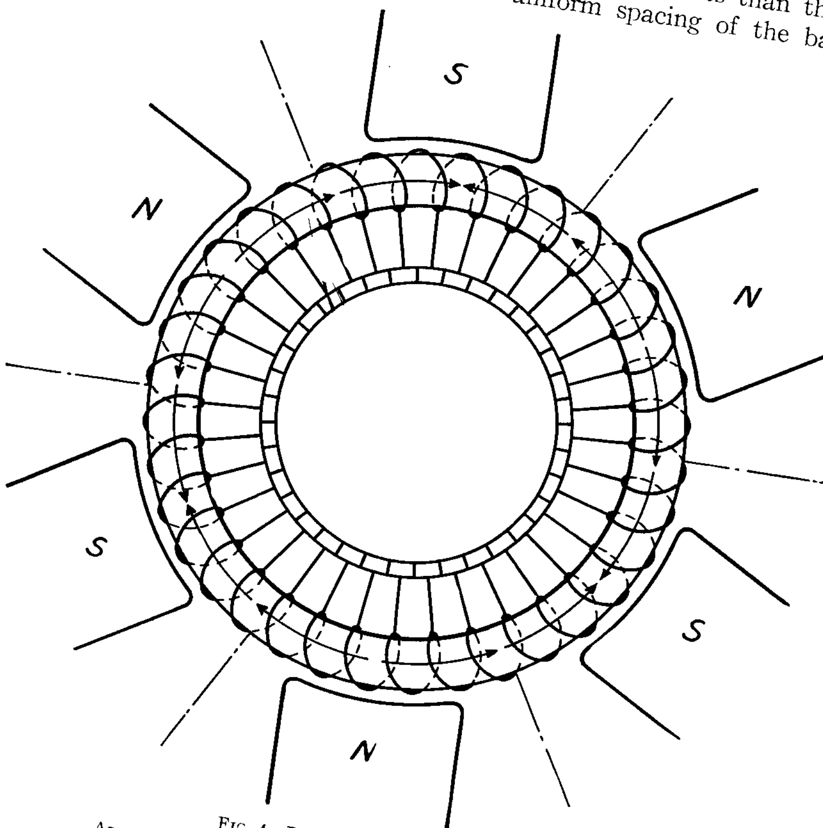


FIG. 4—RING-WOUND ARMATURE
ARROWS INDICATE VOLTAGE INDUCED WHEN FIELD IS OPENED

The bolts and dowels are so located that the templet cannot be put on in the wrong position.

Locating Brush Position—Where it is necessary for any reason to locate the brush position on commutating-pole machines in the field, the following methods can be used:

Mechanical Method—When it is impossible to set the brushes by the "kick" method a mechanical method can be used. The proper position of the brushes, on most machines, is in a plane which passes through the centers of two diametrically opposite main pole pieces. This position can be approximately located on machines, the armature coil throw of which is exactly one pole pitch, by tracing the lead from a conductor under the center of the commutating pole to the commutator bar. As many machines are made with chorded windings, this method can only be used as approximate and the brushes should be set by actual trial by observing the commutation under load with the brushes in different positions.

Electrical or "Kick" Method—The electrical neutral for brushes may be correctly and simply located if due care is exercised.

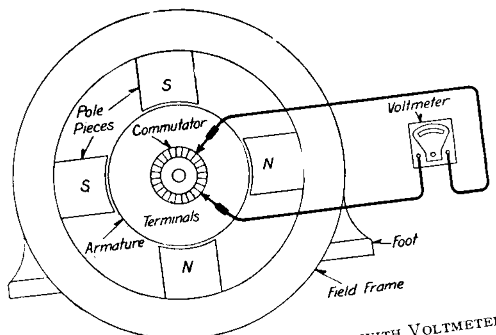


Fig. 5—Finding Electrical Neutrals with Voltmeter

With all the brushes raised from the commutator and the machines standing still, if the shunt field be excited to a few per cent of its normal strength and the field current suddenly broken, voltages will be induced in the armature conductors by a transformer action. Consideration of these voltages in conjunction with the diagram in Fig. 4, will show that the maximum voltages are produced in those conductors located in the interpolar space (between the main poles) and that the minimum voltages are produced in those conductors located nearest to the centers of the main poles. It will also be found that the induced voltages in conductors located at equal distances to the right and left of the main pole centers are equal in magnitude and opposite in direction.

