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PART 16

A PRACTICAL WORK WRITTEN BY EXPERTS

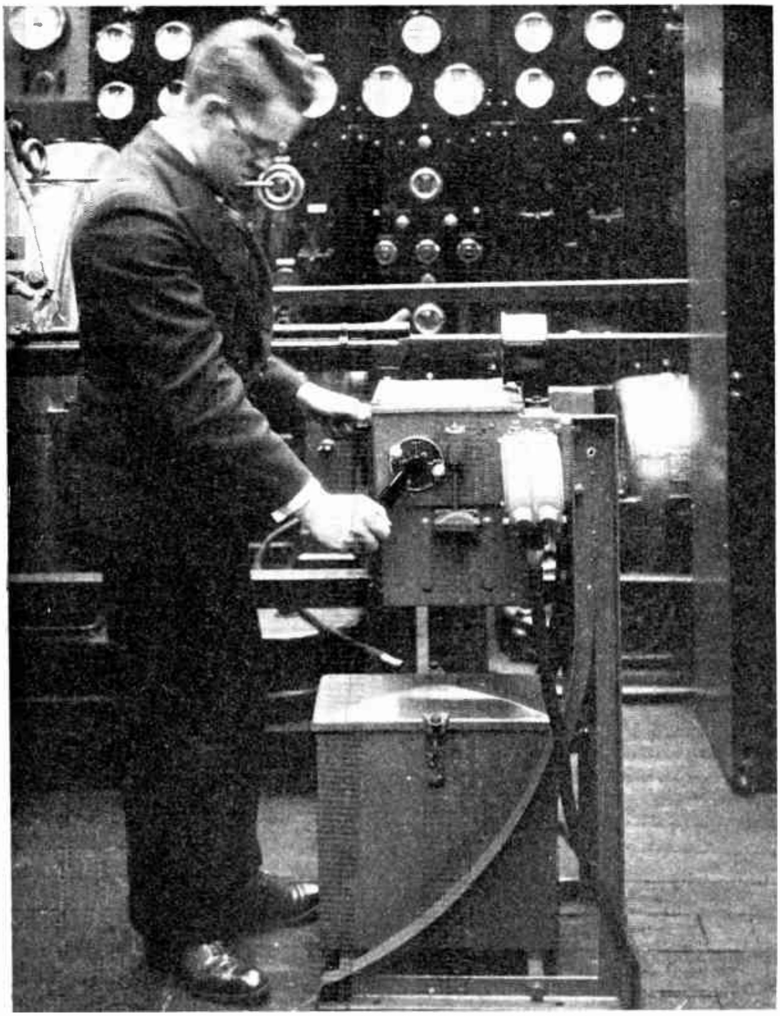

Fig. 15.—STARTING A SQUIRREL CAGE MOTOR.

This starter is of the oil-immersed auto-transformer type, and cable sealing chambers and an ammeter are fitted. The "start," "off," and "run" positions mentioned in the text are clearly shown. (*Metropolitan-Vickers.*)

described for direct coupled machines, the slide rails or slide base taking the place of the bedplate. The lining up between the driving and the driven pulley should be carried out as shown in Figs. 42 and 43, page 247, and described on page 251. Care should be taken to see that the shafts are parallel, since if this is not so the belt will run off, or it will run to one side of the smaller pulley if the out of parallel is not very large. When the shafts are parallel, but the pulleys not in line, the belt will run to one side of the larger pulley.

Jointing the Belt.

When jointing the belt the two ends should be cut absolutely square and the belt fastener should be securely fitted. After the belt is in place the whole drive should be revolved by hand to make sure that everything is working correctly. ▲

Finally, pulleys should always be fitted as close as possible to the bearings so as to avoid excessive strain on the shaft, and for the same reason the power side of fast and loose drives should always be next to the motor bearing. It also follows from this that the pulley should not be too small in diameter, since the belt pull will increase as the diameter decreases. The only way in which the minimum pulley diameter can be arrived at is to consult the motor maker. In any case, a pulley of smaller diameter

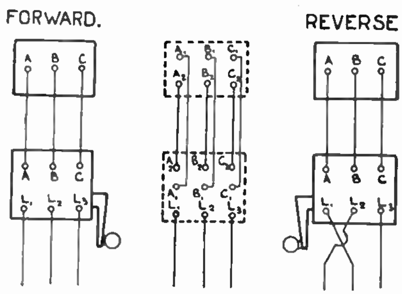

Fig. 16.—Changing Rotation of a Three-phase Motor.

The alterations in connections of a three-phase motor to reverse the direction of rotation are shown above. Observe that it is only necessary to change two of the supply cables at the motor starter. It is unnecessary to alter any connections in the motor terminal box. The connections for a star-delta job are shown dotted in the centre. Here also the rotation is reversed by changing over L_1 and L_2 on the starter.

than is given on the manufacturer's outline drawing should not be employed until it has been approved. If this is not done motor makers will not take any responsiblity for broken or bent shafts.

Calculating Belt and Pulley Sizes.

Let us work out the belt and pulley particulars for the following drive. A motor of 20 h.p. output when running at 1,000 r.p.m. is to be belted to a lineshaft which must run at about 250 r.p.m.

In order to make a start let us take the belt speed at 3,000 feet per minute. This is good average practice for main belt drives. The motor pulley diameter in inches will then be :—

$$\frac{\text{Belt speed} \times 3.8}{\text{Motor r.p.m.}} = \frac{3{,}000 \times 3.8}{1{,}000} = 11.4 \text{ ins.}$$

An $11\frac{1}{2}$-inch diameter pulley would be used here. For the size of pulley required on the lineshaft we may use the same formula, which gives us :—

$$\frac{\text{Belt speed} \times 3.8}{\text{Lineshaft r.p.m.}} = \frac{3{,}000 \times 3.8}{250} = 45.6 \text{ ins.}$$

Here again the diameter would be rounded off to $45\frac{1}{2}$ inches.

The pulley face is fixed as follows. From the curve it is seen that a single oak tanned leather belt will transmit 4.5 h.p. per inch of width when it runs at 3,000 feet per minute. The rated output of our motor is 20 h.p., and a standard ventilated type motor of this size will carry 25 per cent. overload for two hours. It is usual to allow for this overload so that the horse power to be transmitted by the belt should be taken as $20 \times 1.25 = 25$.

The belt width will therefore be :—

$$\frac{\text{Horsepower load (max.)}}{\text{Horsepower per inch}} = \frac{25}{4.5} = 5\frac{1}{2} \text{ inches}$$

It would be good practice to make the belt width 6 inches and the pulleys should be about 1 inch wider than the belt, so that both pulleys should be about 7-inches face. Both the pulleys should be larger in diameter in the centre than at the edges. This is termed "crowning" and a good value is $\frac{1}{4}$ inch per foot of pulley face ; that is to say, a pulley of 12-inches face and 11-inches diameter at the centre would be $10\frac{3}{4}$ inches diameter at each edge of its face.

Crowning.

The crowning should be independent of the diameter, so that in our case both pulleys should be crowned the same amount, which should be :—

$$\frac{\text{Actual face}}{12} \times \text{Crowning per foot} = \frac{7}{12} \times \frac{1}{4}$$
$$= 0.146 \text{ inch.}$$

In a case like this we should crown the pulley about $\frac{1}{8}$ inch (0.125 inch) and we will round the calculated dimension off to that figure. The minimum centre distance for this drive should be :—

Centres of pulleys = diameter of large

pulley × 4 = 45½ × 4 = 182 inches, say, 15 feet.

Summarising our calculations, therefore, we have :—

Motor pulley : 11½ inches diameter × 7 inches crowned face, to sketch.

Lineshaft pulley : 45½ inches diameter × 7 inches crowned face, to sketch.

Belting : 6 inches wide, best oak tanned leather.

Minimum centre distance : 15 feet.

Rope Drives.

Rope drives are very popular in textile mills and they are capable of carrying large powers very efficiently ; the life of a good rope drive also is very long and the drive is smooth and sweet.

The ropes which are employed are made from cotton and the common sizes of rope are from ¾ inch to 2 inches diameter. While the rope speed which is employed varies from about 2,000 to 6,000 feet per minute, 3,000 feet per minute may be taken as a good average and at this speed the horse power transmitted per rope will be approximately as follows, when good quality cotton ropes are employed :—

Rope diam., inches.	H.P. per rope at 3,000 ft./min.	Rope diam., inches.	H.P. per rope at 3,000 ft./min.
¾	7.0	1⅜	23.5
⅞	9.5	1½	27.5
1	12.0	1⅝	32.5
1⅛	15.5	1¾	38.0
1¼	19.0	2	49.5

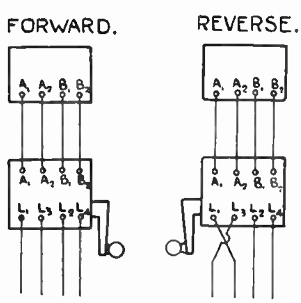

Fig. 18.—CHANGING ROTATION OF TWO-PHASE, FOUR-WIRE MOTOR.

The motor connections to the starter should not be interfered with. To reverse the motor, change over supply leads L_1 and L_3 as shown.

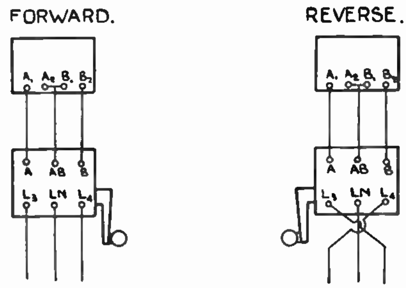

Fig. 17.—REVERSING ROTATION OF A TWO-PHASE MOTOR.

This figure refers to motors connected on two-phase, three-wire systems. As in the case of three-phase motors, the rotation is reversed by changing over the supply cables only, the connections from motor to starter remaining untouched. As shown, L_3 and L_4 should be reversed.

Pulleys for Rope Drives.

