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Post Office Engineering Department

**TECHNICAL PAMPHLETS
FOR WORKMEN**

Subject :

**Maintenance of Power Plant for
Telegraph and Telephone Purposes**

ENGINEER-IN-CHIEF'S OFFICE

May, 1934

(*Reprinted: August, 1927, incorporating amendments to date.*)
 (" *December, 1930,* " " " " ")
 (" *March, 1932,* " " " " ")
 (" *April, 1936* " " " " ")

LONDON
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[Continued on page iii of Cover.]

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MAINTENANCE of POWER PLANT for TELEGRAPH and TELEPHONE PURPOSES

(G.3.)

*The following pamphlet in this series is of
kindred interest :—*

G.2. Power Plant for Telegraph and Telephone Purposes.

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MAINTENANCE OF POWER PLANT FOR TELEGRAPH AND TELEPHONE PURPOSES

DAY TO DAY MAINTENANCE

Importance of Cleanliness.—It is impossible to over-emphasise the importance of cleanliness in connection with the satisfactory operation of electrical machinery. The cleanliness here referred to is the systematic cleaning of working parts, contact faces, connections, interior of dynamo and motor carcase, field coils, brush holders, bearings, commutator surface, armature winding, etc.

On completing a run the machine should be thoroughly cleaned of dirt, copper dust and oil, and left in proper order for the next run. This work can be done much more easily when the machine is warm.

Dust covers should always be placed over machines not in use.

Before starting a motor or dynamo make sure that the machine is clean throughout, paying particular attention to the commutator or slip rings, brushes and electrical connections. Remove all copper dust. Where carbon brushes are used in box type holders see that they move freely in the holder, and in other types see that the holders move freely on spindle and make good contact with the commutator. Examine oil gauges to ascertain that the oil is up to proper level, and as soon as the machine has been started inspect the oil rings to see that they are working freely. Failure to attend to this is a frequent cause of trouble, especially with small machines used for driving ringers. If the machine is provided with ball bearings, give the grease-cup caps a full turn, which will suffice for a day's run. If the machine has been out of use for more than a day or two, it should be given a turn by hand to ascertain that the armature turns freely in its bearings. Where belts are used they should be examined to ascertain that they are free from grease, in proper tension, and that the joints are in good order.

Starting D.C. Motors.—To start a direct current motor, first see that the starting rheostat is in the " off " position, then close the main switch and turn the starter handle slowly to " full on " position. Should the motor fail to start when the starter handle has been moved to the second contact, the main switch should be opened and the cause investigated in accordance with directions given later. The time occupied in bringing the motor

up to full speed varies with the size of machine, ten seconds being sufficient for motors up to 1 h.p., increasing up to, say, thirty seconds for the largest sizes used for telephone purposes. Unduly prolonging the starter-up period results in overheating the resistance in the starter and leads to faults, while cutting out resistance too quickly may cause the motor to "flash over" at the brushes, blow the fuses and do other damage.

Starting A.C. Motors.—A.C. motors used by the Department are chiefly of the induction type, although in some cases Repulsion, Repulsion-Induction, Series and Shunt Motors are used. The smaller sizes of two or three-phase motors offer no difficulties so far as starting is concerned, the only operation necessary being to close the main switch. The larger sizes of two or three-phase motors are provided with either a starting resistance or an auto-transformer, combined with a two, three or four-pole double-throw switch, and usually termed an auto-starter. Fig. 1 shows the connections of the former dia-

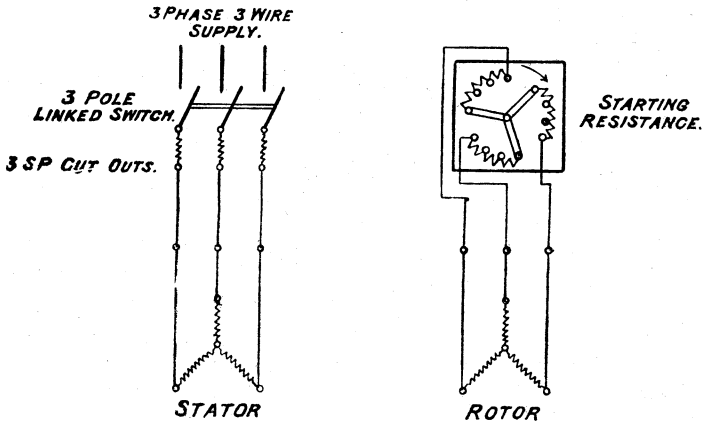
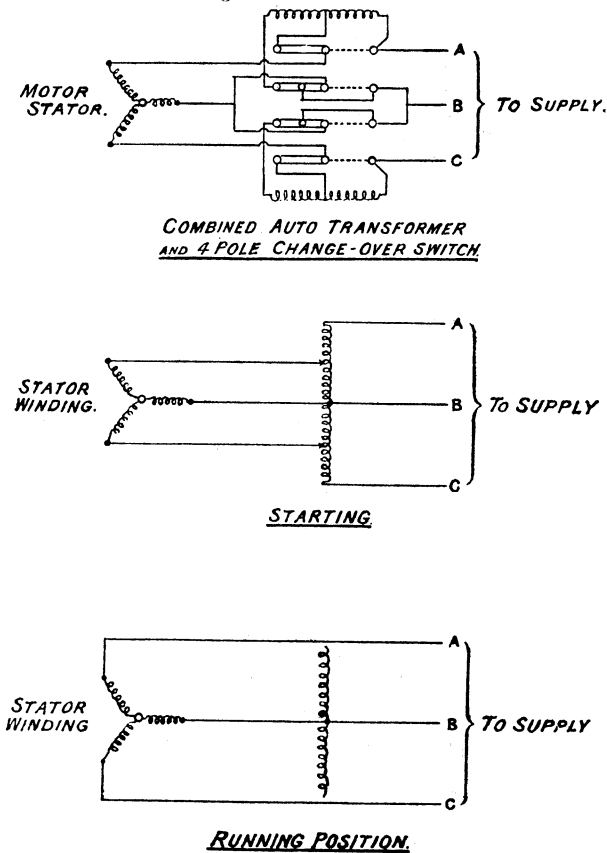


Fig. 1.

**CONNECTIONS OF 3-PHASE MOTOR WITH STARTING RESISTANCE
IN ROTOR CIRCUIT.**

grammatically. The motor is started by closing the main switch and turning the starting resistance handle slowly in a clockwise direction until all resistance is cut out.

The connections of a three-phase motor fitted with an auto-starter are shown in Fig. 2. In this case the motor is started



NOTE.—In starting position the voltage applied to motor is only one half the supply voltage.

Fig. 2.

CONNECTIONS OF AUTO STARTER FOR 3-PHASE MOTOR.

by closing the switch on the side marked "starting" and holding it there until the motor attains full speed, when the switch should be quickly moved into the "running position", thus cutting out the transformer and applying the full voltage of supply to the motor terminals.

Single-phase induction motors are the most difficult machines to start, especially when they are direct coupled to a dynamo and special phase-splitting devices have to be provided. Usually the stator of the motor is provided with two distinct sets of windings, one set of which, known as the "starting" coils, is connected direct to the supply circuit, while the second, known as the "running" coils, is connected to the supply mains through a resistance, or choke coil, thus setting up a

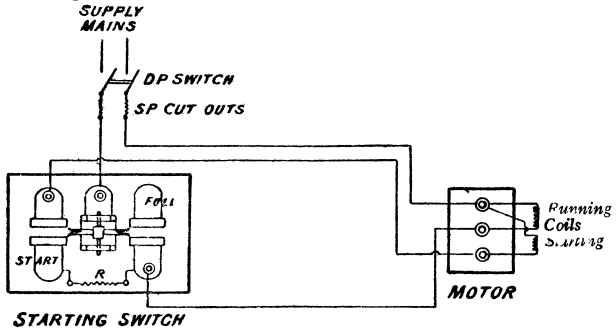


Fig. 3.

SMALL SINGLE-PHASE MOTOR. CONNECTIONS OF STARTING SWITCH AND MOTOR.

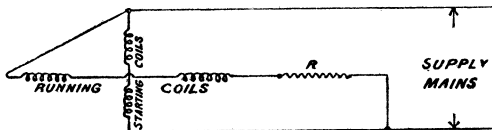


Fig. 3a.

SINGLE-PHASE MOTOR. STARTING CONNECTIONS.

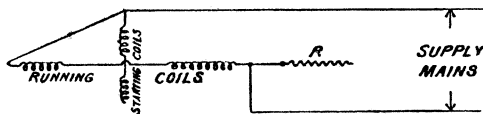


Fig. 3b.

SINGLE-PHASE MOTOR. RUNNING CONNECTIONS.

phase difference which produces a weak rotating field somewhat similar to that produced by a two-phase supply. It is necessary, therefore, to provide the motor with a special switch or starting device. For the smaller motors this usually consists of a single-pole two-position switch, or a S.P. switch and press-button. With the former the main switch is first closed and

the S.P. two-position switch is then moved and held to the side marked "start," when the two sets of coils are brought into circuit, as shown in Fig. 3a.

As soon as the motor attains full speed the two-position switch is moved quickly to the "running" position. This cuts out the starting coils, and the conditions are as shown in Fig. 3b. Where a S.P. switch and press-button are provided it is only necessary to close the switch and keep the press-button depressed until the motor attains full speed, when it should be released.

In the case of larger motors, a resistance in the rotor circuit is provided, in addition to the two sets of windings on the stator, to limit the rush of current from the mains when the machine is switched into circuit. The connections are shown in Fig. 4.

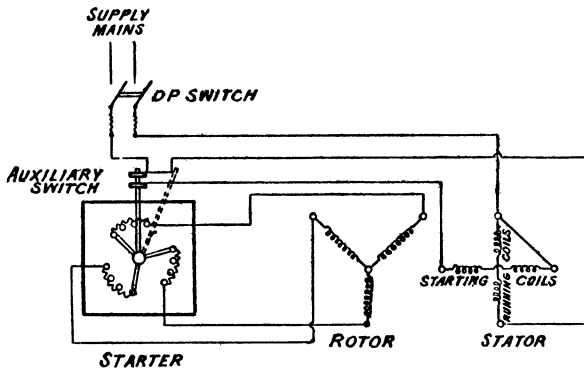


Fig. 4.

Single-Phase Induction Motor with Wound Rotor. Starting Coils of Stator Wound to give necessary Phase Angle without use of External Resistance. The Starter Handle opens the Auxiliary Switch at a predetermined moment and thus cuts out the Starting Coils.

Usually the whole device is mounted in a manner very similar to that adopted on a D.C. starter, and the method of operation is much the same, except that the period required to bring the machine up to full speed is much longer, and, in some cases, it is necessary to give the rotor a turn by hand to overcome static friction and assist the weak field. An ammeter is nearly always provided in the supply leads, and this should be carefully watched to see that the current taken does not exceed the full-load current (or such other figure as the supply authority may stipulate) during the starting period, which will happen if the starter handle is turned too quickly.

Series and shunt-wound single-phase A.C. motors are started in the same manner as D.C. machines, while "Repulsion-Induction" motors are started in a similar manner to an induction motor.

Starting Dynamo and Switching on to Charge Battery.—A dynamo should be examined in the manner described for motors. The field rheostat should always be turned to the position where all resistance is in circuit. This direction is usually indicated by an arrow and engraved "To lower volts."

Having brought the machine up to speed, examine brushes to see that they are bedding properly and that there is no sign of sparking; next place voltmeter switch in position marked "Generator" and turn the field rheostat handle slowly in the direction marked "To raise volts" until the voltmeter shows a figure slightly (say, 1 to 2 volts) higher than that of the battery to be charged. Examine brushes again to see that there is no sparking, check voltage of battery and generator, place ammeter switch in "Charging Battery" position, and, finally, close circuit breaker if of the hand-operated type. If these directions have been carefully followed it will be found that a weak current "flows" into the battery. The rheostat handle is now moved in the direction "Raise volts" until the *Ammeter* indicates that the proper current is flowing; a further examination of the brushes should be made and, if any sparking is observed, the brush rocker arm should be moved carefully in the *direction in which the armature* is rotating until the sparking disappears. (Note.—The whole of the brushes should be examined, as it sometimes happens that, due to slight errors in adjusting or bedding, one set of brushes may be quite free from sparking when an appreciable amount of sparking is occurring on the opposite set. If difficulty is experienced in examining the brushes on the under side of the commutator, a small mirror will be found useful.)

Adjusting Current During Charge.—It will be found that the current tends to diminish rather rapidly during the first hour of charge, due to the rise in E.M.F. of the cells, and for this reason the field resistance will require adjusting three or four times during this period.

The efficiency of the charging machine is generally highest when delivering full load and, therefore, economy can be effected if the machine is run at full load during the greater portion of the charging period. The maximum rate of charge for secondary cells used by the Department is twice the 9 hour charging rate. This rate may be continued until the cells commence to gas freely when the rate of charge must be reduced so that the 9 hour rate is not exceeded.