Hence, if the terminals of a low-reading voltmeter (say five volts) be connected to two commutator bars on opposite sides of the center line of a main pole (Fig. 5) and exactly half way between the center lines of two main poles, it will show no deflection when the field current is broken, because there will be equal fluxes in opposite directions through equal numbers of turns. The spacing of these commutator bars is evidently the correct distance between brushes on adjacent brush arms.

In Fig. 4 a ring-wound armature is shown for simplicity. The leads come straight out to the commutator bars and the neutral points, in this case, will be midway between the main poles. In actual practice, the armature conductor, which lies in the exact neutral zone on the surface of the armature, leads to a commutator bar located approximately under the center of a main pole, hence the electrical neutral on the commutator will be found approximately in line with the main pole centers.

To find the electrical neutral in practice, two pilot brushes are made of wood or fibre to fit the regular brushholders and each brush carries in its center a piece of copper fitted for making line contact with the commutator and for connection to the voltmeter leads, Fig. 5. These two brushes are put into regular brushholders located on adjacent brush arms and connected to the terminals of the voltmeter, Fig. 6. The holders and brushes are then shifted

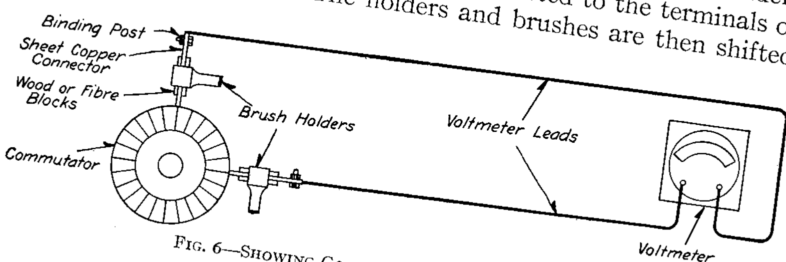


Fig. 6—Showing Construction of Pilot Boxes

slightly forward or backward as necessary until breaking the field current occasions no deflection on the voltmeter.

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

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

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

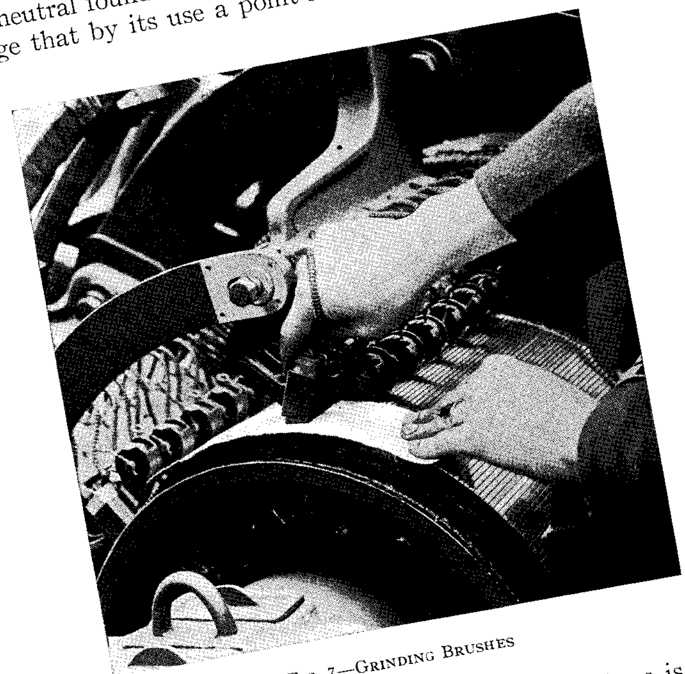


FIG. 7—GRINDING BRUSHES

is obtainable where the number of commutator bars is divisible by two, as in many 6-pole machines.

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 most easily accomplished after the brushholders have been adjusted and the brushes inserted. Lift a set of brushes sufficiently to permit a sheet of sandpaper to be inserted. Draw the sandpaper in the direction of rotation under the brushes, releasing the pressure as the paper is drawn back, being careful to keep the ends of the paper as close to the commutator surface as possible and thus avoid rounding the edges of the brushes. It will be found by this means a satisfactory contact is quickly secured, each set of brushes being similarly treated in turn. If the brushes are copper plated, their edges should be slightly beveled so that the copper does not come in contact with the commutator. (See Fig. 7.)

Make frequent inspection to see that—

(1) Brushes are not sticking in holders.

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

(3) Tension is changed as brush wears.

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

(5) Worn-out brushes are replaced before they reach their limit of travel and break contact with the commutator.