The pulleys for rope drives are grooved and are generally made of cast iron. The effective diameter of a rope pulley may be found in the same manner as was described for a belt drive, but it is necessary to ensure that the pulley is not too small for the rope size adopted, and the minimum size of pulley may be found as follows. These figures refer to rope speeds of 3,000 feet per minute and under these conditions the minimum pulley diameter should be:—

Rope diam., inches.	Minimum pulley diam. in rope diameters.
¾, ⅞	20
1, 1⅛	22
1¼, 1⅜	24
1½, 1⅝	25
1¾, 2	30

As an example, the minimum advisable pulley diameter for a 1½-inch diameter rope running at 3,000 feet per minute would be 25 rope diameters, or 1½ inches × 25 = 37½ inches.

Foundation Work for Rope-driven Motor.

The foundation work and grouting for a rope-driven motor will be exactly

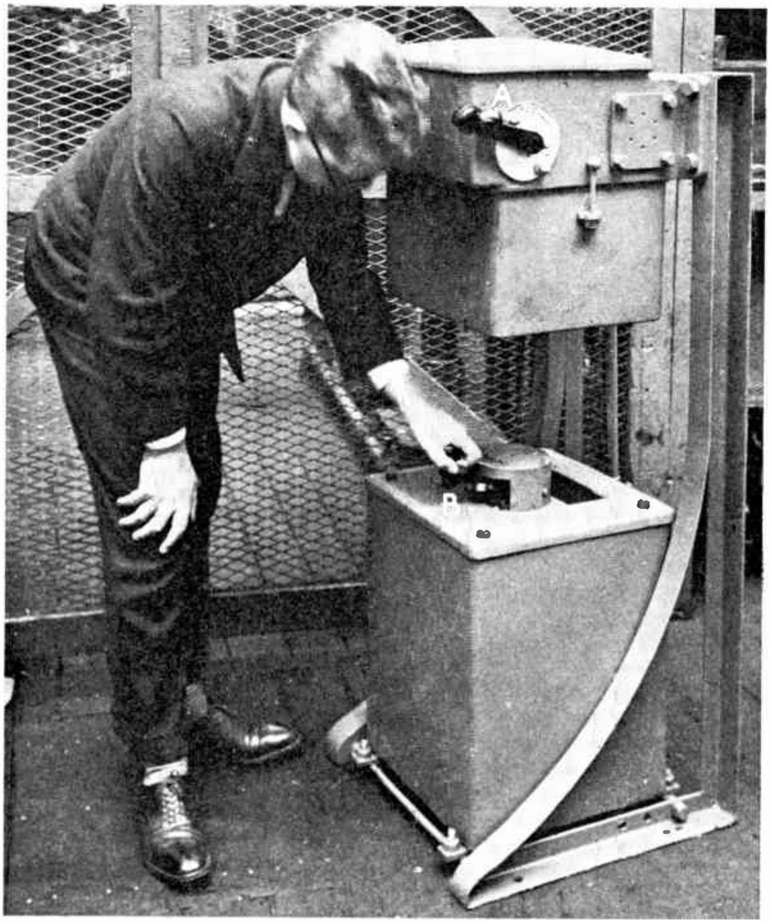

Fig. 19.—STARTING A SLIP-RING MOTOR.

Handle A is shown at "on" and the operator is working handle B to bring the motor up to speed. The starter is of the oil-immersed type, comprising a circuit breaker for the stator and a resistance controller for the rotor, the stator breaker is at the top. (*Metropolitan-Vickers.*)

as already described, and the lining up will be the same as for a belt drive. The distance apart of the pulley centres is of little importance, since the ropes drive on the sides of the grooves. Some drives work well with pulleys almost touching, while the use of idler pulleys to support the rope makes very long centre drives quite practicable.

Rope driving is a very specialised matter and space is too limited to do full justice to it; for further information the reader should consult the cotton driving rope makers, who have full figures, and will advise on any drive.

"Texrope," "Whittle" and Other Shaped Belt Drives.

Drives of this type are becoming very popular and they certainly have much to recommend them on the scores of life, space utilisation and load capacity. It is not possible to give any information here regarding these different types of shaped belt drive, since each manufacturer has arrived at his own table of loadings, and the pulley shaping varies for nearly every type of belt. It can be stated, however, that in all cases where the centre distance will be short, the speed high, or the space restricted, it will pay to consult the makers of these special types of belt.

CHAIN DRIVES.

Chains are of value where a positive and silent drive with a high load capacity and long life is required. Here again chain makers, such as Messrs. Hans Renold, Ltd., should be consulted, but the following brief notes may be of assistance in preliminary considerations affecting chain drives.

There is practically no centre distance limit for a chain drive, but it is good practice to make the distance between the pinion and wheel centres about 45 chain pitches. That is to say, a good centre distance for a 1-inch pitch chain would be about 45 inches.

Speed Ratio with Normal Chain Drive.

It is not advisable to have more than 120 teeth in the large wheel and the pinion should not have fewer than about 19 teeth, although 17 can be used in certain cases. This means that the speed ratio with a normal chain drive will not usually be greater than :—

$\frac{120}{19} = 6.3$, or in special cases $\frac{120}{17} = 7.06$

Chains and wheels should be enclosed in gear cases and well lubricated, and the lining up should be done on the same lines as for belt drives. The selection of a correctly proportioned chain drive can only be done from a maker's list, and application should be made to the manufacturers when a chain installation is contemplated.

GEAR DRIVES.

There are many types of gear drive which may be employed, but we may first state, as a general rule, that the alignment of the gearing is of the utmost importance. Lack of attention to this will result in violent vibration and breakage of gear teeth, and in any case it is advisable to consult the motor makers regarding a gear drive in order that the shaft may be suitably proportioned. All gears must be machine cut.

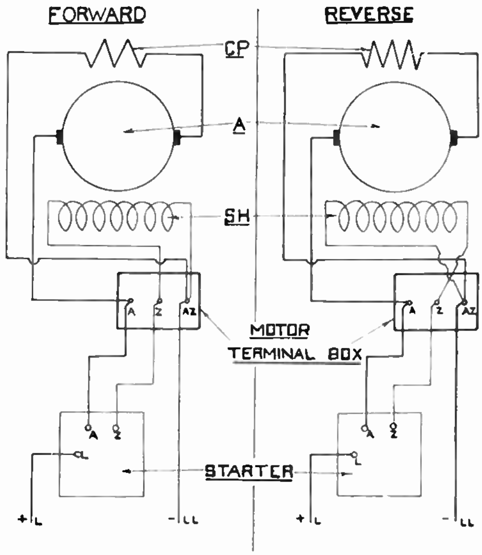

Fig. 20.—Reversing a Shunt-wound D.C. Motor.

For D.C. motor reversals, the supply cables should remain untouched and the connections should be altered in the motor terminal box as shown, where the connections from the shunt field to terminals Z and AZ are changed over. The brush rocker should be moved if necessary, when the motor is reversed.

Types of Gears.

With regard to the types of gears, spur gear reductions are common and they may be employed to give a speed reduction of not more than six to one. It is good practice to limit the pitch line speed of a gear train to not more than 1,000 feet per minute, and rawhide, paper or fabric pinions give good life and impart a certain resilience to the drive. In this respect the "Fabroil" pinion of the B.T.H. Co., Ltd., can be recommended.

Single helical and bevel drives must never be used without consulting the motor makers, since they give rise to thrust loads which may ruin the motor bearings unless special provision is made for them. Worm gears also give rise to thrust loadings and should be the subject of special consultation with the motor manufacturers.

In general, it may be said that the designing of a gear train of any type is the job of a specialist, and for this reason the reader is advised to consult a gearing manufacturer before deciding on the type of gear drive to be used.

Installation of Motor with Gear Drive.

The installation of a motor with a gear drive is quite straightforward, but great care must be taken to see that the shafts are parallel and that the teeth are fully in mesh, both in depth and also along the full face width. The lining up can be done as for a pulley drive and there is nothing unusual in the foundation work.

BORING AND FITTING COUPLINGS, PINIONS AND PULLEYS.

When it is required to fit any of these details to the shaft extension it should be bored for the correct type of fit, and

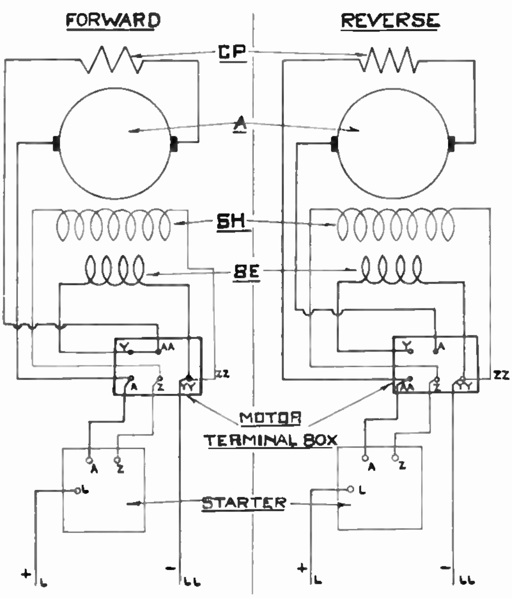

Fig. 21.—Changing Rotation of a Compound-wound D.C. Motor.

Here again the supply connections are unaltered, all changes being made in the motor terminal box. Reverse the armature and interpole connections to terminals A and AA, as shown, and adjust the brush position, if the motor sparks. Take care not to reverse the series field current, otherwise the motor may run up to a dangerous speed.

TABLE II.

Bores of Shaft Details.

Nominal Shaft Diameter.	Pulley Bore for Correct Fit.	Pinion or Coupling Bore for Correct Fit.
Inches.	Inches.	Inches.
½	0.501	0.5005
1	1.0015	1.0007
2	2.002	2.001
3	3.0025	3.0012
4	4.003	4.0015
6	6.004	6.002

The sizes given above will ensure a correct fit for the type of drive specified and assume the use of a taper key.

this means that the bore should be larger than the shaft extension by the amount shown in Table II. The extension should be micrometered before boring is commenced and when the pulley, say, has been finished to the correct dimensions it should be fitted on the shaft extension as follows. The shaft should be lightly greased and the pulley should be started squarely on the extension and driven on by light blows if necessary. Care should be taken that the pulley remains square with the shaft extension during the whole operation of fitting, and a suitable wood or soft metal driver must be used to deaden the hammer blows. Figs. 50 (A, B, C and D), 53, 54 and 55, page 250, clearly show the method of fitting shaft details. When the pulley is being fitted the shaft keyway and the keyway in the pulley boss should be kept opposite to each other, and after the pulley is driven to its final position a tapered key should be driven home. The correct amount for the key taper is about ⅛ inch per foot.