Shutting Down Dynamo and Motor.—On completion of charge the field rheostat should be turned in the direction "Lower

volts" until the ammeter pointer falls to zero. Now open main dynamo switch, trip current breaker, turn field rheostat handle as far as it will go in "Lower volts" direction, open main switch of motor, observe that handle of starter returns to "Off" position if of automatic release type, or turn it to "Off" position if of the hand operated type.

CARE OF COMMUTATOR AND BRUSHES.

The satisfactory working of any direct current motor or dynamo which has passed the test at the maker's works and on site depends very largely on the good maintenance of commutator and brushes, and it is, therefore, most important that they should receive regular and careful attention.

Condition of Commutator.—A well-maintained commutator should have a smooth, dark, burnished surface free from grooves. Any sign of scoring, grooving, flats, high mica, pitting at edges of segments, carbon deposit or stickiness to touch is an indication of lack of attention or the existence of a specific fault.

Recessing Mica to Reduce Sparking.—Where carbon brushes are used, there is very little trouble in maintaining the commutator in good condition, except in occasional cases where a hard class of mica is used for insulation between segments and does not wear down at the same rate as the copper. In such cases the best remedy is to recess the mica to a depth of about $\frac{1}{16}$ in. between segments. If the armature can be spared it should be sent to the makers for this to be done, otherwise the work can readily be done *in situ* with a tool of the form shown in Fig. 5.

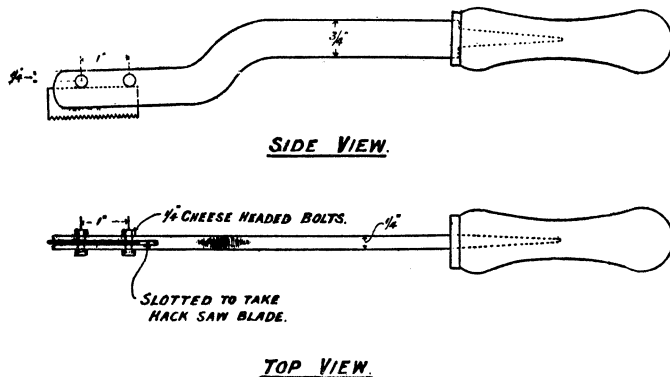
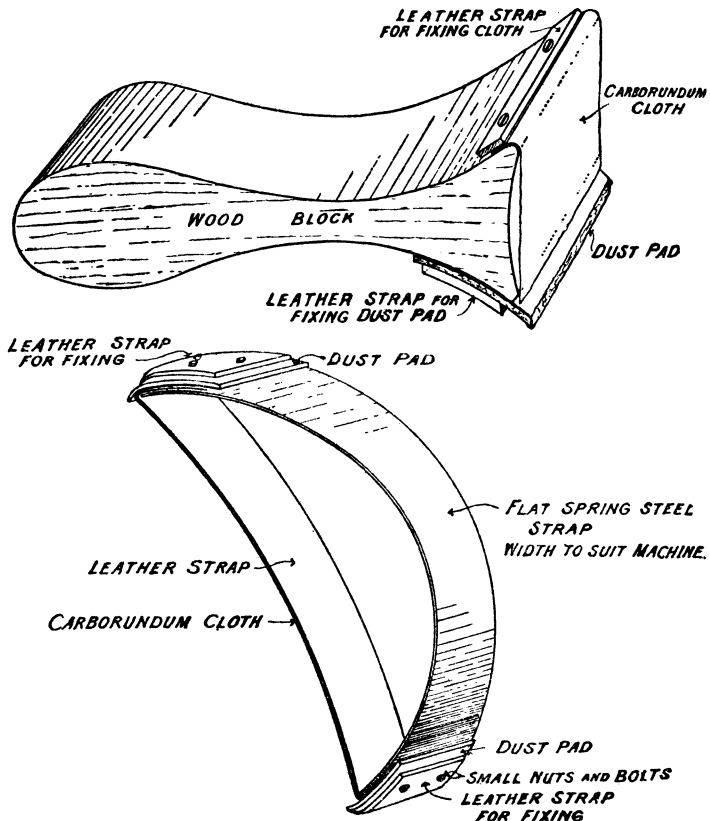


Fig 5

TOOL FOR RECESSING MICA ON COMMUTATORS.

It consists essentially of a short length of hack-saw blade fixed in a slot in a cranked rod by means of cheese-headed bolts. On completion of work the commutator should be cleaned and tested for contact between segments, as described later.

Re-surfacing Commutator.—As soon as a commutator shows any sign of uneven wear, scoring, pitting, etc., it should be



Figs. 6 and 6A.

HAND BLOCKS FOR POLISHING COMMUTATOR.

smoothed down and polished. If taken in time, this can be done by placing a strip of No. 1 carborundum cloth in a block shaped to a radius slightly greater than that of the commutator

and lined with a strip of leather belting (see Fig. 6), and pressing this lightly on the commutator while the machine is running at normal speed. The carborundum cloth should be moistened very slightly with paraffin oil so as to avoid causing copper dust to fly about. Where carbon brushes are used, the oil should be applied very sparingly, if at all, as it spoils them, and the brushes should be re-bedded when the commutator has been finished. The polishing of the commutator should be completed with the finest grade of carborundum or crocus cloth, followed by a piece of clean linen moistened with paraffin oil and then with a dry cloth. The machine should then be stopped and thoroughly cleaned to remove any copper dust which may have settled on the windings, brush holders, terminals, etc., and the commutator carefully examined to see that no particles of metal are embedded between segments. The cloths used for cleaning the commutator after grinding should not be used for cleaning bearings or spindles. In the case of a dynamo, the brushes should be removed from the holders when the commutator is being smoothed.

Precautions to Avoid Shock when Smoothing a Motor Commutator.—In smoothing down a motor commutator, it is usually necessary to do so while the machine is connected to the supply mains, and insulating gloves should always be worn to avoid risk of shock. It is also desirable to stand on a rubber mat or dry board as a further precaution. The block should be used as near as possible to a set of brushes, as the difference or potential is less between adjacent segments in this position than midway between the brushes, and there is less liability of sparking taking place under the block.

Removal of Carbon Deposit.—A spun glass fibre brush is useful for removing carbon deposit and polishing the surface of a commutator which is in good order, but neither this nor glass paper is much use for smoothing down roughness or cutting down high mica.

Type of Carbon Brush.—Where carbon brushes are used, the type originally supplied by the maker should be carefully noted, and replacements should always be made with the same make and class. This is necessary owing to the fact that carbon brushes are at present made in a great number of varieties, which differ in resistance, abrasive quality and other respects. If there is no distinguishing mark on the brush, it is better to make enquiry of the maker of the machine as to the class of brush to be used than risk using an unsuitable brush which may cause damage to the commutator and perplexity to the attendant.

Setting Brushes.—The brushes used on D.C. Motors and Dynamos require setting correctly as regards (a) neutral point, (b) distance between sets, (c) the angle at which they make contact with the commutator, and (d) contact pressure with commutator.

(a) *Neutral Point.*—In all direct current and certain A.C. machines it is necessary that the brushes should make contact with the commutator segments connected to those coils which are momentarily inactive, *i.e.* when they are midway between adjacent poles, but the fact that the method of leading out the wires from the armature coils to commutator lugs varies in different makes of machine renders it impossible to lay down any hard and fast rule as to the correct position of the brushes relative to the pole pieces. Generally speaking, however, almost all modern drum armatures require the brushes to be set opposite the pole pieces, but there are some machines on which the brushes have to make contact at a point midway between the poles, while in others they have to be placed at a point intermediate between these positions. Ring armatures, on the other hand, require the brushes to be set midway between pole pieces. Since the correct position of the brushes depends on the particular winding and internal connections, it is never safe for anyone not perfectly familiar with the machine to assume that they should be set in any particular position. It is usually possible, however, to trace the segment of commutator to which a given coil is connected, and, having noted this, the armature should be turned until the *coil* is midway between two adjacent pole pieces, when the brush rocker arm can be moved round until a brush or brushes cover the segments to which the coil is connected.

(b) *Distance between sets.*—This depends upon the number of poles and type of armature winding. With two poles, the brushes are set 180° apart, *i.e.* at opposite sides of a diameter ; with 4 poles and 4 sets of brushes they will be 90° apart and alternate sets connected to the + and - leads, but if only 2 sets of brushes are used, they will be placed 90° apart. On a 6 pole machine there may be either 2 or 6 sets of brushes which in either case will be set 60° apart.

If the commutator has not been marked, the simplest method of determining the correct distance apart is as follows : Take a strip of paper about $\frac{1}{2}$ in. wide, wrap it tightly once round the commutator, make a pencil mark where the two ends overlap, cut off the ends at this mark, replace the paper strip round the commutator to ascertain that the ends just meet. The strip should next be subdivided into as many parts as there are pole pieces on the machine (for a 2 pole machine fold the strip once, and for a 4 pole fold it twice). Replace the strip once

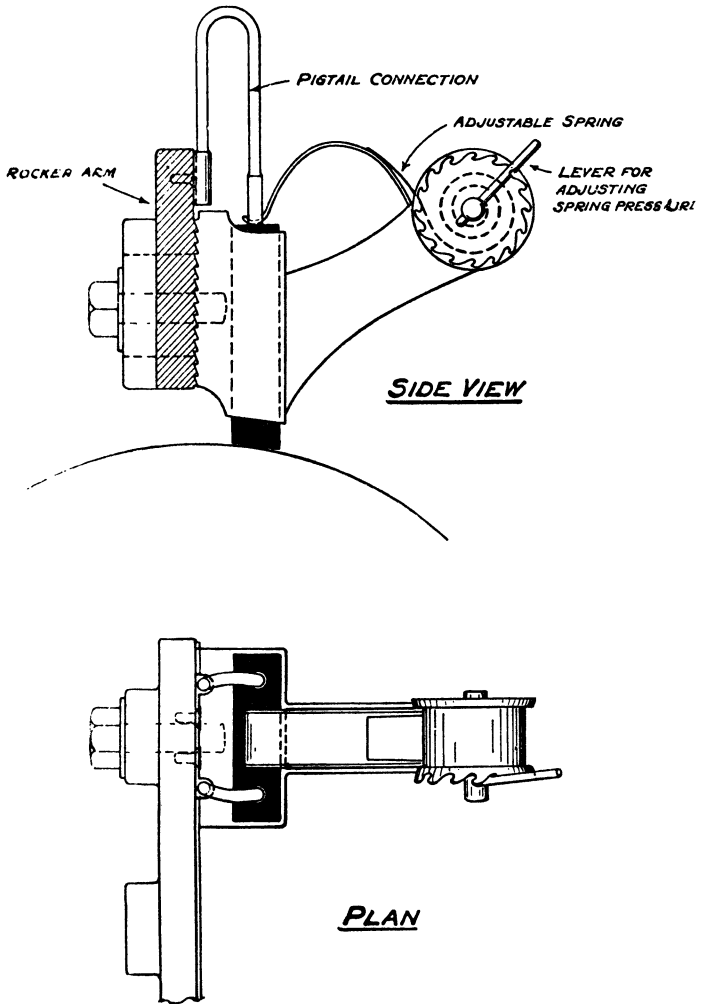


Fig. 7.

BOX TYPE CARBON BRUSH HOLDER WITH SLOTTED BRACKET ARM.

more around the commutator and make a mark on each bar which comes under a crease or line on the paper strip. This gives the exact distance which *similar* edges—leading or trailing—of two adjacent sets of brushes should be apart. The brush-holders should be set so that the brushes come on to these points, and if the box type holder is fitted it should be fixed so that its edge is not more than $\frac{3}{16}$ in. nor less than $\frac{1}{8}$ in. off the commutator. As the latter wears, it is necessary to slack off the clamping screw holding the brush-holder on the spindle and to turn the holder through a small angle towards the commutator. In some machines the spindle is fitted in a slot in a rocker arm to permit of the brush-holder being moved inward as the diameter of the commutator is reduced by wear without altering the angle at which the brush makes contact (Fig. 7).

(c) *Angle of contact.*—The brushes should, as a rule, bear radially on the commutator (Fig. 8), but it is sometimes found advantageous to set the brush slightly against the direction of rotation, as shown in Fig. 9.

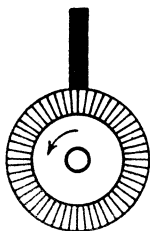


Fig. 8.

Carbon brush bearing radially on commutator.

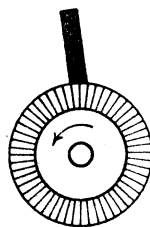


Fig. 9.