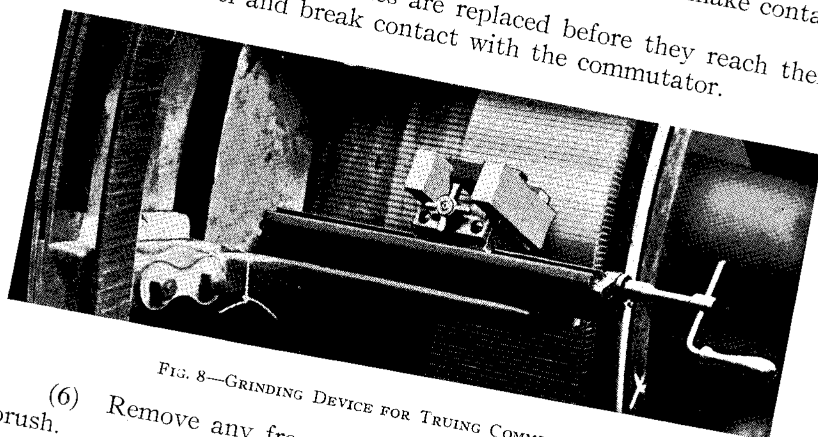


Fig. 8—Grinding Device for Truing Commutators

(6) Remove any free copper picked up by the face of the brush.

Commutator—The commutator is perhaps the most important feature of the whole machine in that it is most sensitive to abuse. Under normal conditions, it should require little attention beyond frequent inspection. It is important that the commutator surface should be kept in good condition. Rough commutator or misalignment may cause bad commutation and possibly flashing at the brushes, and will have the effect of shortening the life of the commutator. The mica between commutator bars should be slotted $\frac{1}{16}$-inch below the level of the bars, the armature removed and the commutator turned down in an engine lathe. If necessary to true up the commutator, it should be done with a grinding tool at the normal running speed of the commutator. The surface should be finished smooth. Sometimes with large machines it is more convenient to rig up a temporary truing device, leaving the armature in its own bearings and running it slowly either as a shunt motor or from a separate belted motor. Ordinarily, unless in very bad condition, it may be dressed down with a piece of sandstone conveniently mounted in a device especially designed for this purpose. (See Fig. 8.)

This grinding device is mounted on one of the brushholder arms or brackets, the carbon holders being removed to accommodate it. The stone should be properly adjusted against the rotating commutator until a clean cutting effect is secured; the surface can then be finished with No. 00 sandpaper. Sometimes a little sandpapering is all that is necessary. Emery cloth or paper should never be used for this purpose on account of the continued abrasive action of the emery which becomes embedded in the copper bars and brushes. Even when sandpaper is used the brushes should be raised and the commutator wiped clean with a piece of canvas lubricated with a very small quantity of vaseline or oil. Cotton waste should never be used and an excess of lubricant must be avoided.

All commutators are thoroughly baked and tightened before leaving the factory, but if a bar should work loose it should be attended to promptly. The same may be said of flat spots or "flats" which will sometimes occur, due to a loose bar, unusually soft copper, or even to a severe flash or short-circuit.

Under normal conditions the commutator should become dark and highly polished after a few weeks' operation, and so remain unchanged for years.

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

Even with the most careful workmanship, high mica will sometimes develop and start sparking, which burns away the copper and aggravates the difficulty. By prompt action serious damage can be prevented by cutting away the mica to a depth of one-thirty-second to one-sixteenth of an inch below the adjacent copper. A hack-saw blade held between suitable guides will serve the purpose of a cutter, but undercutting is much better done by a commutator slotting tool.

OPERATION AND CARE

After the machines are placed in regular service, the entire equipment should be kept clean, particularly the insulation. It is advisable to keep all machines painted, as the paint will not only be a benefit to the machines by preventing rust and also making them easier to clean, but it will be an incentive to the operators and attendants to keep the motor-room and apparatus neat. This in itself helps to reduce maintenance. In addition to painting the iron and steel parts of the machines, the exposed parts of the windings, and particularly the creepage surfaces over the insulation, should be gone over at least once a year with a good insulating varnish. Most of these varnishes will air dry in from 24 to 48 hours with a room temperature of approximately 80 degrees Fahrenheit. If a shorter time is necessary, the varnish can be dried more quickly by covering the machines with a tarpaulin, leaving an opening at the top and placing resistance grids under the machine to dissipate energy as previously mentioned in this book. This treatment will cause the insulation to become smooth and glossy so that dirt will not adhere readily.