WIRING AND CONNECTING.

Every manufacturer of repute sends out a terminal diagram with his motors and this generally shows how the internal windings are arranged and how the terminals are lettered. This diagram should be frequently consulted during the connecting up, and it should be used in conjunction with the control gear diagram.

Size of Cables.

All cables should be of large enough size to carry the current which is stamped on the motor nameplate, and the following table gives the size of cable which will be required providing the wiring run is not long enough to cause a voltage drop of more than 5 per cent. To read the nameplate current and then select the appropriate cable for a short run is perfectly simple, but it is not so easy to decide what cable to use when the voltage drop question enters into the choice. Let us therefore take an example.

Our 20 h.p. motor is of the D.C. shunt wound type and is wound for 100 volts, its nameplate current being 170 amps. Its point of location is 150 yards from the point of supply.

TABLE III.
CURRENT-CARRYING CAPACITIES OF SINGLE-CORE V.I.R. CABLES.

Nominal Area of Conductor.	No. and diameter of Wires Comprising Conductor.	Permissible current to I.E.E. Regulations.	Total length in circuit (lead and return) for 1 volt drop at rated current.
Sq. inch.	Inch.	Amps.	Feet.
0.001	1/.036	4.1	30
0.0015	1/.044	6.1	30
0.002	3/.029	7.8	30
0.003	3/.036	12.0	29
0.0045	7/.029	18.2	28
0.007	7/.036	24.0	33
0.01	7/.044	31.0	39
0.0145	7/.052	37.0	45
0.0225	7/.064	46.0	55
0.03	19/.044	53.0	61
0.04	19/.052	64.0	71
0.06	19/.064	83.0	83
0.075	19/.072	97.0	90
0.1	19/.083	118.0	98
0.12	37/.064	130.0	103
0.15	37/.072	152.0	112
0.2	37/.083	184.0	123
0.25	37/.093	214.0	132
0.3	37/.103	240.0	145
0.4	61/.093	288.0	162
0.5	61/.103	332.0	172
0.6	91/.093	384.0	181
0.75	91/.103	461.0	185

On consulting Table III we see that 0.2 square inch cable will carry 184 amps. and it would appear, therefore, that this will be satisfactory. Let us check the voltage drop, however. The motor is 150 yards from the supply, so that there will be $150 \times 2 = 300$ yards of cable in circuit, allowing for the two wires (lead and return), which are necessary. From Table III we see that 123 feet of cable causes a drop of 1 volt when carrying 184 amps.

In our case, therefore, the voltage drop will be :—

$$\frac{\text{Yards of cable} \times 3}{\text{Feet per volt drop}} \times \frac{\text{Motor amps.}}{\text{Cable rated amps.}}$$

$$\frac{300 \times 3}{123} \times \frac{170}{184} = \text{Say, } 6.75 \text{ volts.}$$

The supply voltage is 100, so that the percentage drop is :—

$$\frac{6.75}{100} \times 100 = \text{Say, } 6.75 \text{ per cent.}$$

This is too much ; therefore we will try 0.25 square inch cable and check the voltage drop as before :—

$$\text{Volts drop} = \frac{300 \times 3}{132} \times \frac{170}{214} = 5.4 \text{ volts,}$$

giving us $\frac{5.4}{100} \times 100 = 5.4$ per cent. drop, which is still above the 5 per cent. limit ; we must therefore use 0.3 square inch cable, which gives 4.4 per cent. drop.

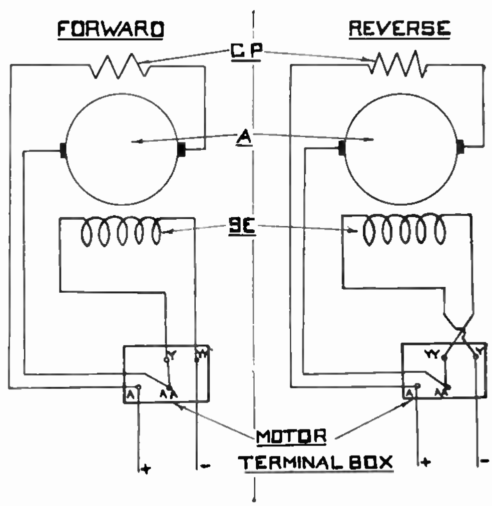

Fig. 22.—REVERSING A SERIES MOTOR.

No starter is shown here because the starting arrangements of series-wound motors are so diverse. To reverse rotation, change over the series field connections to terminals Y and YY and adjust the brush rocker position, if required.

Earthing the Frame of the Motor.

The frame of the motor must be earthed, and a copper earth wire is generally employed, although the steel conduit or the cable sheathing may be used providing this is efficiently earthed. When flexible metallic tubing ("flexible conduit") is used (to allow for movement) on a motor with slide rails, a copper earth wire *must* be fitted to comply with Home Office Rules.

Soldering Cables into Sockets.

All the cables must be soldered into the sockets which are provided on the motor terminals and when this has been done all the terminals should be well tightened down. Care should be taken that no cables cross and make contact with each other, and for this reason it is inadvisable to fasten the raw cable ends under the terminal studs, since strands may stray out and cause short circuits.

When the wiring is completed it should be very carefully checked against the terminal and wiring diagrams supplied, and if all connections are found to be correct we may proceed to set the overload trips and time lags and to fill up any oil-immersed control gear.

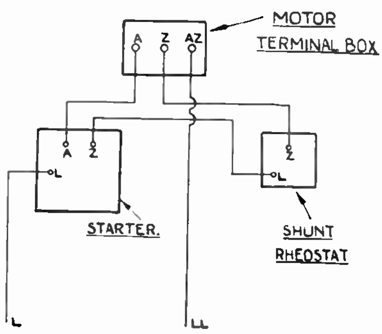

Fig. 23.—Varying the Speed of a Shunt or Compound D.C. Motor.

When a variable speed is required on a shunt or compound-wound D.C. motor, a shunt rheostat should be fitted in the shunt field circuit between the motor terminal Z and starter terminal Z. The motor speed will be increased as the resistance is increased; the rheostat should be fitted with an interlock to prevent starting the motor with resistance in circuit with the field.

Overloads.

The overloads should be set at about 150 per cent of the current which is stamped on the motor nameplate, and oil-immersed time lags, if any, should be filled with the correct grade of oil to give a lag of about 30 seconds. The oil grade required will be settled by the control gear maker, and if the starter is of the oil-immersed variety it should be filled up to the level marked upon it with good grade transformer or switch oil. If fuses are fitted the correct size of fuse wire for 150 per cent. to 200 per cent. full load current should be used and the size of the wire may be obtained from the following Table.

TABLE IV.

Tinned Copper Fuse Wire.

Diameter of Wire.	Fusing Current.
Inch.	Amps.
0.0092	8.0
0.010	9.8
0.0108	11.0
0.0120	12.8
0.0124	13.5
0.0148	17
0.018	22
0.022	30
0.028	41
0.029	43
0.036	62
0.040	73
0.044	86
0.048	98
0.052	111
0.056	125
0.064	150
0.072	191
0.080	229

Inspection Before Closing the Main Switch.

Before closing the main switch the installation should be carefully inspected to ensure that :—

1. The motor is well bolted down.
2. The belt or other driving equipment is tight.
3. The motor and belt drives, etc., will revolve freely when turned by hand or barred round.

4. All covers, guards, terminal lids, etc., are in place.
5. All wiring is tightly and correctly connected.
6. All starter, switches, controllers and brushgear handles are in the *off* position, if such a position is fitted; otherwise these handles should be in the *start* position.
7. All driven machines are out of work.

Having made sure that this is so we may proceed with the

STARTING UP.

In order to start the motor, we must first close the main switch so as to make the machine and control gear alive and we must then operate the starter so as to bring the motor and load gradually up to full speed. Let us first consider two and three-phase A.C. motors of the squirrel cage type, for each of which three types of starting are in common use, namely, direct-on starting, star-delta starting and auto-transformer starting. For two-phase motors, star-delta starting is replaced by series parallel starting.

First of all it should be stated that the type of starting to be used will depend upon the regulations issued by the supply authority who will provide current for the motor. These regulations must be consulted and complied with. Otherwise a supply may be refused.

Methods of Starting.

Turning now to the methods of starting which have already been mentioned, the equipment for all of these methods is generally almost identical in outside appearance, consisting of a case which contains the starting mechanism, with an operating handle projecting from it. This operating handle usually has three positions marked as in the illustration, namely, "Off," "Start" and "Run." A trip knob or button is often, but not always, fitted. The function of this is to return the starter to the "Off" position quickly without the necessity of operating the starting handle. In all these types of starter there is only one handle to operate, although there may be more than one case.

Operation of Starting Gear.

We are not concerned here with the mechanism inside the starter case; that and the function of the starting gear is explained in another article. That in which we are interested, however, is how the starting gear should be operated.

The operation of direct, star-delta and auto-transformer starters is identical. To start a motor under any of these systems the procedure is as follows:—

1. Close the main switch.
2. Move the starter handle smartly to the "Start" position and hold it there until the motor has got up to a fair speed.
3. Move the starter handle from "Start" to "Run." It will stay in this position, being held by the trip gear. This last movement should be decisive, but not too quick, or else it will not be possible to get into "Run."

Stopping the Motor.

After this the machine should be up to full speed, and it will be capable of taking load immediately. When it is desired to stop the motor:—

1. Operate the trip knob.
2. Open the main switch or button.
3. Return the starter handle to "Off."

Failure to start or carry the load will be dealt with later.

Starting Gear of Two or Three-phase A.C. Motors.

We must now consider slip-ring, two and three-phase A.C. motors. The starting gear for these is usually contained in two or three cases, but there are always two handles to operate. The first of these handles has only two positions, "Off" and "On," and serves as a main switch for the motor. A trip knob or button is generally fitted on this switch.