Carbon brush set against direction of rotation

(d) *Brush pressure.*—The springs should bear radially on the brush so that there will be no tendency for the latter to “wedge” in the holder if of box type, and the tension should be the minimum which will keep the brush in good contact with the commutator when the machine is running. Each brush should bear with approximately equal pressure. This can be ascertained by means of a spring balance. In slow-speed machines, not subject to much vibration, a pressure of $1\frac{1}{4}$ to $1\frac{3}{4}$ lb. per square inch of contact surface gives good results. In the case of high-speed machines, or where there is considerable vibration, it may be necessary to increase the pressure to 2 lbs., or even 3 lbs., per square inch. In testing the pressure with a spring balance the pull should be at right angles to that portion of the surface of the commutator in contact with the brush.

Thickness of Brush.—In those cases where holders of the type shown in Fig. 10 are used it is important that the brush should be made the right thickness. If a *new* brush is not available

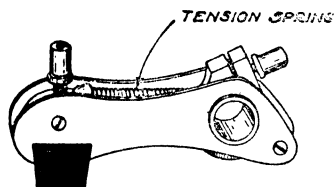


Fig. 10.
Carbon brush holder.

as a pattern, this thickness can usually be found in slotted armature machines by dividing the number of segments in the commutator by the number of slots in the armature and multiplying this by the width of the commutator segments. It is usually better, however, to hold a sample, to which new brushes should be made. All brushes in box holders (Fig. 11) should have flex wires (usually known

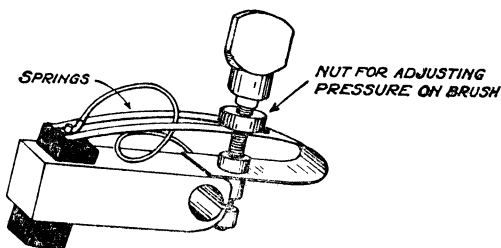


Fig. 11.
Box type carbon brush holder.

as pig tails) soldered or screwed into the carbon at one end and provided with a slotted "thimble" at the other for clamping to the holder.

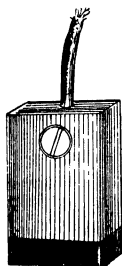


Fig. 12
Copper plated carbon brush showing copper plating removed.

Copper-plated carbon brushes should have the plating cut away about $\frac{3}{16}$ in. from the contact surface, and this should be repeated as the brush wears down to avoid risk of copper being carried between face of brush and commutator (see Fig. 12).

Bedding Carbon Brushes.—When new brushes are fitted, the commutator turned or ground down or brush-holders adjusted, it is necessary to re-bed the brushes in order that the entire surface

shall be in contact with the commutator. The bedding is most readily done by inserting a strip of fairly coarse glass paper between the commutator and brush surface with the cutting face towards the brush. On pulling this to and fro around an arc of the commutator the surface of the brush is quickly cut to the same curvature as the commutator. A fine grade of glass paper should then be used to finish off the brush surface, after which all carbon dust should be carefully removed by wiping with a dry cloth. The greatest possible care should be exercised to prevent the carbon dust from getting into the windings. It is a good plan to bind a piece of clean cloth around the end of the armature before commencing to bed brushes.

Adjusting Brush Rocker.—When the brushes have been properly bedded and cleaned, the brush Rocker should be adjusted to the sparkless running position and clamped there. In some machines it is possible to adjust the position of the brush rocker when the machine is carrying half load when no further alteration will be required for variations between no load and full load, but this cannot always be done with dynamos used for charging accumulators in telephone exchanges. In this case it is usually necessary to alter the brush position for any appreciable variation in load.

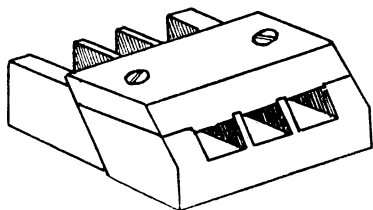


Fig. 13.

Jig for trimming copper brushes.

Setting Copper Brush.

—Where copper brushes are used, a "jig" (Fig. 13) should be used to ensure that the brushes are filed, or cut, to the correct angle (usually 45 degrees) before being fitted in the brush holder. Gauze brushes can be dealt with most satisfactorily by placing the jig in which the brush

has previously been fixed, in a bench vice and filing (in one direction only) from back to tip with a seconds cut file until the brush face is flush with the face of the jig. Copper or brass foil brushes are best cut to shape with a clasp knife.

The correct position for setting brushes is obtained in the manner described for carbon brushes. It is usually best to set the tip of the brushes to the edge of the commutator bars which have previously been marked, and care should be taken that the

brush bears properly. Fig. 14 shows a correctly set brush, while Figs. 15 and 16 show incorrect setting.

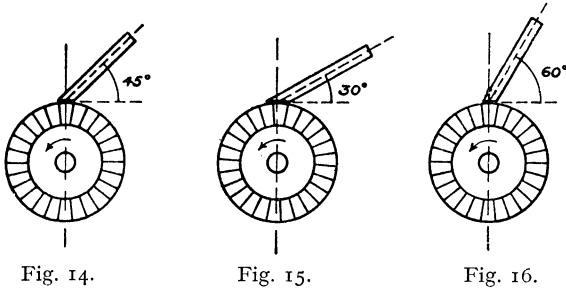


Fig. 14.

Fig. 15.

Fig. 16.

Copper Brush set at Correct Angle.

Copper Brush incorrectly set, angle of contact too acute.

Copper Brush incorrectly set, angle of contact too obtuse.

The distance which the brush projects through the holder varies with different makes of brush gear, but the correct position is obtained when the face of the brush just covers the right number of segments. A brush too far through the holder will, as it wears down, short circuit too many coils and turn up at the tip, while a brush not far enough through will not cover a sufficient width, and thus cause sparking. With copper gauze brushes it is desirable to keep the tip of the brush slightly blunt. (Fig. 17.)

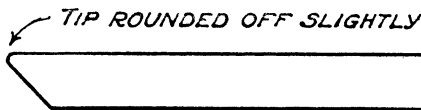


Fig. 17.

Copper Brush with rounded edge.

As the brush wears down, the contact surface first increases, then, as wear continues, the brush tends to become perpendicular to the commutator. This is accompanied by a reduction in the width of brush contact and contact pressure, and sparking ensues. Consequently, it is most important that brushes should be reset at frequent intervals, the length of which will be determined by the amount of running and the rate at which the wear takes place.

Since brushes always tend to groove the commutator (Fig. 18), it is desirable, where the width of commutator permits,

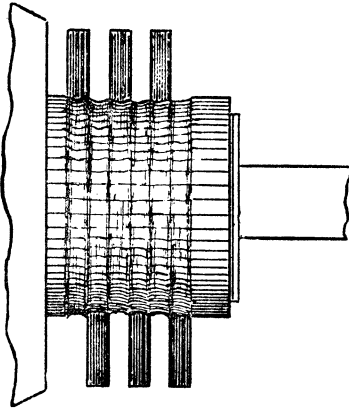


Fig. 18.

COMMUTATOR BADLY GROOVED.

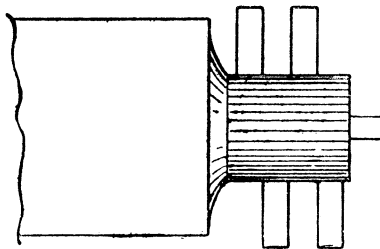


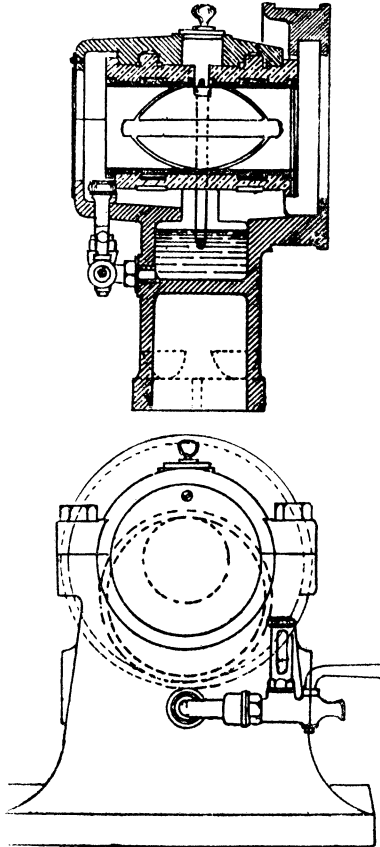
Fig. 19.

BRUSHES SET TO EQUALISE WEAR.

to set the brushes as shown in Fig. 19, so as to equalise wear as far as possible.

LUBRICATION.

The type of bearing most frequently used on modern machines is that in which ring lubrication is employed. A typical bearing is shown in Fig. 20.



Figs. 20 and 20A.

TYPICAL SELF-OILING BEARING SHOWING OIL RING, OIL WELL GAUGE AND DRAIN COCK.

In this type the oil should stand at some definite level in the oil well, which is usually indicated by a mark on the gauge glass or an overflow hole in the side of the bearing.

In filling the oil well, the oil should be poured in slowly, otherwise there is a risk of overflow which may get on to the commutator or windings and cause damage.

It is important that the right class of oil should be used, and in no case should a vegetable oil, *e.g.* linseed or cotton seed, be employed, as it is rarely free from acid which attacks the bearings. It also tends to thicken and prevents the rings from working properly. For practically all dynamos and motors with plain bearings used for telegraph and telephone purposes, "oil, dynamo, No. 1" should be used.

Oil wells should be drained off and washed out with paraffin at least twice a year, or more frequently if the machine does a considerable amount of running or is exposed to much dust, or if the oil is noticed to be dirty. After washing out, the paraffin should be thoroughly drained off before fresh oil is poured into the well. Old oil should not be used again without being filtered.

The Δ section ring fixed on the shaft to prevent oil creeping on to the commutator should be kept clean or it will not work effectively.

On certain machines there is a tendency for the oil ring to chatter and to mount the bush at the side of the slot in the event of the oil getting low in the well. The remedy, of course, is to keep the oil up to the right level, but, as an additional precaution, a small bridge piece should be fitted over the slot in the bush or, alternatively, the sides of the slot may be filed to a V-shape so that there will be no shoulder for the ring to rest on.

When a machine is provided with ball bearings and a grease cup with screw-down cap is fitted, the latter should be given a full turn for each day's run. In the absence of instructions to use a special lubricant, pure vaseline should be used for refilling the grease cups. Petroleum jelly should not be used. When ball bearings are used without grease cups, the housing is usually filled with grease and covered with a cap or gland to prevent the grease escaping. In such cases it is generally sufficient to clean out the housing and to refill with grease once or twice a year according to the amount of work done by the machine. On these occasions the ball cages should be removed, and these and the races cleaned with paraffin or benzine and examined for flaws, wear, or cracks, a fresh supply of grease introduced, and the whole bearing reassembled.

In taking down a ball bearing, especially if it includes a thrust ring, the greatest possible care should be taken to mark each part so that it can be replaced in the same position and order, as it is quite possible in certain cases to ruin a bearing by simply reversing a ring. The cone nut should be so adjusted that, while the armature turns quite freely, there is no slackness when the end of the shaft is lifted.

CORRECTION OF DEFECTS IN DYNAMOS AND MOTORS.

Reliability of Dynamo Electric Machinery.—Modern dynamos and motors are amongst the most reliable machines produced, and given reasonable attention, may be expected to run for long periods without developing faults, or breaking down.

Sparking at commutator has already been mentioned, but some of the most common causes are enumerated below.

<i>Defect.</i>	<i>Remedy.</i>
(1) Brushes not set at equidistant points.	Reset as already described.
(2) Brushes not set at neutral points.	Move rocker slowly back or forward until sparking stops.
(3) Brushes not properly trimmed.	Cut off all ragged edges and, if necessary, place in jig and file.
(4) Brushes not clean.	Copper gauze brushes should be cleaned by soaking in petrol or benzine, afterwards draining and, if necessary, trimming or filing in jig. Carbon brushes are best cleaned with methylated spirit or ether.
(5) Brushes not making good contact. Where copper-plated carbon brushes are used a particle of copper may become embedded in contact face, cut the commutator, and cause unequal distribution of current.	Clean commutator, if "sticky," with paraffin or methylated spirit applied on clean piece of white rag, afterwards polishing with clean rag. Clean and bed brushes if necessary. Adjust tension screws and springs to secure light, firm contact.
(6) Commutator worn in grooves, rough or eccentric; or high mica between segments.	Grind with fine carborundum on curved block. Polish with crocus paper. Examine carefully to see that no particles of metal have lodged between segments. If grooving is too great to permit of removal in this manner, have commutator turned down in lathe. This should always be done by an experienced turner. Recess mica if high.