When operating the machines, the bearing water should always be kept running on such bearings as are designed for water cooling and, upon starting a machine, all bearings should be examined to see that the oil rings are turning and feeding the bearings with an ample supply of oil. The bearing oil should be kept clean and changed or filtered once a year or upon any evidence of dirt or grit. The question of the best grade of oil to use should be given careful study, particularly where oil ring lubrication is depended upon. It is sometimes found that the grade of oil giving the best results in some localities or seasons will be too thick or too thin for the best results in other places or times. A little study and experimenting will enable a supervisor to determine the best grade of oil for his particular conditions.

BEARINGS

All bearings are arranged with oil ring lubrication. In addition bearings 9 inches in diameter and above are piped for gravity oil feed as an emergency feature and to be used in case of high speeds to carry away excess heat generated in the bearing. The bearings are piped on both sides, but the oil feed should be connected only on that side where the rotation on the shaft will tend to carry the oil downwards. The oil drain pipe used with the gravity feed system may be connected up on either side of the pedestal. The oil rings should have a free "restless" motion rotationally and sideways in order to get the best lubrication. When a bearing is re-babbitted particular attention should be paid to attain this result. The bearings are arranged with two or four oil rings dipping deeply into the oil cellar. The oil rings deliver more oil than is actually required for lubrication and the excess flows back into the cellar. The lower half of the bearing is championed off from the top downwards to about 30 degrees to the negative or entrance point. (Fig. 9.)

This arrangement permits the oil to enter the bearings in a perfect film and maintains a wedge shaped entrance which is kept full by the oil ring. In case a bearing is rebabbitted, the babbit should be cut away to confrom to this arrangement.

All bearings should be carefully aligned when the motor is installed. In addition where three or more bearings are used on the same line of shaft the bearings should be kept in alignment at regular intervals by means of surveyor's instruments. This is in order to prevent excessive strains on any bearing or in the shaft.

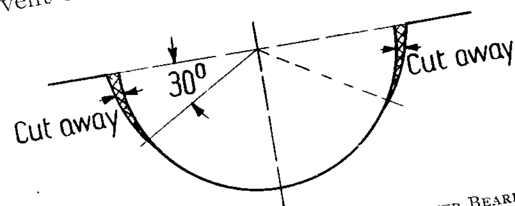


Fig. 9—Outline Showing Champhering of Lower Bearing

Where thrust bearings are used it is essential that they have good lubrication. As a general rule thrust bearings serve as an emergency feature only, and therefore the best results are usually obtained by setting the stator in such manner that the thrust surfaces run just clear of each other except when the end thrust comes on.

The collector should run true at all times. If it for any reason is out of true, steps should be taken at once for remedying this condition. The rings should be preferably trued up when running at full speed, taking care to obtain a smooth wearing surface. Before truing up the ring make sure that all bolts and nuts are tight.

It is important to keep the collector thoroughly cleaned. Particularly at the points where the rings are fastened to the bush, the mill dirt and dust has a tendency to collect, and unless these parts are kept clean the dirt is liable to cause arcing even where liberal insulation is provided.

A periodic inspection should be made of all equipment and attention directed to the following points. All bolts should be tight and particular attention should be given to the commutating pole bolts, commutating coil bolts, and all bolts securing current carrying connections. A watch should be kept on sweated joints to detect cracking. Creepage surface on stationary and rotating parts should be kept free from dust and care taken that there is no clogging of the air ducts in the armature punchings and air spaces between the armature and coils; neglect of this may cause hot spots and the consequent roasting of the insulation.

It is advisable to carry a reasonable supply of spare parts for each motor. Ordinarily one-fourth set of coils for stator and rotor, and one set of brushes and one bearing of each kind is sufficient. All repair parts should be ordered from Westinghouse Electric & Manufacturing Company, giving the name of the part wanted and the serial number of the motor on which the part is to be used.

Periodic inspections should be given to the entire equipment, say every week or two, at which time the machine should be thoroughly blown out with a moderate pressure air blast; about 25 or 30 pounds per square inch is the most satisfactory. As the mill line is usually high pressure, it is advisable to provide a reducing valve and water trap so as to obviate any danger to the insulation due to moisture or a high-pressure blast. In come cases a low pressure air compressor is installed for this purpose. Care should be taken to prevent dirt from getting into the bearings during this cleaning.