The second handle usually has five or more positions, and is the actual starting controller. In addition to this, there may be a handle on the motor itself, generally projecting from the end bracket or slip-ring cover. This will always have only two positions, "Start" and "Run," and if it is not present the instruction given for its operation should be ignored.

In order to simplify the instructions, let us call the handle having "On" and "Off" positions A; the handle having five or more positions B; the handle on the motor with "Start" and "Run" C.

Starting a Slip-ring Motor.

The procedure in starting a slip-ring motor should be as follows:—

1. See that the handle C is in "Start" position, and that handle B is at "Start," "Off" or 1, whichever is marked on the case or is at the "all resistance in" position if there is no marking.
2. Move handle A from "Off" to "On."
3. Operate handle B by moving smartly from its first position to the second step and holding there until the motor has gained some speed; then move smartly to the third step and hold there as before. This procedure should be gone through until the handle is in the last position and the motor should then be up to full speed.
4. Move handle C from "Start" to "Run."

The motor is now ready to carry its full load.

Stopping a Slip-ring Motor.

To stop the machine:—

1. Operate the trip knob or button.
2. Open the main switch.
3. Move handle A from "On" to "Off."
4. Move handle B from the last to first position; this only applies where handle C is not fitted.

Single-phase Motors.

We have now dealt with two and three-phase motors. The starting arrangements of single-phase motors are usually similar, but there are several makes of single-phase machines which have special starters. In any case, the use of single phase for anything but the smallest motors is rapidly decreasing, and these are always simply switched on the line. The reader is advised to consult the starting gear and motor makers when he has any problems involving fair-sized single-phase motors.

The starting and control of D.C. motors is treated in the article "Starters and Control Gear for D.C. Industrial Motors" on page 280, and the reader is referred to that article for the method of starting and stopping this type of machine.

MOTOR WILL NOT START.

When the motor will not start as soon as the starter is operated, or if it does not run up to speed in about 30 seconds, the main switch should be opened and the starter handle returned to the "Off" position immediately. If this is not done, the winding will be burnt out.

Before re-attempting to start the motor, make the following examination and rectify any points which are incorrect. If it is impossible to find the fault consult the manufacturers immediately.

1. Make sure that the supply voltage is reaching the starter.
2. Check all connections against the diagrams supplied with the motor and starter.
3. See that there are no breaks in cables or wires and that all terminals and connections are tightened down.
4. Ensure that motor is not overloaded; remove belt, chain, gear or coupling bolts and try to start without load.
5. Examine each step of starting equipment to see that there is no bad contact or short circuit.
6. Make sure that all motor brushes are down and making good contact with the commutator or slip rings.
7. See that line voltage at starting does not drop so much that starting torque is lost. Measure the voltage and if it falls more than 15 per cent. put in new cable of larger size or report matter to the supply company.

MOTOR WILL NOT CARRY LOAD.

If the motor starts but will not carry

the load or attain full speed, the following examination should be made in addition to the other points enumerated above :—

1. See that overload trips are set correctly at $1\frac{1}{2}$ to 2 times the nameplate current.
2. If oil filled time lags are used, see that these are filled with the right oil.
3. Ascertain that the driven machines are not in work and that the drive is free.
4. Starting may be too rapid ; start more slowly.

The above brief notes refer to faults with motors when installed. For further information the reader is referred to the section on "Faults in Dynamos, Motors and Rotary Converters," which begins on page 766.

REVERSING THE MOTORS.

We have now carried out all the installation and the only thing which remains is that the motor may be running in the wrong direction. This can easily be corrected by altering the connections as shown on the diagrams.

The procedure may be summarised as follows :—

Three-phase Induction Motors of Any Kind.

Reverse any two of the three *supply* cables entering the starter or motor switch.

Two-phase Induction Motors of Any Kind.

(1) Three-wire supply : Change over the two *outer supply* cables entering the starter or motor switch. The neutral wire should remain undisturbed.

(2) Four-wire supply : Reverse one phase by changing over its two *supply* cables at the starter or motor switch terminals.

Single-phase Motors.

Consult the manufacturer's instructions, because these vary for nearly every make of motor.

D.C. Motors.

Shunt and shunt interpole types.—Reverse the shunt field connections in the motor terminal box.

Compound and compound interpole types.—Reverse the armature and interpoles in the motor terminal box. *Care should be taken not to reverse the compound winding,* otherwise damage to motor and driven machine may result.

Series and series interpole types.—Reverse the series field in the motor terminal box.

On all D.C. motors it may be necessary to adjust the position of the brushes on the commutator when the motor is reversed, since otherwise they may spark. All reputable manufacturers mark the brush positions for both directions of rotation and the rocker should be moved, if necessary, to the correct marking.

INSTALLATION OF GENERATORS.

Although this article deals primarily with motors, it can be applied also to generators or dynamos, since these are in reality only motors which are supplied with mechanical power, so generating electrical energy, instead of consuming energy and giving out mechanical power.

ELECTRIC AND MAGNETIC CIRCUITS

By PROFESSOR MILES WALKER, M.A., D.Sc., F.R.S.

In this article will be found some simple definitions of the quantities involved in the electric and magnetic circuits and a simple statement of the relations which exist between them. This is intended to help readers to visualise the beautifully symmetrical relations between them. A later article deals with the applications of these quantities in the development of electrical machinery.

ELECTRICITY occurs in positive and negative grains—protons and electrons. The whole of matter, solid, liquid and gaseous, is built up of complicated arrangements of these protons and electrons. The properties of matter are due to the ways that they move as they whirl about one another like suns and planets in a myriad of solar systems.

In a conducting solid such as copper (especially when very cold) the protons, the positive grains, are pretty well fixed but some of the electrons are free to wander. Electrons can flow through solid copper more easily than water can flow through a sponge. It is mainly because electricity flows through copper and aluminium more easily than water through a pipe and because great pressure can be exerted on it without "bursting" the insulation that we use it for transmission of power in preference to hydraulic transmission.

Similarity Between Electric and Water Systems.

The analogy of electricity in a conductor to water in a pipe filled with some very porous substance is very remarkable. No wonder that the early philosophers talked about the "electric fluid." To make the analogy more complete we should consider

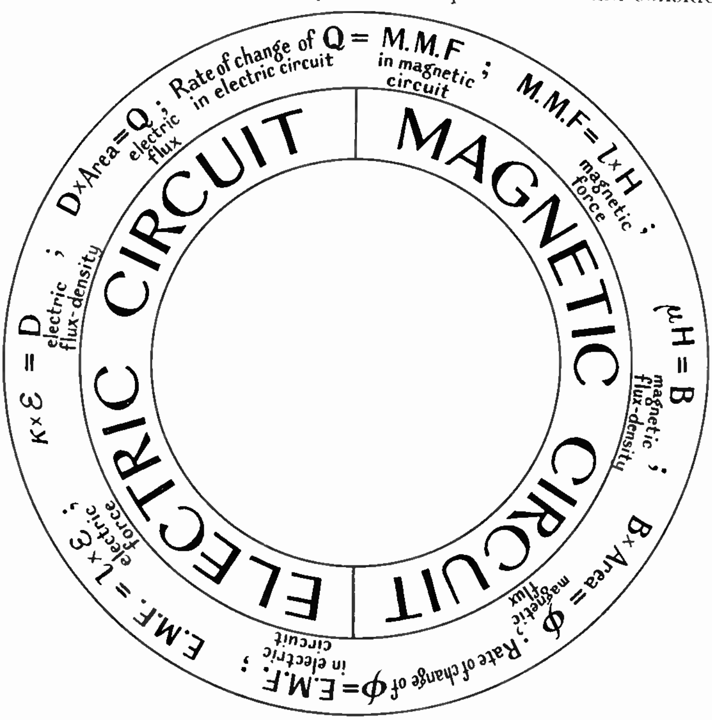

Fig. 1.—SHOWING THE ACTIONS AND INTERACTIONS IN THE INTERLINKED ELECTRIC AND MAGNETIC CIRCUITS.

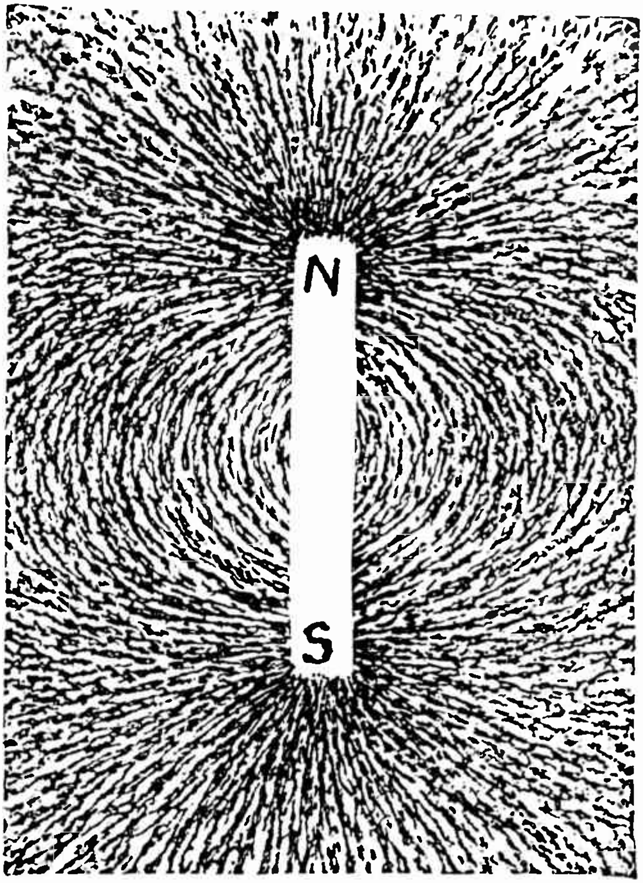

Fig. 2.—THE APPEARANCE OF A MAGNETIC FIELD.
Take a straight permanent magnet, cover it with a piece of white cardboard and sprinkle iron filings over it. The filings arrange themselves in a pattern as shown.

a closed-circulation system such as we have for heating a greenhouse. Reduced to its simplest elements, it may be represented as in Fig. 3. Water rises in a heater on the left, passes along the top pipe and returns by the bottom pipe. The cause of the circulation is the difference of head in the cold and hot vertical columns. If we had pure streamline motion, the three streamlines shown would represent the course of certain particles of water. Where the pipe is wide the streamlines are far apart. Where the pipe is narrow the lines are nearer together. The velocity of the water in the pipe is indicated by the closeness of the lines. If we agreed upon some convention, say that 10 lines drawn shall represent a flux of 10 gallons per minute; then if the pipe were reduced to 1 square inch cross section so that we draw 10 lines per square inch of area, this density would represent a flux density of 10 gallons per minute per square inch.