<i>Defect.</i>	<i>Remedy.</i>
(7) High bar on commutator.	Set high bar down by tapping lightly with wood mallet. Tighten end nuts. If bar will not go down, file flush, grind or turn, afterwards polishing as described under (6).
(8) Low bar or flats on commutator.	Grind or turn down as described under (6).
(9) Weak magnetic field due to :—	Repair, if external. Rewind coil if internal.
(a) Broken circuit.	
(b) Short circuit in field coils.	
(10) Excessive current in armature. <i>If a dynamo</i> due to	
(a) Overload.	(a) Reduce load. Check ammeter and voltmeter.
(b) Faulty insulation of machine.	(b) Test dynamo insulation and remove defect when found.
(c) Partial short circuit on leads.	(c) Test circuit and remove defect when found.
<i>If a motor</i> due to	
(d) Break or partial short circuit in field coils.	(d) Repair break or have coil re-wound.
(e) Overload.	(e) See that armature is not touching pole pieces and that it turns freely in bearings. Renew bearing bushes to clear former. Lack of lubrication is usually the cause of stiffness in the bearings.
(11) Interpole windings	
(a) Reversed.	(a) Only likely to occur after machine has been overhauled. Check against diagram supplied by makers or shown in Appendix II.
(b) Short-circuited.	(b) Remove short.
(12) Short-circuited coil or coils in armature due to	
(a) Contact between adjacent bars of commutator.	(a) Test by passing current through armature and measuring P.D. between adjacent segments. Remove contact when found.

Defect.

(b) Failure of insulation between adjacent bars of commutator or between clamping ring and commutator.

(c) Failure of insulation of one or more coils.

Remedy.

(b) Examine commutator to ascertain if any sign of insulation having charred. If damage is not too pronounced, fault may be removed by grinding down commutator, otherwise commutator must be re-insulated. If fault is between bars and end ring, the repair should be effected by an experienced man.

(c) Re-wind coil.

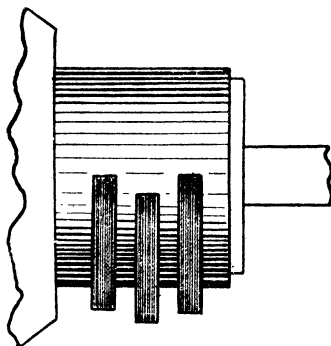


Fig. 21.

BRUSHES STAGGERED TO BRIDGE OVER DISCONNECTION BETWEEN ARMATURE COIL AND COMMUTATOR.

(13) Broken connection between armature and commutator, usually accompanied by violent flashing as faulty coil passes under brushes.

If essential that machine be kept running, stagger the brushes as shown in Fig. 21, to bridge over the segments to which coil is connected. If possible, stop machine and repair if break is near commutator. An internal break necessitates re-winding coil, but machine may be kept in operation by short-circuiting the two segments to which the broken coil is connected and leaving faulty coil disconnected. Care must be exercised to avoid short-circuiting good coils.

Heating of Parts.—Generally the temperature of any part should not rise more than 80° F. above that of the surrounding air. Approximate tests can always be made by feeling the various parts. If the heat is bearable for a few moments it is harmless, but if it is unbearable for more than 3 or 4 seconds the safe limit has been passed except in the case of commutators where solder is not used. In testing with the hand, allowance must be made for the fact that bare metal feels much hotter than cotton covering, also that the sensitiveness of the hand differs. The back of the hand is more sensitive and less variable for this test. If the heat is sufficient to produce any odour or smoke, the safe limit has been far exceeded and the machine should be shut down, and not started again until the cause of the trouble has been located and cleared.

In all cases of heating, it is important to locate the source of heat correctly. It is a common mistake to assume that any part of a machine which is found to be hot is the seat of the trouble. Thus, a hot bearing may cause the armature or commutator to heat, or *vice versa*. If the source cannot be located when first noticed, allow machine to cool down, then run with full load for, say, 5 or 10 minutes, shut down and feel all parts as quickly as possible, when the heat will be found in the right place owing to its not having had time to diffuse over the machine.

A number of defects which lead to heating are enumerated below :—

(*Note.*—Practically all the defects mentioned under the heading “ Sparking ” will also lead to heating.)

<i>Defect.</i>	<i>Remedy.</i>
(1) Sparking at commutator may cause considerable heating before the sparking appears serious.	(See “ Sparking ” in preceding section.)
(2) Overheated commutator decomposing carbon brush which covers commutator with a black film, offering considerable resistance. Excessive pressure on brushes may start this trouble.	Clean off and polish commutator, reset brushes and keep machine under observation. Adjust pressure on brushes if necessary.
(3) Bad connections in brush holders, etc., which may be located by noting fall of potential between brush and holder or holder and cable.	Improve connection by cleaning contact faces, tightening up screws, etc.

Defect.

(4) Carbon brushes heated by unequal distribution of current due to use of wrong class of carbon or particle of copper embedded in contact face of brush.

(5) Moisture in armature or field windings, leading to partial short circuiting, and thus increasing current in coils. (A machine having more than one field coil may have one of its coils cut out, and this would lead to excessive current and overheating, but would also be accompanied with excessive sparking.)

(6) Wrong grade of oil or lack of oil. Due to:—

(a) Oil cup or reservoir empty.

(b) Oil passages clogged.

(c) Self-oiling rings sticking.

(d) Self-oiling ring "jumping" on to end brush. (Very prevalent on small motors driving ringing generators.)

(7) Grit or foreign matter in bearings leading to rough or cut shaft.

Note.—An unduly tight belt will lead to same trouble.

(8) Shaft "sprung" or bent.

Remedy.

Equalise pressure on brushes. See that all brushes are properly bedded, and that the class of brush recommended by the maker is used.

Dry out by:

(a) placing machine over heating boiler, or in some other convenient place where a temperature of about 60° to 80° F. above that of the outside temperature can be obtained.

(b) With the machine at rest, pass a current through the faulty winding regulated to *three-fourths* of the full load current taken by *that winding*. This should be continued for 24 hours if the insulation resistance does not attain a value of at least one megohm sooner.

Supply oil, make sure that oil passages are clear. Wash out bearings with paraffin. Examine rings to see if a "flat" has developed on inside. If so, fit new ring or re-bore ring to clear flat.

"Jumping" usually occurs on small machines subject to vibration when the oil gets low. Fit bridge piece over ring to prevent it mounting on end of bush. Examine oil drains carefully to see that no leakage is taking place.

Examine shaft and bearings to ascertain if any scoring has taken place. Polish shaft in lathe and renew bushes if necessary. Clean out bearing thoroughly and fill with clean oil.

The shaft may be straightened or turned true, but the job is one which had best be left to an experienced man.

Defect.

(9) Bearings out of alignment.

(10) Armature rubbing against pole piece or much nearer to one pole than the other. Usually due to wear of shaft and bearings.

Remedy.

Loosen bolts or screws holding bearing in place, find position where shaft turns most freely by hand, and screw down in this position, using packing pieces if necessary. Care must be taken to see that armature is not displaced relative to the pole faces.

Turn down shaft and fit new bushes in bearings. This may necessitate bushing pulley or half coupling fitted on shaft.

Noise.—This is a most objectionable feature in dynamos or motors provided for telephone or telegraph purposes, owing to its distracting and irritating effect on persons carrying out clerical work or operating duties, while in certain cases it may interfere with the working of the telephone system.

Noise may be due to a great variety of causes. It is inherent in certain types of machines, is due to electrical causes in some cases and mechanical in others, and in nearly every instance is an indication that energy is being wasted. Alternating current machinery is easily the worst offender. There is no simple method of measuring it quantitatively, and it is often most difficult to locate, but a method sometimes found useful is to hold a short stick between the teeth and press the other end squarely against the different parts to ascertain which one is vibrating most. Roughness of commutator surface not distinguishable by other means can be detected in this way. Placing a finger in each ear when making the test increases its sensitiveness.

When a single battery is installed at a C.B. telephone exchange, the generator has to serve the exchange and charge the battery simultaneously during certain periods, and in such cases noise of the telephone system may be caused by incorrect adjustment of brushes, bad brush contact, sparking, dirty commutator, loose or dirty connections, or, in the case of a belt-driven machine, by a loose or badly jointed belt. A choke coil is usually provided to damp out the commutator ripples.

A list of defects likely to produce noise follows. In preparing this list it has been assumed that the machine was free from noise or that, if any existed, it was negligible in volume at the time of installation, and that a proper foundation has been provided. Abnormal noise may therefore be taken as an indication of want of adjustment, wear, or use of unsuitable material.

Defect.

(1) Armature striking or rubbing against pole pieces due to—

(a) Worn bearings.

(b) Worn shaft.

(c) Bearings out of alignment.

(2) Armature, pulley, or coupling out of balance. Only likely to occur if machine has been re-wound or altered, and is usually indicated by strong vibration which varies greatly if speed is changed, and may disappear at certain speeds.

(3) Shaft collar or shoulder of hub or edge of pulley strikes or scrapes against bearings. Usually indicated by a chattering noise which stops when armature is moved lengthways in one direction.

Remedy.

(a) Examine bearings and re-bush if necessary.

(b) Turn down shaft. This should only be done on expert advice and will necessitate the provision of new bushes, and may make it necessary to provide liners in the half-coupling or pulley.

(c) Slack off nuts on bolts holding bearings in position. Move bearings until armature revolves freely when turned by hand, and screw down in new position.

Test armature by resting on two parallel \triangle shaped metallic tracks laid horizontally and far enough apart to permit of armature being placed between them. On rolling armature, the heavy side will tend to turn downward. A weight placed on the opposite side will give an indication of the extent to which it is out of balance, but alteration should not be attempted without first obtaining expert advice. The pulley should be balanced separately and adjusted, if necessary, by filing or drilling away part of the metal on heavy side. (*Note.*—The *armature* cannot be balanced by adding weight to the *pulley*.)

Move collar or pulley, file or turn off shoulder or bearing bush until noise ceases. A well-balanced armature should not bear against collar at either end, and should move endways on the slightest pressure being applied to either end of shaft.

Defect.

(4) Loose bolts, screws, or other parts.

(5) Brushes.

Singing, hissing, or chattering due to—

(a) Sticky or rough commutator.

(b) Tips of brushes not smooth, or layers of copper in brush not being held together properly.

(c) Carbon too hard or gritty.

(d) High mica on commutator.

(e) Brushes set at incorrect angle.

Remedy.

Tighten up loose parts, taking care to keep them in place and properly set. Attention to the instructions *re* examination prior to starting will avoid trouble from this cause.

(a) Clean commutator and smooth down if necessary. Apply a little petroleum jelly or paraffin wax.

(b) Trim brushes and file in jig if necessary. If binding or stitching is badly broken, renew brushes.

(c) Change brushes but do not change type.

(d) Smooth down commutator. Cut down mica with tool shown in Fig. 5.

(e) Alter angle at which brushes are set.

Motor stops or fails to start. Speed too high or too low. Dynamo fails to generate.—Undue variation from normal speed in the case of a motor is generally a serious defect, and the machine should immediately be shut down and the cause of the trouble investigated.

Low speed may be caused by overload, due to lack of lubrication, armature striking pole pieces, short-circuited coil or coils in armature, or brushes not set at neutral point. The remedies for each of these defects have already been described.

Speed too high or too low is usually the result of weak field magnetism due to (a) partial short in field winding, (b) break in field winding, or (c) field coils joined up in opposition, and will cause a shunt-wound motor on a constant potential circuit to run at excessive speed if lightly loaded, or much below speed if heavily loaded. The same faults in a dynamo will result in its failing to “build up” or excite its own field, or give the correct voltage.

ALTERNATING CURRENT MOTORS AND DYNAMOTORS.

The design of alternating current motors covers a very wide range, passing from the induction type with squirrel cage rotor—which, from the maintenance point of view, is one of the most robust and simple machines produced—through the induction motor with wound rotor, simple series, neutralised series, shunt

and repulsion-induction to the variable speed compensated repulsion type.

Much of what has been written in the foregoing pages is equally applicable to A.C. and D.C. machinery, and, consequently, it only remains to refer to those points peculiar to A.C. machines in this section.

Cause of Faults not always obvious in A.C. Machines.—It will have been noticed that with most of the faults on D.C. machines the commutator acts as an indicator and often serves to locate the fault. The majority of A.C. machines have no commutator, and consequently symptoms, although characteristic of the trouble, are not so well defined as in D.C. machines, and owing to the form of winding usually adopted, repairs cannot be so readily undertaken by the operating staff.

Width of Air Gap.—The air gap between the rotor and stator of A.C. induction motors is much less than is usually provided between armature and field pole faces on D.C. machines, and this renders it necessary to watch the wear of bearings very closely to avoid risk of rotor rubbing against stator.

“Star” and Delta Connection.—Three-phase motors are built either for Star circuit (Fig. 23) or Delta circuit (Fig. 23a), and a motor designed for the latter would have its magnetism

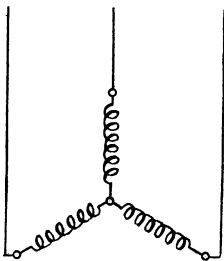


Fig. 23.
STAR.