At these inspection periods, the insulation resistance should be measured while the machines are still warm, and a permanent record kept. This will show whether any deterioration of insulation is taking place, and preventive steps can be taken before an actual breakdown occurs. During this inspection, all bolts and connections should be examined to see that they are tight, as they are liable to become loosened by the continual vibration and shocks from the mill. All switching and auxiliary apparatus should be regularly inspected also, as only by this means can satisfactory and continuous service be realized.

Air-gap should be checked at regular intervals and adjusted when necessary. It is preferable to start in with an air-gap slightly larger at the bottom. Provision for adjustment is made in the stator feet which have shoes, liners, jack screws and bolts arranged in such a manner that the stator may be shifted by small increments in any direction and locked. This adjustment need not to be changed when sliding the stator sideways to uncover the rotor, as this only necessitates loosening up of the holding-down bolts.

If at any time the machines are to be out of service for a while, they should be thoroughly cleaned and inspected mechanically and electrically, so as to be ready for operation on short notice. Tarpaulins should be used to cover the machines, and if the temperature of the motor room is not uniform at all times external heat should be used to keep the machines at a temperature that will prevent sweating. Where high voltage alternating-current machines are installed in localities having high humidity, scheme have been worked out whereby 220 volts alternating-current can be applied to the motor windings by simply switching the motor from its power line to the shop circuit. This can be done very quickly and only a small amount of power is required, as the heat is applied internally and it is only necessary to keep the temperature a few degrees above that of the surrounding atmosphere to prevent precipitation. It is customary to instruct the operators to apply this low voltage when the mill is shut down over the week-end or for any other period of appreciable duration.

The brushes should operate freely in their holders, and it is recommended to check the spring pressure occasionally. The proper pressure is about two pounds per square inch of cross section of brush. It is also important to keep the brush rig clean, particularly the studs on which the brushholders are mounted. Brushes should be wiped out and kept free from dust to prevent sticking in the holders.

In conclusion, it should be emphasized that electrical equipment shows no external signs of fatigue or failure, and hence breakdowns, with resulting interruption to service, are much less liable to occur when the apparatus is systematically and regularly inspected.

WESTINGHOUSE PRODUCTS

For Industrial Use

Motors and controllers for every application, the more important of which are: Machine shops, woodworking plants, textile mills, steel mills, flour mills, cement mills brick and clay plants, printing plants, bakeries, laundries, irrigation. elevators and pumps.

Welding outfits

Gears

Heating devices for industrial use, such as: Glue pots, immersion heaters, solder pots, hat-making machinery, and electric ovens.

For Power Plants & Transmission Lines

Arc lamps and accessories
Circuit-breakers and switches
Condensers
Controllers
Control switches
Frequency changers
Fuse and fuse blocks
Generators
Insulating material
Lamps, incandescent and arc
Lightning arresters
Line material
Locomotives
Meters
Motors
Motor-generators
Rectifiers
Regulators
Relays
Solder and soldering fluids
Stokers
Substations, portable
Switchboards
Synchronous converters
Transformers
Turbine-generators

For Transportation

Locomotives
Railway Equipment
Marine Equipment

For Mines

Arc Lamps
Locomotives
Motors for hoists and pumps
Motor-generators
Portable substations
Switchboards
Line material
Ventilating outfits

For Farms

Motors for driving churns, cream separators, corn shellers, feed grinders, pumps, air compressors, grindstones, fruit cleaning machines and sorting machines.

Generators for light, power, and heating apparatus.

Transformers

For Office and Store

Electric radiators
Fans
Arc Lamps
Mazda lamps

Small motors for driving addressing machines, dictaphones, adding machines, cash carriers, moving window displays, signs, flashers, envelope sealers, duplicators, etc.

Ventilating outfits

For Electric and Gasoline Automobiles and the Garage

Battery charging outfits
Charging plugs and receptacles
Lamps
Meters
Motors and Controllers

Small motors for driving lathes, tire pumps, machine tools, polishing and grinding lathes.

Solder and soldering fluids.

Starting, lighting and ignition systems, embracing: Starting motors, generators, ignition units, lamps, headlights, switches, etc.

Tire vulcanizers
Rectigon

For the Home

Electric ware, including: Toaster stoves, toasters, irons, warming pads, curling irons, coffee percolators, chafing dishes, disc stoves, radiators and sterilizers.

Automatic electric ranges

Fans

Incandescent lamps.

Small motors for driving coffee grinders, ice cream freezers, ironing machines, washing machines, vacuum cleaners, sewing machines, small lathes, polishing and grinding wheels, pumps and piano players.

Sew-Motors.

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