The drawing of streamlines to represent some physical state of matter is very convenient because it gives us a picture of the state in question. The closeness of the lines represents the intensity of the state and the direction of the lines represents the direction of flow.

Magnetic Fields.

A good instance is the case of a magnetic field. Take a straight permanent magnet, cover it with a piece of white cardboard and sprinkle iron filings over it. The filings arrange themselves in a pattern like that shown in Fig. 2. This pattern tells us that we can map out a magnetic field by drawing lines (or imagining lines drawn) throughout the space occupied by the field. Where the field is strong the lines will be close together and where it is weak they will be farther apart. It is a fortunate circumstance that the laws of variation of a magnetic field exactly correspond to the geometrical arrangement of continuous lines drawn through space. The density of the lines, that is the number per square centimetres, corresponds to the strength of the magnetic field. The strength of the magnetic field is defined as the force in dynes on a unit magnetic pole and a unit pole is defined as a pole of such strength that when it is placed one cm. away from a pole of equal strength repels it with a force of one dyne. The field strength is unity at a distance of one cm. from a unit pole.

The Heaviside Units.

Imagine a sphere of one cm. radius, see Fig. 4, described around a unit magnetic pole ; it will have an area of 4π (about 12.57) sq. cms. Call it about 12 sq. cms. for short, then as we draw one line for each sq. cm. in a unit field, there will be about 12 lines (actually 4π lines) radiating from a unit pole. It is this circumstance that introduces the irritating constant, 4π, into all our calculations. Oliver Heaviside proposed new electric and magnetic units that would do away with the 4π but electrical engineers of the day were not sufficiently far-seeing to take his advice. However, in this article I shall adopt the Heaviside units because I must not spoil the beautiful symmetry of the relations between the electric and magnetic circuits. Nature has given us a most beautiful symmetry. Only man is vile with his 4π.

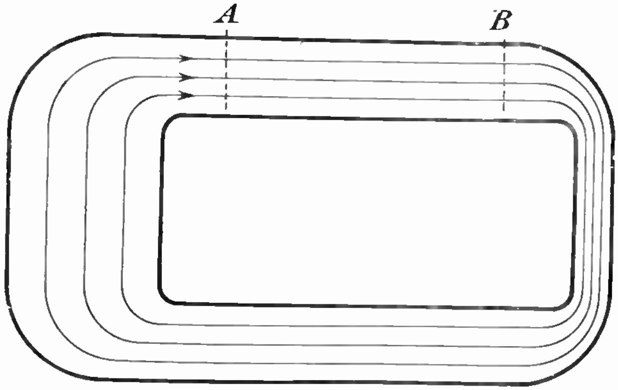

Fig. 3.—THE LINES IN A MAGNETIC FIELD.
This illustration is a good example of the similarity between electric and water systems. Without any alteration it may represent either the flow of water in a pipe, the flow of electricity in a conductor, or the magnetic flux in a closed magnetic circuit.

If we imagine a sphere of two cms. radius described about the unit pole, it would have an area four times as great as that in Fig. 4, and as the number of lines is the same as before the density of the lines will be one quarter as great. This corresponds to the field strength, which is one quarter as great when the distance from the pole is increased to double. Thus the "law of inverse squares" gives a result which corresponds with the density of lines radiating from a point. In considering an isolated magnetic pole as in Fig. 4, we are assuming that the pole of opposite polarity is at such a great distance that the curvature of the lines can be neglected but in practice the lines always curve round and return to the pole of opposite polarity as in Fig. 2.

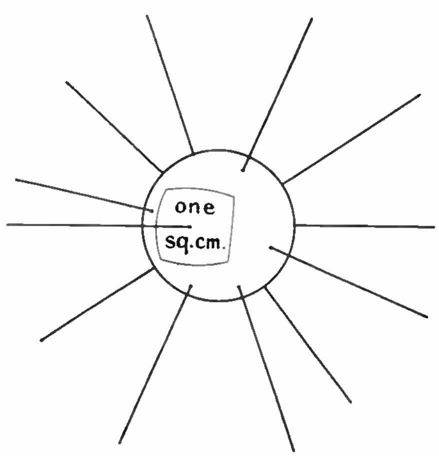

Fig. 4.—SHOWING AN IMAGINARY SPHERE OF 1 CM. RADIUS DESCRIBED ROUND A UNIT MAGNETIC POLE

Lines in a Magnetic Field.

In every magnetic field the lines curve round and form a circuit such as that illustrated diagrammatically in Fig. 3, which without any alteration may represent either the flow of water in a pipe, the flow of electricity in a conductor, or the magnetic flux in a closed magnetic circuit. In each case the closeness of the lines together (e.g., at the right-hand side of the diagram) indicates the intensity of the physical state illustrated.

The Total Flux.

One obvious feature that is common to all these cases is that the total number of lines crossing any total section of the path is a constant. The total number is called the total flux or simply "the flux." We will take the water case as the prototype and see how closely analogous all the other cases are. It is best to consider the pipe

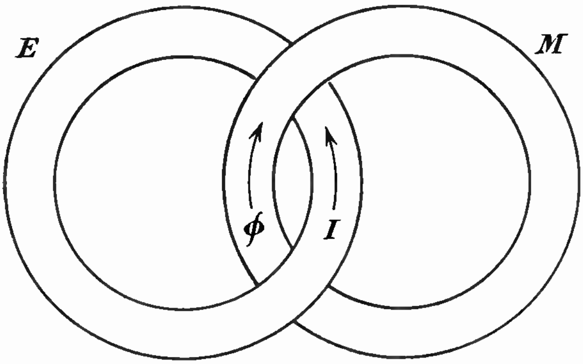

Fig. 5.—A Simple Case of the Interlinking of Electric and Magnetic Circuits.

filled with some very porous substance that causes a slight resistance to flow throughout the whole thickness of the pipe otherwise the water will flow more rapidly in the centre and spoil our analogy.

How the Motive Force is Calculated.

Note that in all cases we cannot get any flux unless we have a motive force that is a tendency to move the flux in question. We have the water motive force in the one case, the electromotive force and the magnetomotive force in the other cases respectively. We have the resistance of the pipe to the flow of water, the resistance to flow of electricity in the electric circuit and the reluctance of the magnetic circuit. In each case we have a law analogous to Ohm's Law, namely :—

The motive force is equal to the resistance multiplied by the flux. The motive force might be measured by grams per square centimetre in the water case, by " volts " in electric case and by " gilberts " in the magnetic case. In each of these cases we can distinguish between the total motive force or pressure required to make the flux go round the whole circuit and the pressure required for a *portion only* of the circuit. We may confine our attention to a portion of the circuit, say between the point A and B one metre apart in Fig. 3. We may then speak of the drop of pressure between A and B and this will be measured by the same units as stated above, appropriate for each case.

Finding Flux Density at any Point.

Now if we take the drop in pressure per unit length we arrive at a quantity of great importance because if we know it and also the nature of the medium, we can arrive at the flux density at any point. This drop in pressure per centimetre length of path is often spoken of as the force at a point. The electromotive force per centimetre gives us the electric force at a point and tells us the stress on the material. The magnetomotive force in gilberts per centimetre gives us the magnetic force at a point and is usually denoted by the letter H. The magnetic force at a point is the force in dynes in a unit pole.

Electric Force.

The electric force at a point denoted by $\mathcal{E}$ multiplied by the distance l over which it is exerted (say distance from A to B in Fig. 3) gives us the voltage E applied to that distance so that $\mathcal{E} \times l = E$. The magnetic force at a point H multiplied by the distance l over which it is applied gives us the magnetomotive force applied to that distance so that $H \times l =$ M.M.F.

Displacement of Electrons.

When an electric force is applied to an insulating material such as air, ebonite or mica it causes a displacement of electrons within the molecules of the material.

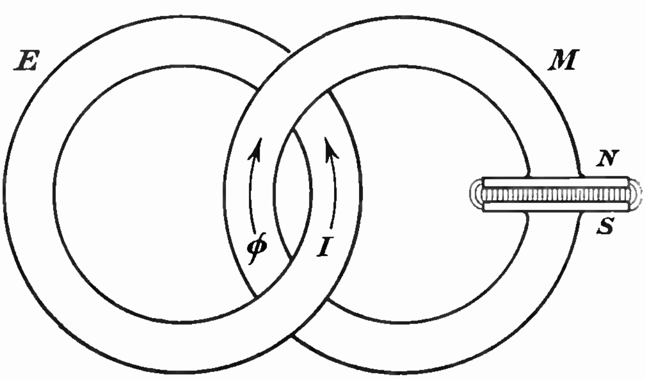

Fig. 6.—Showing Effect of Inserting an Air Gap (Marked N and S) in a Magnetic Circuit.

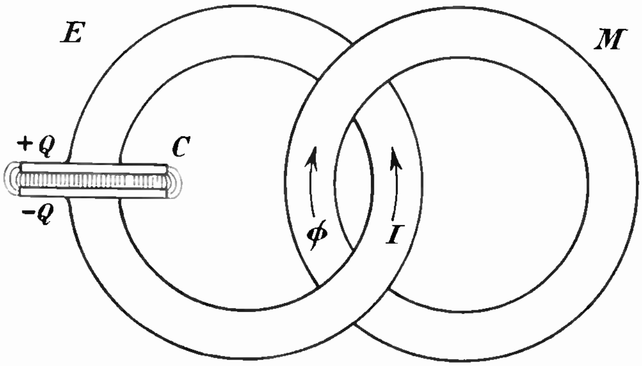

Fig. 7.—EFFECT WHEN A CONDENSER (C) IS INTRODUCED INTO THE ELECTRICAL CIRCUIT.