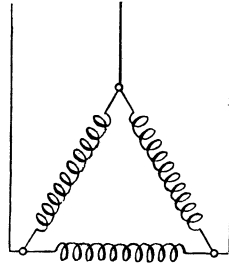


Fig. 23a.
DELTA.

weakened approximately 42 per cent. if connected in Star. This would reduce the starting torque and the motor might fail to start. Conversely, a motor designed for Star circuit, which most motors are, will seriously overheat if joined up for Delta circuit owing to excessive magnetising. Hence *it is important when a motor has been dismantled for any purpose to make sure that the coils are correctly joined up on re-assembling*, and, in those cases where both ends of each set of stator windings are led out to a terminal block, care should be exercised not to cross the ends of any one-phase winding, since this would result in the motor not having a correct rotating field or full starting torque.

Wound Rotor.—When an A.C. motor is provided with a wound rotor and fitted with slip rings, it is essential that the brushes should make good contact with the slip rings, and the instructions relative to type, bedding and contact pressure of carbon brushes on D.C. machines are equally applicable to A.C. motors or generators.

Variation of Torque.—It has also to be remembered that the torque of polyphase motors varies as the square of the voltage and, consequently, it is important that there should be no appreciable fall of potential in switch-gear or leads, etc., when the motor is carrying full load : special attention to cleanliness of contacts, etc., is, therefore, essential.

Low Starting Torque on S.P. A.C. Motor.—It has already been explained that single-phase induction motors have a low starting torque, and for this reason, it is always desirable, before assuming that any specific fault exists, to give the motor a turn by hand with current on and two-way switch, starting resistance, or auto starter in starting position, as it sometimes happens that the motor is unable to overcome the inertia of the machine to which it is coupled.

Clutch for Single-Phase Motor.—Single-phase induction motors are in some cases provided with a clutch which permits of the motor being uncoupled from the driven machine. In these, it is necessary to keep the cone faces free from oil or grease and the adjustment should be such that, while the two faces are quite clean when the motor is starting up, there shall be no slipping when they engage nor should it be necessary to exert undue pressure on the coupling lever to secure this result. The clutch should be uncoupled after each run, just before the machine comes to rest.

A.C. Commutator Motors.—Series wound and shunt wound single-phase motors require the same attention as direct current motors. There is, however, a greater tendency to sparking at brushes than on D.C. machines, and they require more frequent attention in consequence.

In the case of repulsion-induction motors, there is a tendency to spark when starting, and this is accompanied by a certain amount of noise, but since the brushes are lifted clear of the commutator when the machine attains normal speed this need not cause any alarm. For efficient operation, it is necessary that the brushes should make very good contact with the commutator at starting ; there should be no appreciable resistance in the short-circuiting leads connecting the two sets of brushes, the brushes should lift quite clear of the commutator at normal speed and the short-circuiting plate or plates which connect together all the segments of commutator should make good contact.

Defects in A.C. Motors.—The most common defects met with are enumerated below, and, while to locate the defect is to know the remedy, the latter has been added to assist those who may not be familiar with this type of plant.

Defect.

(a) Motor fails to start, due to switch not making good contact, fuse blown or brushes not making good contact with slip rings.

(b) Starting resistance or choke coil burnt out or disconnected.

(c) Disconnection in stator coils. Three-phase motor may start with weak torque.

(d) High resistance in rotor winding, due to bad connection between bars and end rings on "squirrel cage" rotors usually follows overheating, and is accompanied by drop in speed if motor does start.

(e) Worn bearings allowing rotor to rub on stator or cease to be concentric with stator, usually indicated by machine becoming gradually more difficult to start up.

(f) Motor windings not correctly joined up. Usually follows overhaul, and motor hums more or less audibly.

(g) Motor will not take its full load. Most of the faults enumerated under (a), if present in a modified form, may cause the speed to fall or the motors to stop.

Remedy.

Clean switch contacts and adjust if necessary. Replace fuse if blown. Bed brushes and clean slip rings.

Repair or replace defective coil.

Repair if external. If internal, re-winding is the only remedy. The disconnection frequently occurs near ends of rotor or stator windings.

Examine for indication of solder having melted out. Resolder if necessary.

Re-bush bearings.

(*Note.*—The wear may not appear appreciable to the eye, and the clearance between rotor and stator should be checked by a tapered "feeler.")

Check connections against makers' diagram or relative diagram in appendix and correct if necessary. Measure current in each phase; any difference indicates incorrect connection or partial short.

See (1), (2), (3) overleaf.

<i>Defect.</i>	<i>Remedy.</i>
Motor heats excessively due to—	
(1) Overload.	Check current taken by motor and reduce load if excessive. The overload may be due to fault in dynamo or other machine driven by motor.
(2) Lack of lubrication.	See that oil rings are working. Add oil, if necessary, and clean out bearings if dirty.
(3) Wrong circuit connections.	Check connections against makers' diagram and correct if necessary.
(h) Humming due to alternating current.	Since this defect is practically inherent in alternating current machinery, the only thing to do is to mount the machine in such a manner as will reduce or deaden the sound. This may be done by interposing rubber or cork pads between bed plate and foundation, and slacking off or dispensing with holding down bolts.
	If this does not suffice, it may be necessary to renew the foundation and to insulate it by providing deadening material under and around it.

Dynamotors.—Dynamotors used for supplying ringing current at large telephone exchanges, being a combination of A.C. and D.C. machines, are liable to defects peculiar to each type. On the whole, however, they give very little trouble provided that they receive reasonable attention. Small D.C.-D.C. dynamotors are also used for battery charging purposes.

Need for Good Insulation Between Windings.—The armature of a dynamo is provided with two distinct windings—the usual condition when the supply voltage is less than 100 or more than 120 volts D.C.—it is important that good insulation should be maintained between the two windings to avoid the risk of supply voltage getting connected to the telephone system, and this should be tested periodically with a megger.

Sparking on Battery Driven Dynamotors.—In those cases where the dynamotor is run off the exchange battery the brushes

require special attention to avoid sparking, which, in addition to wearing out the commutator, may cause noise on the telephone system. Indifferent contact between brushes and interrupter drums is a frequent source of trouble, and the brushes should be examined often to see that they are bedding properly, the tension correct, and no tendency to "chatter."

When copper-plated carbon brushes are used the copper should not be allowed to come in contact with the drums. To avoid this, it should be cut back about $\frac{1}{16}$ th of an inch from the contact surface.

Cleaning Interrupter Drums.—The high-speed drums may be cleaned with a spun-glass fibre brush (commutator cleaner) pressed lightly against the surface while the machine is running. The slow-speed rings should first be cleaned with a cloth *slightly* moistened with paraffin oil, then with a clean dry cloth. Polishing paste or commutator compounds should not be used, as they often contain materials which damage the insulation.

Reduction Gear.—The reduction gear requires regular attention. Where the open type worm gear is used, a small quantity of graphite lubricant should be applied daily, care being exercised not to allow it to get on to the surface of drums. With oil immersed type gear the oil must be kept up to the correct level—usually indicated by a mark on gauge glass—and the oil well should be cleaned out at least twice a year. Fresh oil should be used for refilling.

BATTERY CHARGING DYNAMOTORS D.C.—D.C.

These machines are used, where D.C. main supplies of not more than 250 volts are available, for charging secondary cell batteries having a capacity not exceeding 250 A. hrs.

During the process of charging the voltage of the battery rises, and, unless the e.m.f. of the charging generator be increased or the resistance of the charging circuit reduced, the charging current will diminish. The methods of regulating the charging current are :—

- (1) Automatic method by use of a "Compensator."
- (2) Manual method by altering the position of the brushes.

(1) **Automatic Regulation.**—The "Compensator," consisting of a number of iron wires in parallel connecting in series with the output, functions as an automatic rheostat and reduces the extent of the diminution in the charging current. Before commencing a charge, the voltmeter should be switched on to the "generator" and the output brushes regulated so that the voltage is equal to the value of the "O.C." volts indicated on the rating plate. This will ensure, when the battery is switched

on, a correct charging current rate, and also that the energy taken from the machine does not exceed the maximum permissible.

At the moment a battery is switched on to the machine the charging current may exceed the maximum permissible of the machine, but within a minute or so, that is, as soon as the iron wires of the "Compensator" have warmed up, the current should drop to a value not exceeding the maximum of the machine, and this should be checked by the ammeter.

At the commencement of a charge the current should be approximately equal to the $4\frac{1}{2}$ -hour rate of the cells and at the end of the charge equal to the 14-hour rate.

(2) **Manual Regulation.**—When charging rates required exceed those obtainable with the "Compensator" in circuit, such as for "initial" and "equalising" battery charges and where continuous engineering attendance can be given for regulating purposes without additional expense, the "Compensator" may be cut out. The regulation of the generator e.m.f. during a charge is effected by altering the position of the brushes on the output side. It is important that the current is not allowed to exceed the maximum indicated on the rating plate.

Defects in Battery Charging Dynamotors.—These machines are liable to defects common to D.C. motors and generators, and the section of this pamphlet dealing with this subject should be referred to for necessary information.

The iron wire of the "Compensator" deteriorates with use, and renewal is required from time to time. Care should be taken to see that the length and gauge of the new wire corresponds with the wire replaced, otherwise the "Compensator" will not function correctly.

RECTIFIER TUNGAR.

These rectifiers are used where a single-phase A.C. main supply not exceeding 250 volts is available for charging secondary cell batteries having a capacity not exceeding 120 A. hrs.

The rectifier transforms down the voltage and converts the alternating current to unidirectional current suitable for battery charging.

The Tungar Rectifier consists of a transformer and a bulb which operates in the same way as the rectifying thermionic valve used in wireless telegraphy and telephony. It is in effect an electrical check valve which permits current to flow in one direction only. The bulb has a low tension tungsten filament served from a low voltage winding of the transformer. The

filament acts as the cathode, and there is a graphite electrode which forms the anode. The bulb is filled with an inert gas (Argon), the combination of the heated tungsten filament and the gas providing the valve action permitting the current to flow in one direction only, i.e. from the anode to the cathode. It will be noted that the valve action also prevents the batteries from discharging back through the rectifier should the A.C. supply fail and the charging will resume automatically when the A.C. supply returns. A regulator with 14 points is provided for the D.C. output.

Double valve rectifiers are fitted with a regulator and a current indicating instrument for each valve. For ordinary use the regulation should be such that the valves are supplying approximately equal currents. For currents of less than one half the full load output one valve only may be used. The instruments on the Rectifiers are not grade 1 instruments, and should not be used to determine the actual charging current.

The current at the commencement of a charge should be as high as possible, but should not exceed the rate laid down in the secondary cell instructions nor should it exceed by more than 12 per cent. the maximum indicated on the rating plate. During the process of charging the current will, if the regulator is untouched, fall away to about $\frac{1}{3}$ of the initial current.

Defects in Rectifiers Tungar.—The appearance of the filament and sealing lead to the filament offers the best indication of the condition of the bulb.

The filament of a good bulb is straight, although after long life it may sag and become thin at both ends. The turns of the spiral are close together and have a shiny appearance ; there may, however, be a few dull spots on the end turns.

The filament sealing leads of a good bulb are clear of deposits. One of the leads may, however, have a deposit remote from the filament.

The anode of a good bulb is clear from excessive sooty deposit.

A bulb with a straight filament and blackened leads, which lights but will not rectify, is probably very slightly cracked, thus allowing the gas to escape slowly. The anode in such a case will be covered with a black deposit.

A bulb with a large crack will develop a coating of white powder on filament, anode, and bulb.

The result of an overload is indicated by the fused ends of the filament being rounded.

It will be found, generally, that the majority of the failures are due to valve trouble. It may be found, however, that as a

result of the vibration set up by the A.C. current, the terminals and screws become loose. A periodic examination should be made for these defects.

MERCURY ARC RECTIFIERS.

Function of Rectifier.—Mercury arc rectifiers are used for charging secondary cells at a number of exchanges where the public supply is alternating current. They are designed for converting single or polyphase current to unidirectional current, but the former type is usually used by the Department.

Two or more rectifier tubes are used in parallel when one is not sufficient to supply the current required.

Connections.—A diagram of the connections of a B.T.H. single-phase rectifier is given in Appendix 1.

Method of Operating.—To start the rectifier, turn the regulating reactance handle in direction to bring all reactance into circuit, close D.P. main switch, hold "starting and load switch" in lower position and then close D.P. circuit breaker, tilt the tube *gently* by means of handle which is fixed on front of board. This causes mercury in Cathode limb *B* to form a connection with starting anode *C*, and circuit is made from D.P. switch *via* starting anode resistance starting switch, rectifier tube, terminals *C* to *B*, ammeter, starting switch, starting load resistance, centre point of compensating reactance, left hand limb of latter to regulating reactance and D.P. switch. The tilting of the tube should be momentary only. On restoring it to vertical position, an arc is set up momentarily between *B* and *C*, thus producing the "Cathode Spot" at the surface of the mercury, on which the operation of the rectifier depends. As soon as this "spot" or arc appears, the anodes *A* and *D* come into action, and current flows from *A* to *B* during one-half of cycle and from *D* to *B* during the second half; the negative half of the cycle is absorbed in the compensating reactance, and the latter, by virtue of the energy thus stored up, bridges over the period where the current would otherwise fall to zero and allow the arc to die out. The starting switch should be held in the starting position for 4 or 5 seconds in ordinary weather, but in very cold weather it should be held in this position for about 30 seconds after the arc is set up in order that the tube may be warmed up before the battery is thrown on. Under the latter condition, it may be necessary to rock the bulb a few times before the arc strikes up. If the voltage of the battery is higher than that of the rectifier, the arc will go out as soon as the battery is put on, in which case a portion of the regulating reactance should be cut out and the tube restarted. If the tube does not start when five-sixths of the regulating reactance

has been cut out, turn the compensating reactance handle in an anti-clockwise direction until the desired voltage is obtained. Once the correct position for the compensating reactance is obtained, it is not necessary to alter it so long as the number of cells in battery is not changed, as any variation of voltage required can be obtained by means of the regulating reactance.

Rated current not to be exceeded.—It is most important that the current for which the tube is rated should not be exceeded, and for this reason it is better to start up with sufficient regulating reactance in circuit to reduce the current to three-quarters of the rated value. As the charge proceeds, reactance should be cut out to keep the current up to the proper value, but towards the end of charge the current may be allowed to fall off to 50 per cent. of the normal figure. If the supply voltage fluctuates to any appreciable extent the best results are obtained by using the maximum amount of compensating reactance which will give the voltage required.

Precautions essential to ensure good results.—The following points should receive careful attention to ensure satisfactory operation and to avoid breakage of tubes :—

(1) The setting of the circuit breaker should never exceed the rated capacity of the tube.

(2) A tube should not be worked at a higher voltage or current than that for which it is designed.

(3) When handling the tubes, great care should be exercised to prevent the mercury from suddenly flowing from one part to another, *e.g.*, tilting the tube in the hand may cause the mercury to set up a hammer action which might break the glass.

(4) When two tubes are provided with the equipment they should each be worked for six months and then allowed to rest for a similar period ; during the resting period, the tube should be kept in a special box provided or packed in a vertical position in cotton-wool.

(5) The starting load and starting anode resistances should be measured periodically. A partial short in these might destroy a tube.

(6) The makers' instructions relative to the operation of the set should be strictly adhered to.

(7) All contacts should be kept scrupulously clean and connections tight.

Faults may be due to low vacuum in the tube ; this may be tested by allowing the mercury to roll about the end of the tube remote from anodes. A clear metallic click indicates that the vacuum is good, but if the mercury moves sluggishly and is accompanied by a dull sound, the vacuum has been either wholly or partially destroyed.

Low temperature may cause difficulty in starting the tube and over-running may lead to the rapid destruction of the graphite anodes.

Bad connections on transformer, switches, fuses, circuit breaker, ammeter, reactances, or resistances are possible sources of trouble, which proper maintenance will avoid.

Separation of battery from supply leads.—When the set is used for charging a battery while it is connected to the exchange, it is important that there should be no connection between primary and secondary windings of the line transformer, and the insulation between these windings requires testing periodically.

Noise on the exchange system during charge may be due to a partial short in the choke coils in leads to battery.

MAINTENANCE TESTING AND EXAMINATION.

Testing motors, dynamos, etc.—The insulation resistance of motors, dynamos, switch gear and leads should be tested at least twice a year, and additional tests should be made if at any time there is reason to doubt the condition of the machines or apparatus.

Test pressure.—Insulation tests should be made with a megger or Evershed ohmmeter and generator. The voltage of the testing set should be 500 volts for all motors, etc., on which working pressure exceeds 200 volts, and in no case should the test pressure be less than 250 volts.

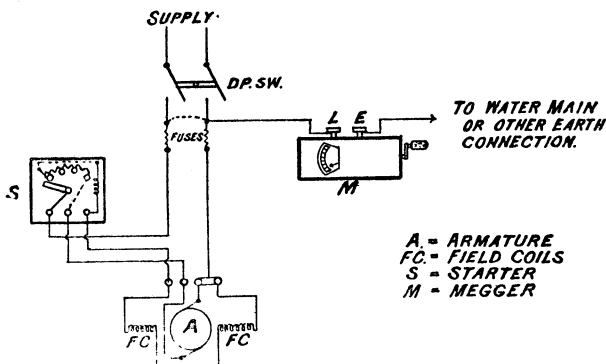


Fig. 24.

TESTING INSULATION WITH MEGGER OR OHMMETER AND GENERATOR.

The "L" Terminal of Megger should be connected to Both Fuses.

Type of testing instrument.—The 500 volt megger used for testing A.S. P.C. cables is unsuitable for testing power plant. An instrument calibrated from 10,000 ohms to 100 megohms is most suitable and is now a Rate Book item. In testing power

plant, it is important that the tests should include all parts of the circuit or machine under test. Thus, in testing a dynamo from its terminal block, it is necessary that the brushes should be in contact with the commutator, otherwise the armature will not be tested. Fig. 24 shows a convenient method of testing a motor together with its starting switch and leads. The leads from the terminal L of Megger M should always be connected to both fuses, otherwise some portion of the circuit will be missed.

Care should be taken to cut off the supply current before attempting to make any tests.

Testing with voltmeter.—If a megger is not available, an insulation test may be made by means of a high resistance voltmeter of known resistance, using the supply mains or a battery to supply the voltage required. If the supply voltage is used, the voltmeter is first applied to the mains to measure the voltage. The main switch is then opened, the starter moved to running position, and the voltmeter connected as shown in Fig. 25 if one side of the supply is earthed, as in the case of a 3-wire system, having the middle wire earthed at the generating station. The deflection of the voltmeter pointer is again noted and the insulation is found by the equation, insulation resistance = $\frac{D \times R}{d} - R$ where D is the first and d the second deflection and R the resistance of the voltmeter.

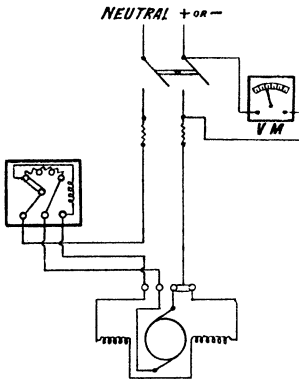


Fig. 25.

Testing Insulation with High Resistance Voltmeter Motor connected to one Outer and Middle Wire on 3-Wire System.

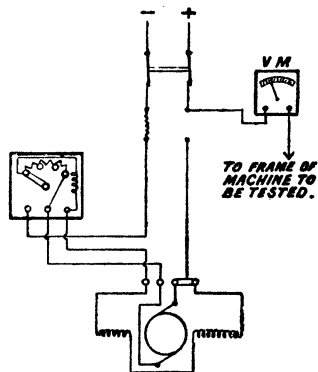


Fig. 26.

Testing Insulation with High Resistance Voltmeter on 2-Wire System.
NOTE.—To Check Test Remove Fuse on Negative Side when Voltmeter should give no Deflection.

The connections for a similar test on a *2-wire system* are shown in Fig. 26. In this case one fuse is removed and the positive terminal of V.M. connected to positive terminal on supply side of cut-out, the other side of V.M. being connected to the frame of machine to be tested. The starting switch is fixed in the running position and the main D.P. switch closed. The reading of the voltmeter is noted and insulation resistance calculated as before. In this case it is necessary to check the test by removing the fuse on the negative side when any deflection on the voltmeter will indicate a fault on the supply system and render the test unreliable.

(*Note.*—If the resistance of the voltmeter is not known and the instrument is a fairly modern one of the moving-coil type, the resistance may be taken as 10,000 ohms for each 100 volts : thus, an instrument calibrated to read to 250 volts would have a resistance of 25,000 ohms.)

Testing Switchboard, etc.—When a telephone power switchboard is installed, it usually consists of at least 3 panels designated “Motors,” “Generators,” and “Batteries,” respectively. A fourth panel, fitted with measuring instruments, is sometimes provided and it is necessary to make a number of tests to cover the whole installation. As the arrangement of these boards differs to some extent, it is not possible to outline a definite scheme which would be applicable in every case.

Usually the most convenient method is as follows :—

Motor Panel.—Cut off power supply at point where it enters building, open main switch to each motor at switchboard, and test switchboard wiring by connecting *L* terminal of megger to both Bus bars or points to which supply mains are connected ; join the other side of the megger to the earth wire. The voltmeter and ammeter switches should be placed in position to measure main supply and the test will then cover the motor panel wiring, mains from point where supply enters building and H.V. measuring instruments.

Testing Motor from Switchboard.—Each motor and its wiring should be tested from the D.P. switch in the manner already described for testing motors, and the generators can be tested from the D.P. switch to which they are connected on switchboard ; the D.P. switch should be in the “ off ” position and the circuit breaker closed.

Testing Insulation of Batteries.—Where duplicate batteries are provided, the idle battery and its leads can be tested from the power board unless the positive ends of both batteries are permanently connected together as in certain automatic exchanges, in which case it is necessary to arrange to serve the exchange from the generator and carry out the test during a

slack period. In these circumstances the test may be carried out as follows :—

Place megger on a dry board or other support which ensures good insulation and is firm. Connect "Line" terminal of megger to positive end of battery and "earth" terminal to earth side of link or fuse at positive end of battery as shown in Fig. 27. Remove link or fuse from positive lead and fuse from negative end of battery, and test. Replace fuse or link in positive lead and fuse in negative lead and finally disconnect test leads.

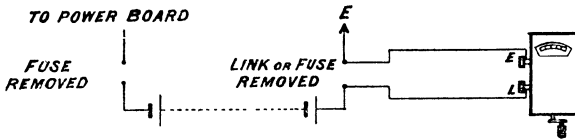


Fig. 27.

CONNECTIONS FOR TESTING INSULATION OF BATTERY.

The Exchange Supervisor or Officer in Charge should be advised before the test is made, in order that any slight noise on the circuits resulting from the use of the generator alone will not cause alarm.

Telegraph Secondary Cell Installation.—Telegraph secondary cell installations should be tested half-yearly, and since it is usually essential that the service should not be interrupted for any appreciable period, it is desirable to complete the test in the fewest steps possible. Sunday forenoon is generally the most suitable time for carrying out the test.

Testing Secondary Switch Cabinet, Cells and Leads.—When a rotary switch cabinet is installed, the whole of the main and local batteries, leads from rotary switch to cells, and leads between rotary switch and distributing fuse case in Instrument Room can be covered by a single test, the procedure being as follows :—

(1) On positive main batteries, connect "Dynamo + " terminal to "E" terminal by means of plugs and cord.

(2) On negative main batteries, connect "Dynamo — " terminal to "E" terminal as described above.

(3) Place *all* local battery switches in "working" position.

(4) Remove all U links on distributing fuse tablet in Instrument Room.

(5) Disconnect earth lead at back of local switch tablet on rotary switch cabinet.

(6) Connect line terminal of megger to terminal from which earth has been removed, join earth lead to earth terminal of megger and make test.

If the steps are taken in the order indicated, the service should not be stopped for more than five minutes.

Loop batteries may be tested from the charging tablet by withdrawing the *U* links and connecting the *L* terminal to positive terminal of battery and *E* terminal to any convenient "Earth."

Low Insulation.—If low insulation resistance readings are obtained on any of the foregoing tests, the terminals should be regarded with suspicion, as it frequently happens that a film of moisture and dust forms a connection between the terminal and frame of machine, switchboard or battery under test. This is particularly noticeable when the terminals are carried on a porcelain base. Slate bases are liable to have metallic veins, and, while specifications always provide for their freedom from this defect, the ebonite or mica bushes and washers usually used for insulating the terminals from the slate should be carefully examined in such circumstances.

The connections between adjacent field coils on shunt-wound machines are a frequent cause of low insulation, especially in the smaller sizes, and this is aggravated when oil from the bearings leaks into the carcass. Copper dust and oil is sometimes responsible for low insulation between the commutator and shaft of a motor or dynamo, and a cracked bush insulating brush spindle from rocker arm may cause the same result if the test is made with the brushes in contact with commutator without showing any visible defect.

On completing an insulation test, the following matters should receive special attention.

Examination of Switches.—Switches should be examined carefully to see that they make good contact, that contact faces are clean and free from any sign of pitting, that the switch works smoothly, and, in the case of the quick break type, that the pull-off springs are in good order and working effectively. Insulating handles and shields should be closely examined, and the nuts on bolts fixing switch to switchboard or mounting, or connecting cables to switch, should be tried with a spanner to ensure that they are secure.

E.M. Circuit Breakers.—Circuit breakers should be examined in the same way as switches and the adjustment of the setting at which they trip for overload or reverse current should be checked, as there is sometimes a risk of this being altered during cleaning operations.

Auto. Cut-Outs.—Automatic cut-outs of the "Crawley" or "Neville" type should be examined to see that the balanced arm works freely and is in proper adjustment. The mercury in cups should be cleaned if necessary by pouring into a piece of closely woven clean white rag folded two or three times and made into the form of a bag, and squeezing it through this into a wide-necked glass bottle or a clean iron scoop or spoon. The

cups should be wiped out and mercury replaced and added to if necessary to make up any loss. Connections should be cleaned and tightened up.