The electrons behave as if they were tethered with an elastic tether to the protons of the molecule. They can only move so far under the electric force and they spring back again when the force is removed. An insulator will not allow a continuous flow of electrons, as occurs in a conductor, but only a displacement.

The amount of this displacement, denoted by D, for a given electric force depends upon the dielectric constant denoted by κ. For air this is taken as 1, for ebonite it is 2.5, for mica about 7. We multiply the electric force by the dielectric constant to obtain the displacement so that $\kappa \times \mathcal{E} = D$. It is the displacement which allows current to flow into a condenser. While the displacement is occurring we have an electric current for the time being. After the displacement has occurred in the insulation of a condenser we say that we have put in a certain quantity of electricity, denoted by Q. Thus current multiplied by the time it flows gives us the quantity. An electric current through a dielectric is the rate at which the quantity is changing.

We see that Fig. 3 might represent a structure of homogeneous insulating material subjected to an electromotive force which has brought about a displacement of electricity around the whole circuit. The intensity of the displacement is everywhere indicated by the closeness of the streamlines. To achieve the actual result shown, the material would have to be surrounded by another material whose $\kappa = 0$; no such material exists.

What Happens when a Magnetic Force is Applied to a Material.

Similarly when a magnetic force H is applied to a material it brings about a certain magnetic displacement or magnetic flux-density denoted by B. The amount of this depends on the permeability of the material denoted by μ. So that $B = \mu H$. This corresponds to the electric case where $D = \kappa \mathcal{E}$. Assuming that B is constant over some complete cross-section of the magnetic circuit; then B multiplied by the area gives us the total magnetic flux, φ. Assuming that D is constant over some complete cross section of the electric circuit in a dielectric; then D multiplied by the area gives us the total quantity of electricity, Q.

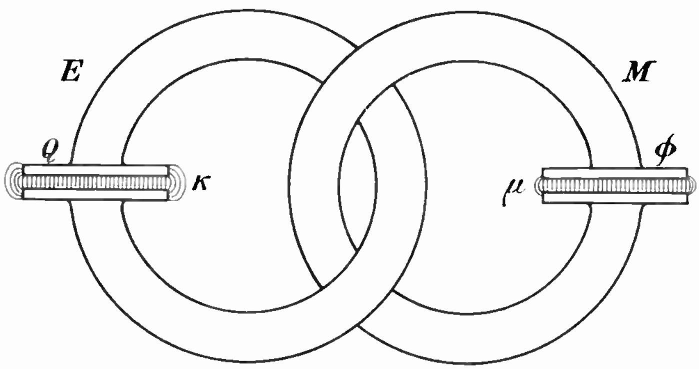

Fig. 8.—SHOWING A CONDENSER IN THE ELECTRIC CIRCUIT AND AN AIR GAP IN THE MAGNETIC CIRCUIT.

Interlinking of Electric and Magnetic Circuits.

Having now defined the various electric and magnetic quantities and the symbols by which they are denoted we can discuss the relations which exist when an electric circuit is interlinked with a magnetic circuit. Every electrical apparatus from the electric bell to the turbo generator consists of a more or less complicated interlinking of electric and magnetic circuits.

A simple case is illustrated in Fig. 5. The copper ring on the left marked E is the electric circuit and the iron one on the right marked M is the magnetic circuit. A current flowing in E in the direction shown by the arrow creates a magnetomotive force (M.M.F.) in the iron ring. Assuming that the ring is uniform and of length the M.M.F. divided by l gives us H; and $H \times \mu = B$ the flux-density. B multiplied by the area gives us the total flux ϕ.

Effect of Changing Magnetic Flux.

So long as ϕ remains constant it has no effect upon the electric circuit; but when it sinks in value it creates an E.M.F. in the direction of the arrow tending to maintain the current. When it rises in value it generates an E.M.F. which opposes the flow of the current. An interesting case to consider is where the temperature of the copper is so low as to make the resistance of E nearly zero. A current once started will go on flowing until it is killed by the resistance. At a temperature of liquid hydrogen it will go on for hours without showing appreciable diminution. In this case it is maintained by the minute E.M.F. supplied by the very small change in ϕ.

How a Permanent Magnet is Magnetised.

If the resistance were zero the current would flow for ever and ϕ would remain constant. This would be a case of permanent magnetism. A permanent magnet is magnetised by moving electrons whose orbits have no resistance and go on rotating for ever. In the hypothetical case illustrated in Fig. 5, the iron ring is supposed to constitute the whole of the magnetic circuit and the magnetic lines are supposed to lie wholly within it. In practice there would also be some lines in the air space all around and even within the copper conductor. The electric and magnetic circuits are never quite distinct from one another but occupy some of the same space; but for the sake of simplicity we will neglect the parts of the circuits where they overlap.

The Air-Gap.

Now make an air-gap like that marked N and S in Fig. 6. The magnetic lines must now cross this air-gap and the magnetomotive force required to drive the flux round the circuit would be greater than for a closed iron circuit. The pieces N and S become magnetic poles. If we were to straighten the ring out into a bar the magnetic field would stretch out on all sides and resemble somewhat the field illustrated in Fig. 2. Every line would still form a complete circuit. Now assume that the iron part of the circuit becomes smaller and smaller, until it finally disappears. We will have left a magnetic field something like that illustrated in Fig. 2, but maintained entirely by the current in the circuit E without the help of the iron core. For a given current in the copper ring the total flux in this case would be very much less than for a complete iron circuit, but if the current were big enough it could make ϕ the same as before.

When a Condenser is Introduced into the Electrical Circuit.

Now consider the case illustrated in Fig. 7 where a condenser C is introduced into the electric circuit. This consists of a slab of insulating material introduced between the plates shown at C. The electric current cannot now flow on indefinitely. The current I will charge the condenser, the quantity Q being equal to I multiplied by the time it is flowing. The current will not flow at all unless it is urged by some E.M.F. We may for the purpose of our argument say the E.M.F. at the moment shown is supplied by the rate of change of ϕ which is sinking so rapidly as to enable I to charge the condenser. But ϕ cannot go on changing continually.

When the Condenser Begins to Discharge.

There will come a time when it sinks to zero and the current also sinks to zero.

The charged condenser will then begin to discharge. The current will be reversed. It will be driven by the spring action of the electrons in the dielectric which

B

are always trying to discharge the condenser. As the reversed current rises the reversed ϕ must also rise. But an increasing ϕ means that there is a back E.M.F. generated in E. This balances the E.M.F. supplied by the charged condenser. The condenser goes on discharging until it is empty, but the current does not stop then.

Charging the Condenser in the Opposite Direction.

Both ϕ and I have been increasing all the time that the condenser was discharging because it was the increase of ϕ that balanced the E.M.F. of the charged condenser. The current must, therefore, go on and charge the condenser in the opposite direction. The E.M.F. which maintains it during this operation is generated by the sinking of ϕ. Both ϕ and I sink in value until the condenser is charged in the opposite direction and as soon as ϕ is zero the condenser again discharges. Thus we get an oscillatory discharge such as occurs in the condenser circuits of our radio apparatus.

Now refer to the symmetrical arrangement shown in Fig. 8. Here we have a condenser in the electric circuit and an air-gap in the magnetic circuit. Fill the space of the condenser with a slab of material having a dielectric constant κ. Assume for simplicity that the resistance of the rest of the circuit is zero. Fill the air-gap with a slab of material having a permeability μ and assume that the reluctance of the rest of the circuit is zero. The whole of the E.M.F. in the electric current is thrown on the condenser and the whole of the M.M.F. of the magnetic circuit is thrown on the slab of material of permeability μ. Let us denote by l the effective length of the electric circuit through the thickness of the dielectric and the effective length of the magnetic circuit through the thickness of the slab of material. The effective areas are the area of the condenser plate in one case and the area of the pole pieces in the other.

Actions and Interactions in the Interlinked Electric and Magnetic Circuits.

All the actions and interactions in the interlinked electric and magnetic circuits are then given in Fig. 1. It is necessary to write these in the form of a circle, because they are mutually related and one cannot say where to take the beginning. In describing the diagram one may arbitrarily start at the top with Faraday's discovery that the E.M.F. in a circuit is equal to the rate of change of flux through it. If the whole of the E.M.F. is exerted on a dielectric as in this case, we get the electric force $\mathcal{E}$ by dividing the E.M.F. by l. We then get the electric displacement by multiplying by κ and so on, from one quantity to another, round the whole circle. The right half of the circle relates to the electric circuit; the left hand is the magnetic. What is so beautiful and symmetrical about Nature's invention of this interlinking is that if we draw a diameter to the circle at any point we will find exactly analogous equations opposite to one another. Man did not make this symmetry, he only discovered it. Every electrical engineer ought to understand and appreciate it.

Importance to the Wireless Engineer.

In separating the two circuits for the sake of simplicity we necessarily fail to tell the whole story. But in most apparatus used for the generation and transmission of power the two circuits can be separately considered. We have neglected to take account of the time taken for the effect in one circuit to reach the other. This is negligible in most apparatus not concerned with electric waves. A correct understanding of Fig. 1 is also important to the wireless engineer. If he opens out the condenser and straightens out the electric circuit into a straight bar, he gets his aerial. All the relations given still hold except that the time taken for an effect to travel outward gives rise to electric waves and the loss of energy by radiation. These features lie outside the province of this article.

THE PLANNING OF AN INSTALLATION

By H. W. Johnson.

THE subject of illumination is a most important one for the practical electrical engineer. Readers who desire to study the important question of illumination at greater length will find the subject dealt with fully in the articles on the illumination of houses, factories, churches, shops, etc. For the present purpose the following brief notes on domestic illumination will suffice to show the general principles.

Before the work of fixing electric wires in a building is commenced, careful attention must be given to the following points :—

(1) The requirements of the installation.
(2) The type of building, and the system of wiring which will be most suited to it.
(3) The illumination which will be adequate at the various lighting points.
(4) The convenience and safety of control.
(5) The arrangements of the various circuits.
(6) The economical operation and maintenance of the installation.
(7) The initial cost of the installation.