Polarised Relays.—Polarised relays require testing to see that they operate correctly, the contacts should be cleaned and adjusted if necessary.

Fuses.—Fuse-holders of the clip type require special attention as the contact faces become oxidised, and this introduces appreciable resistance which leads to heat being developed, and, on C.B. systems, may cause noise. If lead or tin wire fuses are used in porcelain holders they should be renewed at each half-yearly test. Copper and platinoid fuses do not deteriorate so rapidly and may be left for longer periods, but in all cases where fuses are held by a clamping screw, it is desirable to renew them once a year, the contact faces being cleaned at the same time. Silver wire fuses soldered to the terminals of fuse-holders may be used indefinitely, but the terminal contact faces should be cleaned at least twice a year. When the fuses are fitted in battery rooms, more frequent cleaning may be necessary and the terminals should be served with petroleum jelly after each cleaning.

Since the fuse is the safety valve of the electric circuit, it is necessary that great care should be exercised to ensure that the correct capacity is used.

Starters and Field Rheostats.—Starters and rheostats should be examined to see that all connections are in order, that the brush on travelling arm makes good contact on each stud, that the overload trip is set to operate at the correct current and that the armature of this coil effectively short-circuits the "No volt" coil. The resistance coils should be examined for signs of oxidation, due to overheating, or short-circuiting due to sagging which, in certain types, follows overheating, and carbon contact blocks should be renewed if necessary.

Indicating Instruments.—Indicating ammeters, voltmeters, etc., should be examined to see that there is no zero error, that the pointer moves freely with minimum current, that the scale indicates and that connections are clean and tight. Where fitted with a multiway switch the contacts of the latter should be cleaned and adjusted to make good contact.

Recording Instruments.—Recording ammeters require examining to see that contact pressure of pen on chart is the minimum that will make a continuous mark when the pen is clean, that the oil in dash pot—where this is fitted—is up to proper level, that there is no zero error; also that the clock-work keeps correct time, and holding-on and guide clips allow paper to pass freely. The readings should be checked against the indicating ammeter.

Integrating Instruments.— Ampère-hour and Watt-hour meters should be examined to ascertain that the connections are good, that the armature rotates with a current not exceeding one per cent. of full load and, where a commutator is fitted, that no sparking is taking place. The most frequent causes of trouble are broken jewels, damaged pivots, sparking at commutator, friction on dial train and, in the case of mercury motor meters, leakage of mercury or dirty mercury.

Cables, Wiring, etc.—Cables and wires should be examined to verify that the covering is in good condition and free from risk of mechanical damage where they leave pipes, chases or ducts ; that high-voltage cables, wires and connections are clear of low-voltage connections and the sheathing of lead-covered cables effectively earthed.

Guards and Earthing.—The metal covers on enclosed switches and guards on high-voltage portion of switch gear should receive special attention, and the greatest possible care should be taken to ensure that the earth wiring of the same is in good order and effective.

The importance of earthing all metal work which does not normally carry current on dynamo, motors, switching gear and switchboards, cannot be too strongly emphasised. The golden rule is “**earth all metal work, earth it thoroughly and keep it earthed.**”

SOME “DON'TS” FOR POWER PLANT ATTENDANTS.

Don't change the type of brush used on a motor or dynamo without first obtaining expert advice.

Don't fail to see that oil rings are working properly *after* machine has started.

Don't use oil other than that authorised.

Don't allow oil to “creep” on to commutator or windings.

Don't expect a machine to run without attention.

Don't overload a motor or dynamo.

Don't neglect small defects. They frequently lead to serious breakdowns.

Don't fail to call attention to anything abnormal observed in operating machines.

Don't use a fuse larger than that authorised for any machine or circuit.

Don't lift brush while motor or dynamo is running where there is only one on each spindle.

Don't fail to adjust the position of brushes when load on dynamo is varied.

Don't alter adjustment of circuit breakers without Engineer's consent.

Don't attempt to replace a fuse without opening the switch controlling the circuit.

Don't bridge over fuses or circuit breakers. They are the " safety valves " of the electric circuit.

Don't touch any " live " parts with bare hands when voltage exceeds 65 volts A.C. or 125 volts D.C.

Don't allow belts to become saturated with oil.

Don't use belt joints which cause a " hammer " action in passing over pulleys.

Don't have belts too slack—undue slipping causes excessive wear.

Don't have belts too tight—it overloads motor and causes bearing to heat.

Don't open the field circuit of a shunt-wound machine in operation.

Don't use uninsulated tools on live parts of machine, etc.

Don't leave iron or steel tools lying near a dynamo or motor.

Don't attempt to start a machine with which you are not familiar without reading instructions or obtaining advice.

Don't be afraid to ask questions concerning anything you do not understand.

LOCALISATION OF FAULTS.

Minimum Insulation Permissible.—Supply authorities stipulate that the insulation resistance of any machine or piece of apparatus connected to their system shall have a certain minimum value. The actual figure varies, but the general tendency is towards adopting the I.E.E. rules which require a minimum figure of 1 megohm. The Department's rule is that the leakage current shall not exceed $1/10,000$ of the maximum current carried in the circuit. When, therefore, figures less than the former or greater than the latter are obtained, it becomes necessary to localise the fault.

Low Insulation in Motor or Dynamo.—In the case of a motor which has been tested with its leads and starter, the leads should be disconnected from motor terminals and tested separately. If these prove in order, lift brushes off commutator and test field winding by connecting *L* terminal of megger to field terminal and *E* terminal to frame of motor. This test includes the brush-holders and, if a low reading is obtained, the other end of the field winding should be disconnected from the terminal and another test taken. To test terminal blocks, disconnect all wires and take readings between (a) all terminals " bunched " and frame of machine and (b) each pair of terminals. Brush-holders should be tested separately by connecting *L* of megger to holder and *E* to frame or rocker arm.

Short-circuited Coil in Armature, Contact between Segments of Commutator or Break in Armature Winding.—To test an armature for any of these defects, disconnect the field windings and send a current through armature equal to half full load current taken by machine, and measure the fall of potential between each pair of segments with a millivoltmeter. A short circuit is indicated by no reading; a partial short (section of coil short-circuited) by a low reading compared with that obtained on other sections; a broken coil by a higher reading than normal; and a reversed coil will be indicated by a reversed reading on millivoltmeter provided that the leads from the latter have not been crossed during the progress of the test. The connections for this test are indicated in Fig. 28, where,

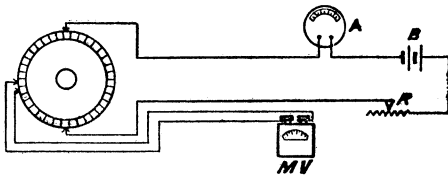


Fig. 28.

CONNECTIONS FOR TESTING FOR DISCONNECTION OR REVERSED COIL IN ARMATURE WINDING.

A = Ammeter. B = Battery of secondary cells or other source of current.

R = Adjustable resistance to limit Current.

MV = Millivoltmeter or Detector No. 2.

for clearness, an end view only of commutator is shown. The armature need not be removed from the motor, except in the case of very small machines, where difficulty is experienced in getting to the commutator, and the current may be passed through armature *viâ* the brushes. If the armature is removed, the leads carrying the current may be lightly soldered to two diametrically opposite segments of the commutator; in this case it will be found that the direction of current in the millivoltmeter changes on passing either of the soldered wires, due to the fact that the two halves of the armature winding are in parallel, and this reversal should not be confused with a defect.

If the current for testing is taken from the supply mains a limiting resistance should be placed in the positive lead of a 2-wire system or the live lead (either outer) of a 3-wire system, so as to reduce the risk of shock when handling the armature. If a millivoltmeter is not available, the milliampère

scale of a No. 2 detector may be used to measure the fall of potential in each coil of armature winding. Using the 50 M.A. scale, each division represents 12 millivolts. The latest type of detector is provided with a special terminal for millivolt tests. In making the foregoing tests it is essential that the current should be kept steady.

Undue resistance at fuse contacts is a frequent source of trouble which, owing to the low current passing, does not always lead to appreciable heating. It may be located by measuring the fall of potential across the contact when the maximum working current is flowing. Switch blade contacts, bolted connections, etc., may be tested in the same way. A millivoltmeter or No. 2 detector should be used for each of these tests.

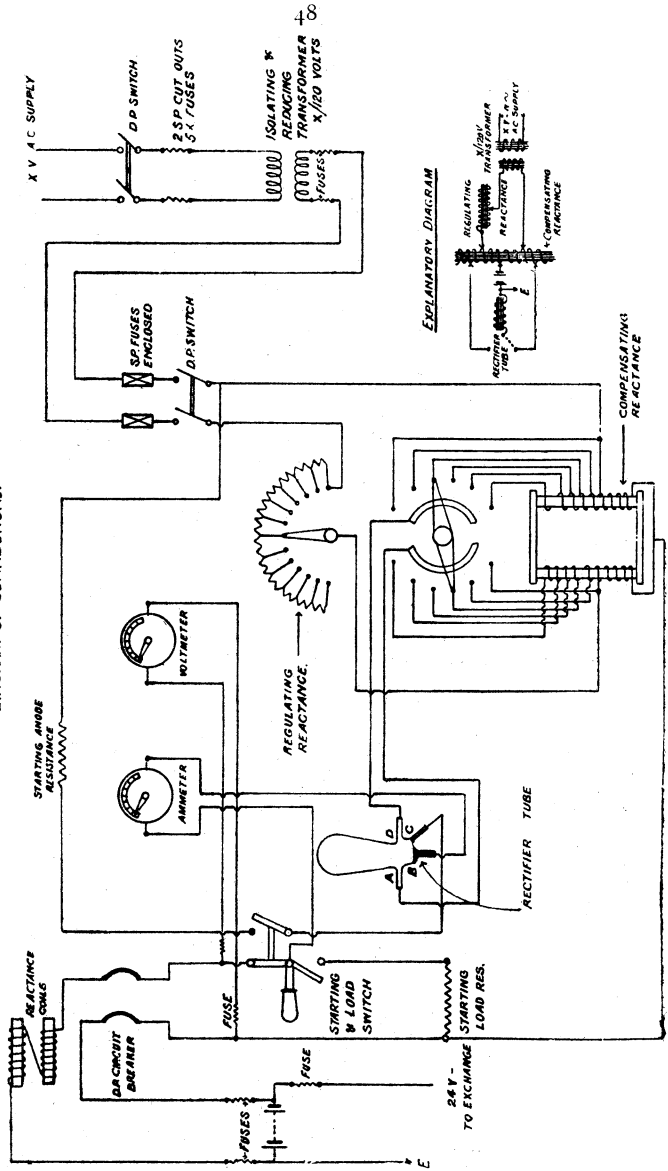
Bad connections between brushes and brush-holders or high contact resistance between brushes and commutator can be located in the same manner, although, in the latter case, it should be borne in mind that the contact resistance is greater with the armature at rest than when it is running.

Position of switches under test.—In all tests for high contact resistance the switch, fuse, brush or connection should, of course, be in its normal position, *e.g.*, a switch should be closed when under test and, in those cases where the hinge of switch carries current (an indication of bad design), it should receive special attention. The leads used in making the test should have sharp pointed terminals which will penetrate the lacquer, otherwise unreliable results will be obtained. The importance of systematic testing of this kind cannot be over-emphasised, and will avoid many causes of complaint.

A partial short in the field winding of a shunt-wound dynamo or motor may be located by passing the normal current through the coils with brushes lifted and measuring the voltage drop on each coil; the faulty coil will show a lower voltage across its terminals than the others. Differences of the order of one to two per cent. should not be taken as indicating a specific fault, since slight variations in the gauge of the wire may be the cause of this.

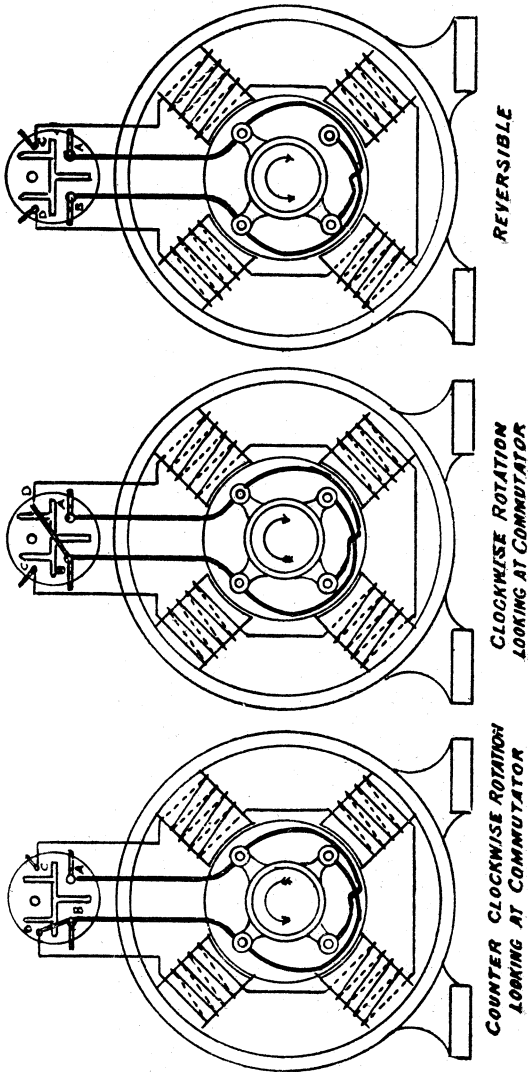
The condition of the interpole windings may be verified by measuring the voltage drop, but, in this case, since it will probably be found inconvenient to make the test with the machine running, a current should be passed through the coils in the manner indicated for armature test, the field coils being disconnected and brushes lifted. The drop of potential across each coil will be only a fraction of a volt, and it will be necessary, therefore, to use either the 5-volt or 500 M.A. scale of a No. 2 detector in making the test.

APPENDIX I.
B.T.H. MERCURY ARC RECTIFIER.
DIAGRAM OF CONNECTIONS.



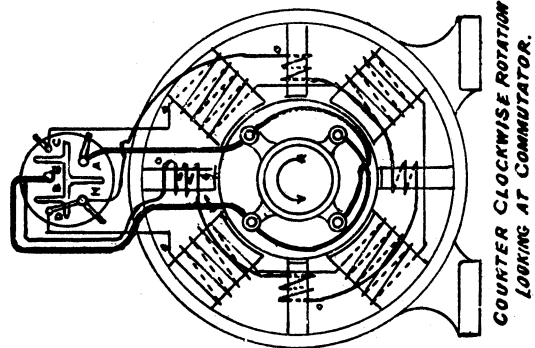
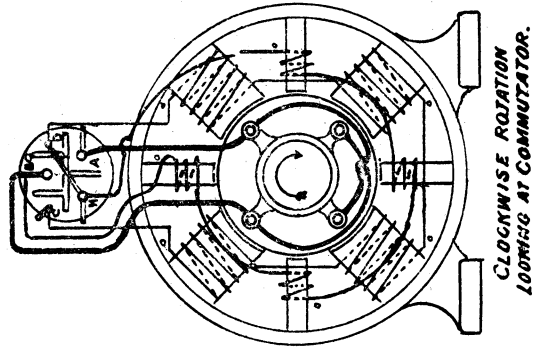
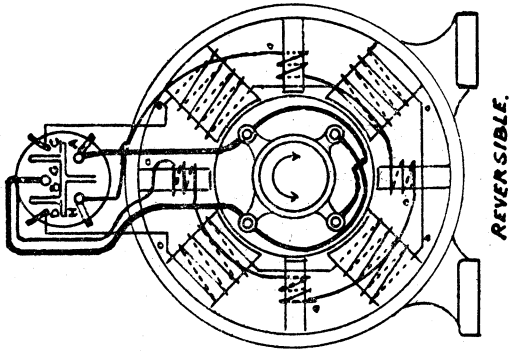
APPENDIX II.

DIAGRAMS SHOWING INTERNAL CONNECTIONS OF DIRECT CURRENT MOTORS AND GENERATORS.
SHUNT-WOUND WITHOUT COMMUTATION POLES.

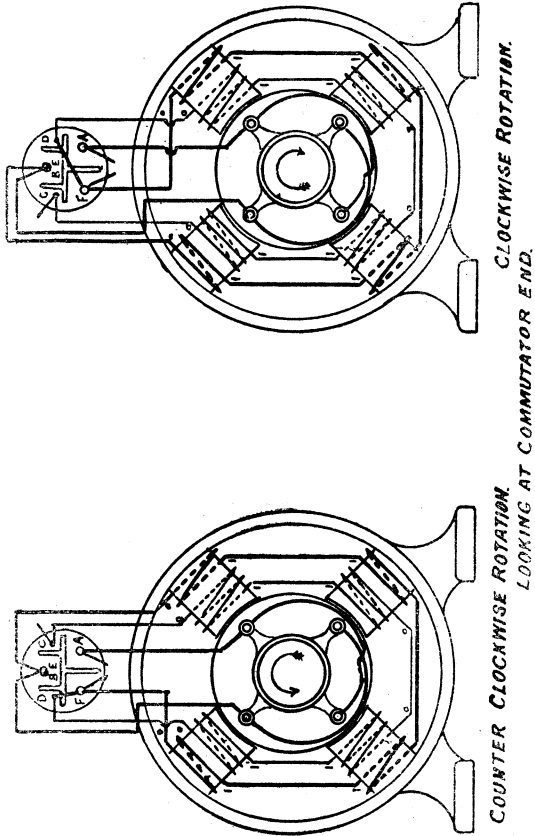


APPENDIX II (continued).

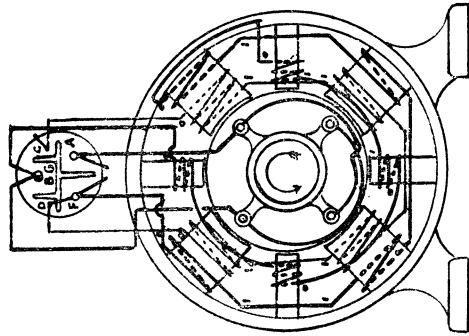
DIAGRAMS SHOWING INTERNAL CONNECTIONS OF DIRECT CURRENT MOTORS AND GENERATORS.
SHUNT-WOUND. WITH COMMUTATION POLES.



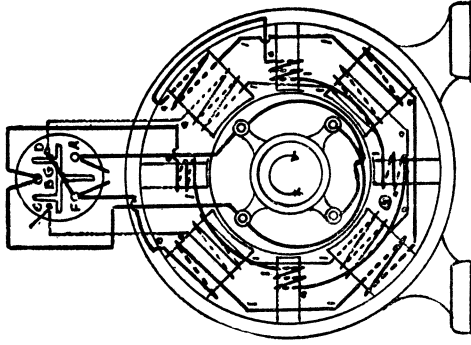
APPENDIX II (continued).
DIAGRAMS SHOWING INTERNAL CONNECTIONS OF DIRECT CURRENT MOTORS.
COMPOUND WOUND. WITH COMMUTATOR POLES.



APPENDIX II (continued).
DIAGRAMS SHOWING INTERNAL CONNECTIONS OF DIRECT CURRENT MOTORS.
COMPOUND WOUND. WITH COMMUTATION POLES.



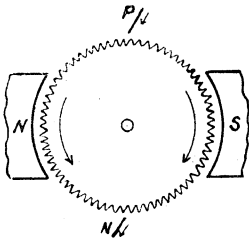
COUNTER CLOCKWISE ROTATION.
LOOKING AT COMMUTATOR END.



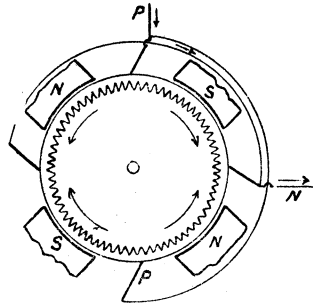
CLOCKWISE ROTATION.
LOOKING AT COMMUTATOR END.

APPENDIX III.

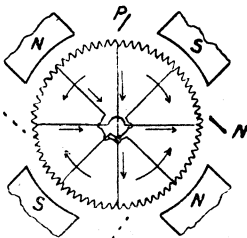
PRINCIPLE OF CONNECTIONS, AND DISTRIBUTION OF CURRENT IN DIFFERENT TYPES OF ARMATURE.



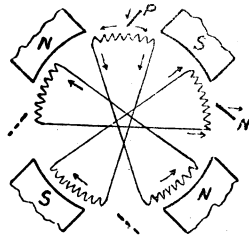
(A) 2 pole, 2 circuit.



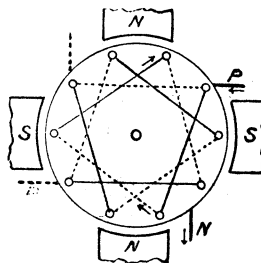
(B) 4 pole, 4 circuit, 4 brushes, 2 in parallel on positive and negative sides.



(C) 4 pole, 4 circuit cross-connected, 2 brushes at 90° . Additional brushes may be fitted as shown by dotted lines.

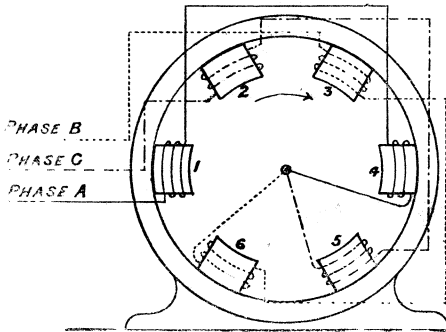


(D) 4 pole, 2 circuit ring, 2 brushes at 90° . Additional brushes may be fixed as in case (C).



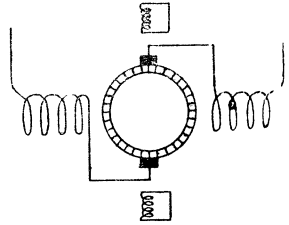
(E) 4 pole, 2 circuit drum, 2 brushes at 90° , or 4 as in (C) & (D).

APPENDIX IV.
A.C. MOTOR CONNECTIONS.



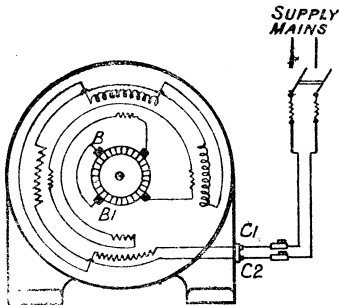
Stator Winding of 2 Pole 3 Phase Motor. The Polar Projections are Imaginary. To Reverse Direction of Rotation, Cross Phase Wires A and C, or C and B.

APPENDIX V.

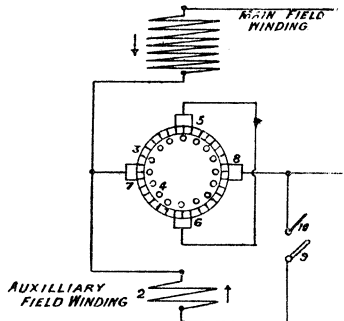


Connections of Neutralised Single Phase Series Motor. Inductive method, so called from the neutralising coils being closed on themselves. In the Conductive method these coils are placed in series with the main winding and armature.

APPENDIX VI.



Connections of Single-Phase Compensated Repulsion Motor. To reverse direction of rotation interchange leads C1 and C2. The Brushes B and B1 are permanently short-circuited.



Connections of "Wagner" Unity Power Factor Single-Phase Induction-Repulsion Motor. The Rotor is fitted with two separate windings, one, the main, being of "Squirrel Cage" construction, indicated by circles, and the second, auxiliary (3) of the usual D.C. type. 5-6 is the main pair of brushes and 7-8 the auxiliary brushes placed at right angles to the former. The switch, 9, is operated when starting and closed when motor attains full speed. The principle is repulsion start and induction operation.

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LIST OF
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Technical Pamphlets for Workmen

(Continued)

GROUP D—continued

20. Superposed Circuits. Transformers. Bridging Coils and Retardation Coils.
21. Call Offices.
22. Units, Amplifying. (*Not on Sale.*)

GROUP E

1. Automatic Telephony. Step-by-Step Systems.
2. Automatic Telephony. Coded Call Indicator (C.C.I.) Working.
3. Automatic Telephony. Keysending "B" Positions.

GROUP F

1. Subscribers' Apparatus. Common Battery System.
2. Subscribers' Apparatus, C.B.S. Part I—C.B.S. No. 1 System.
3. Subscribers' Apparatus. Magneto.
4. Private Branch Exchanges—Common Battery System.
5. Private Branch Exchange—C.B. Multiple No. 9.
6. Private Branch Exchanges—Magneto.
7. House Telephone Systems.
8. Wiring of Subscribers' Premises.

GROUP G

1. Maintenance of Secondary Cells.
2. Power Plant for Telegraph and Telephone Purposes.
3. Maintenance of Power Plant for Telegraph and Telephone Purposes.
4. Telegraph Battery Power Distribution Boards.

GROUP H

1. Open Line Construction, Part I.
2. Open Line Construction, Part II.
3. Open Line Maintenance.
4. Underground Construction, Part I—Conduits.
5. Underground Construction, Part II—Cables.
6. Underground Maintenance.
7. Cable Balancing.
8. Power Circuit Guarding.
9. Electrolytic Action on Cable Sheaths, etc.
10. Constants of Conductors used for Telegraph and Telephone Purposes.

GROUP I

1. Submarine Cables.

GROUP K

1. Electric Lighting.
2. Lifts.
3. Heating Systems.
4. Pneumatic Tube Systems.
5. Gas and Petrol Engines.