Requirements of an Installation.

After consideration of the work an installation has to do, it is usual to state the requirements of the installation in the form of a schedule. This schedule will give the exact position of all the lighting and power points to be fitted and the controls of these points, the particular type of lighting fittings and power apparatus, and the wattage of each point.

The Type of Building and Method of Installing the Wires.

The type of building often determines the system of wiring which is installed. The steel conduit system is to be recommended for private houses and public buildings which are in the course of erection. This system is mechanically strong, fireproof, and safe. Steel conduit may be run between floors and concealed in the plaster of the walls, and therefore is entirely hidden from view.

There are many excellent soft-metal and non-metal sheathed wiring systems which may be used. They are employed to great advantage when the building in which the installation is to be fitted is complete, as most of the work would be on the surface, and the decorations are not interfered with, or damaged in any way. A lead-covered or Macanite wiring system would be less unsightly than a conduit system under these circumstances.

In workshops and mills a cleat system may be used, provided the cables are erected in such positions that they are safe from mechanical injury. The initial cost is very low, and the system lends itself readily to extensions and alterations. Armoured cable should be installed on those sections of the circuit which are liable to rough treatment.

If acid or other corrosive fumes are likely to be present in the atmosphere of the building, cab tyre or Macanite wire should be used.

Lounge.

A lounge requires a good general illumination free from sharp shadows. This effect may be obtained by using a translucent bowl fitting fixed close to the ceiling. In order to obtain the best effects the ceiling should be of a white glossy nature. The bowl throws most of the light on to the ceiling, where it is reflected downwards into the room. This light and the light

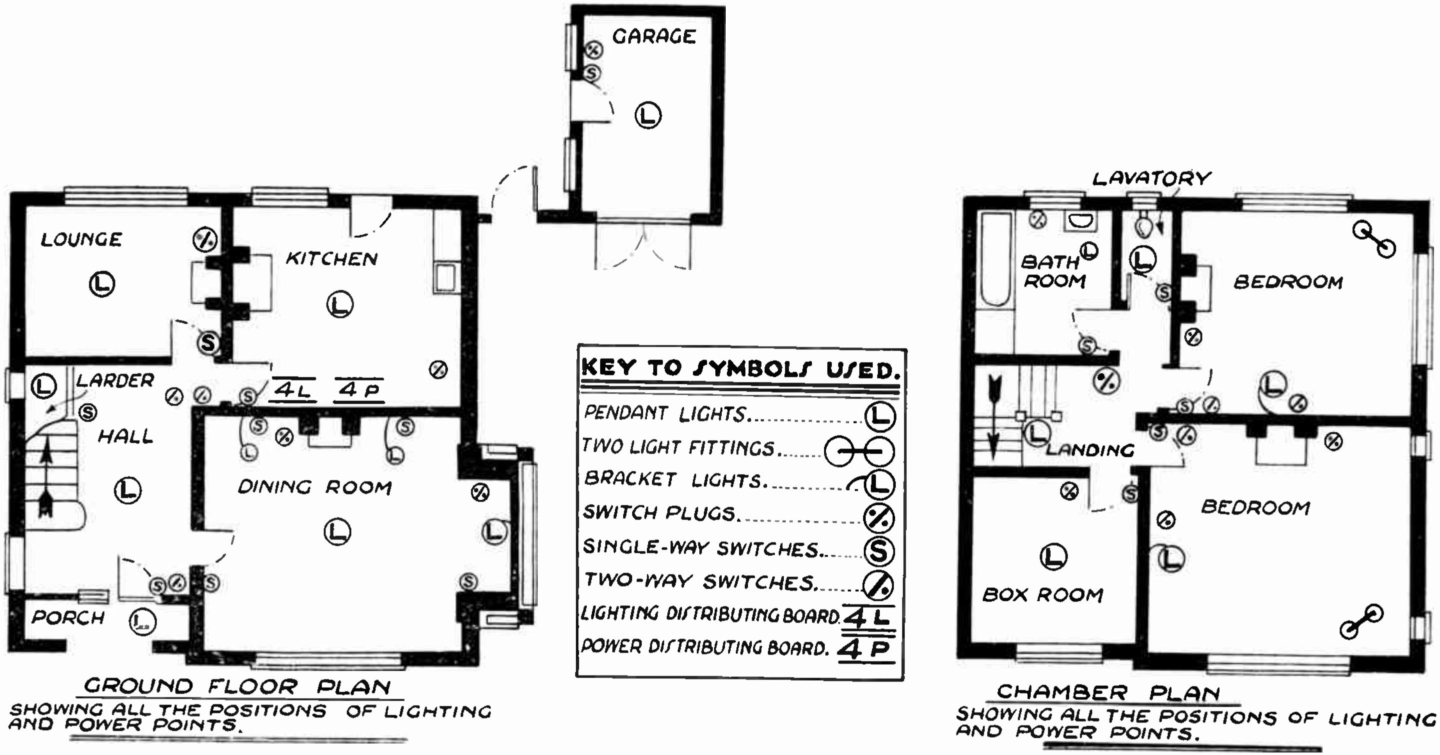

Fig. 1.—Arrangement of Lighting and Power Points in a Small House.

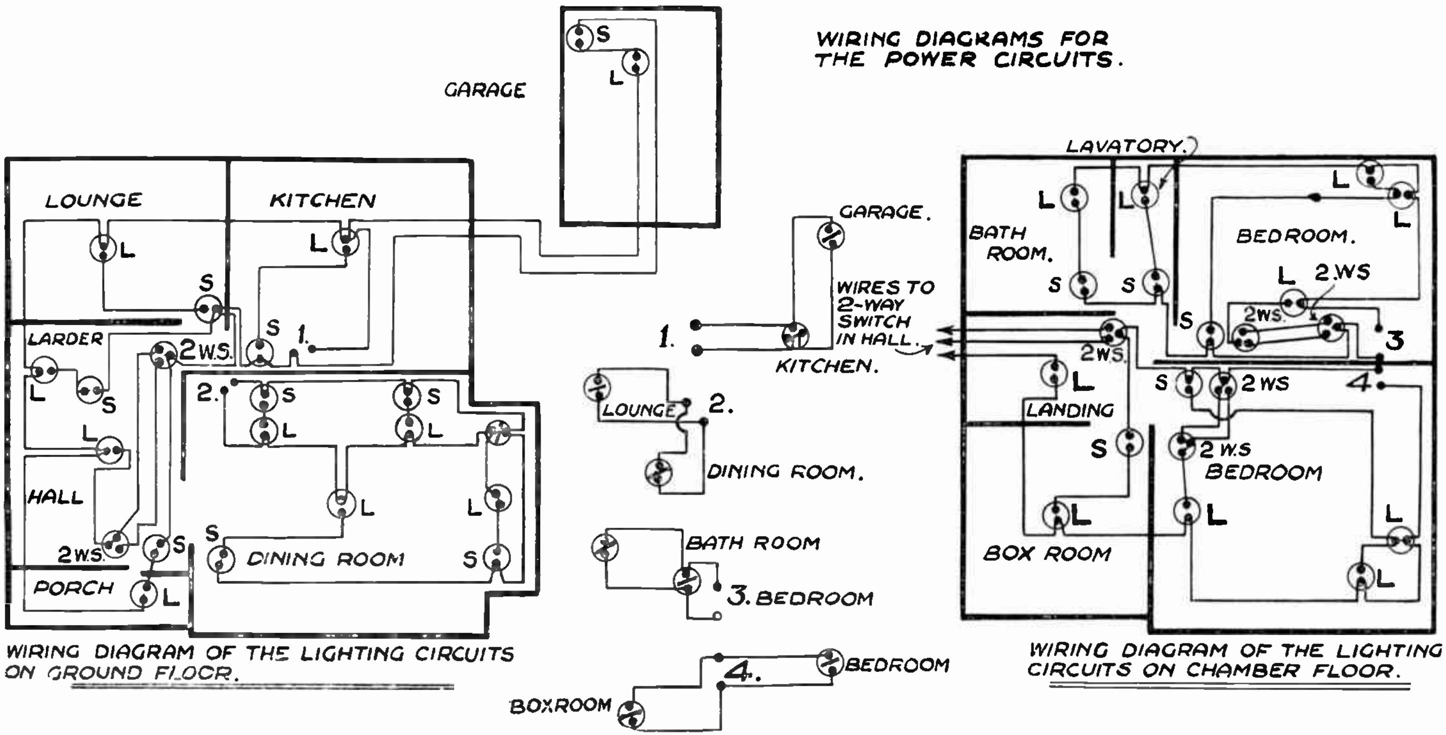

Fig. 2.—Wiring of Lighting and Power Points of House Shown in Fig. 1.

diffused through the bowl combine to give a very pleasing illumination free from sharp or deep shadows.

Dining Room.

A dining room requires a good warm light over the table, and in addition a fair general illumination over the room to prevent too great a contrast between the brightly lighted table and the rest of the furniture.

The table is best lit with a fitting of the counter-weight type, with a silk or parchment shade to harmonise with the decorations of the room. One or two bracket lamps or a tall standard lamp served from a lighting switch plug will supply all the general illumination required. Amber-tinted lamps are sometimes used in these positions to give a more cheery effect.

Bedrooms.

Bedrooms are too often supplied with a single lamp suspended in the centre of the room. This supplies general illumination, but is very inconvenient for lighting the dressing table. Except in small rooms two lighting points should be used, one over the dressing table, and the other a bracket or pendant light over the bed. A method which is gaining in popularity is the use of wired furniture, connected to switch plugs by lengths of flexible cable. The furniture can then be arranged without regard to the position of lighting points.

Kitchen.

A central fitting is invariably installed in a kitchen. This may be a simple pendant with a diffusing reflector, or a totally enclosed opal glass fitting. As most of the work in a kitchen is done facing the wall, at the fireplace, stove, cupboards, sink, etc., a diffusion fitting is most essential to prevent one having to work in one's own shadow.

Small lamps in pantries and large cupboards are very convenient. If desired, these can be fitted with special switches which will only allow the lamp to light when the door is open, thus preventing accidental wastage of current.

In deciding the illumination required for any particular room or purpose, and the type of fitting to produce the illumination, always have in mind the use to which the room will be put, the style of decorations, and the general positions of the furniture and fitments of the room.

Arrangement of the Circuits.

A careful study of the construction of the building must be given in order to obtain the best arrangements of the various lighting and power circuits. The architects' plans will give the information required to get the most economical arrangement and to reduce the amount of fabric cut away to a minimum. It is advisable to feed the lighting and power circuits from separate distribution boards, owing to the difference in size of the lighting and power cables. The mains from the lighting and power distribution boards may be looped together at the main switch where an "all in" tariff for the cost of the electrical energy is adopted.

The loading of the circuits should not be heavier than that specified in the rules of the Institution of Electrical Engineers.

If the conduit system is employed, arrange that each of the conduit runs are uniformly filled with wires. Do not overcrowd the wires in any conduit, so that if a faulty wire has been included, it can easily be withdrawn, and a new wire drawn in to replace it without disturbing the rest of the wires. A wiring diagram should be prepared, which gives the actual connections of the circuits. This will greatly assist the correct wiring of the installation. It should be noted that a wiring diagram is not intended to give the actual fixed positions of the conduit runs to the various circuits.

Convenience and Safety of Control.

The controls of the lighting and power points should be chosen so as to give the maximum convenience and safety. To this end the position of each switch must be carefully considered so that a person operating the switch should not have to walk any distance in the dark, or go out of his way to reach the switch point.

Full advantage should always be taken of two-way controls, especially for corridor and staircase lighting. For bedroom light-

SPECIMEN SCHEDULE
OF REQUIREMENTS OF AN INSTALLATION

Position of Lighting Point.	No. of Points.	No. and Wattage of Lamps.	Type of Fitting.	Type and Nature of Switch Control.
Hall	1	1 60-watt (clear)	Lantern with chain pendant	2 2-way tumblers.
Porch	1	1 40-watt (clear)	Watertight bracket	1 single-way tumbler.
Lounge	1	1 75-watt (clear)	Semi-indirect bowl	1 single-way tumbler.
Kitchen	1	1 60-watt (pearl)	Pendant with opal glass reflector	1 single-way tumbler.
Garage	1	1 60-watt (pearl)	Pendant with dispersive enamelled iron reflector ..	1 single-way tumbler (H.O. Pattern).
Larder	1	1 40-watt (pearl)	Ceiling with dispersive reflector	1 single-way tumbler.
Dining Room ..	5	1 100-watt (pearl)	Counterweight with silk flounce or parchment ornamental deep shade.	1 single-way tumbler.
		3 40-watt (pearl)	Ornamental wall bracket at each position	1 single-way tumbler at each position.
		1 3-ampere	Switch plug to supply wireless set	———
Back Bedroom ..	3	2 40-watt (pearl)	Counterweight 2-light with ornamental shades ..	1 single-way tumbler.
		1 40-watt (pearl)	Bed bracket	2 2-way tumblers.
Bathroom ..	1	1 60-watt (clear)	Bracket with lamp in enclosed opal glass globe ..	1 single-way tumbler (H.O. Pattern).
Lavatory ..	1	1 40-watt (pearl)	Pendant with opal glass reflector	1 single-way tumbler (H.O. Pattern)
Front Bedroom ..	3	2 40-watt (pearl)	Counterweight 2-light with ornamental shades ..	1 single-way tumbler.
		1 40-watt (pearl)	Bed bracket	2 2-way tumblers.
Box Room ..	1	1 60-watt (pearl)	Pendant with opal glass reflector	1 single-way tumbler.
Landing	1	1 60-watt (clear)	Opal glass enclosed bowl	2 2-way tumblers.

Lighting circuits are fed from a 4 circuit, 5 amperes per way distributing board, which is fixed in the kitchen.

No. 1 circuit supplies hall, porch, lounge, kitchen, garage and larder.

No. 2 circuit supplies dining room.

No. 3 circuit supplies back bedroom, bathroom and lavatory.

No. 4 circuit supplies front bedroom, box room and landing.

Power circuits are fed from a 4 circuit, 20 ampere per way, distributing board which is fixed in the kitchen.

No. 1 circuit supplies kitchen and garage.

No. 2 circuit supplies dining room and lounge.

No. 3 circuit supplies back bedroom and bathroom

No. 4 circuit supplies front bedroom and box room.

A 10-ampere 3-pin switch plug is fixed at each power plug position.

ing a two-way control is indispensable.

Home Office type switches should be used in bathrooms, basements, cellars, and outbuildings, where the floors and walls are likely to be damp or semi-conducting, and where there is any earthed metal work, such as gas stoves, steel girders, etc., in the vicinity of switch positions. Three-pin plugs should be installed for supplying current to portable apparatus with a metal framing, so that this metal work can be connected to earth through the third pin. When the plug is not in use, the supply sockets should be "dead."

Initial Cost.

The cost of an installation varies over a large range with the system of wiring adopted, the type and quality of accessories and fittings, and the labour involved. The approximate life of an installation which is operated under normal conditions of working is about twenty years. This life is only obtainable by using the most suitable wiring system, good quality materials and reliable labour. The switches play an important part in maintenance costs. A switch with a good mechanical contact, and a quick make and break, will last much longer than an inferior switch costing 20 per cent. less. The saving in renewals and labour will more than compensate the additional first cost.

The convenience of one or two spare points on the lighting or power board should not be overlooked, as the cost of these at the time of installation works out much less than that of fixing them individually whenever an extension of the system is undertaken.

Prepare Specification and Schedule.

A complete specification and schedule of the installation should be prepared according to the following plan, and competent supervision of the work when in progress should be undertaken. This will considerably assist in the reliable erection and fitting of the installation.

SPECIFICATION.

System.

The whole of the installation is to be wired on the multiple circuit distributing board system. A list of points on each circuit to be fixed near each distributing board.

Cables.

All the cables to be of the 2,500 megohm grade Cable Makers' Association cable. No cable is to be single stranded and of less sectional area than that of a 3/.029-in. cable.

No cable must carry more current than that permitted by the regulations of the Institution of Electrical Engineers.

Protection.

The cables are to be drawn into welded steel conduit with screwed junctions. The whole of the conduit must form an electrically continuous and watertight system, and be efficiently earthed. The conduit must be of the standard required by the British Engineering Standards Association.

Accessories and Switchgear.

All accessories and switchgear must conform to the requirements of the British Engineering Standards Association. Main switchgear must be ironclad. Lighting switches must be of the Crabtree sunk type, with quick "make" and "break" action.

Flexible Wires for Pendants.

High insulation pure rubber flexible wires must be used for all pendant lights.

Standard of Work.

All work done must conform to the Institution of Electrical Engineers' regulations for the electrical equipment of buildings, and to the requirements of the electrical supply authority.

Guarantee.

The installation shall be guaranteed for a period of 12 months.

Testing.

The whole of the wiring shall conform to the standard of the tests required by the regulations of the Institution of Electrical Engineers, and the electrical supply authority.

AUTOMATIC RAILWAY SIGNALLING

By JOHN DUMMELOW, B.A. (Cantab.)

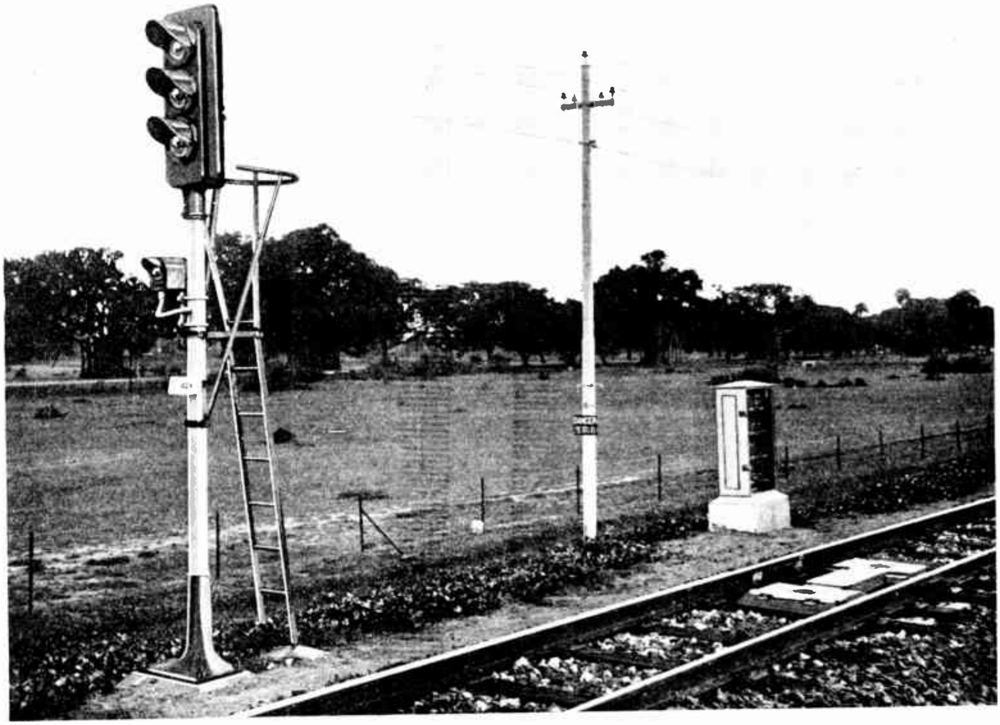

Fig. 1.—A MAIN LINE RAILWAY TRACK CIRCUIT.
Showing signals, apparatus case and auto-bonds in position.

THE main objects of railway signalling systems are to prevent two trains being on the same section of line at once; to prevent trains passing over points, crossings, etc., that are set against them, and to control the traffic generally. The signals, points, and other apparatus may be operated either manually or by power, e.g., electrically or pneumatically.

With power signalling the link between the trains and the signals is often provided automatically by electricity; each train on passing certain points opens or closes electrical circuits controlling the appropriate signal levers.

Advantages of Automatic Signalling.

Automatic signalling allows the track capacity to be increased and the upkeep of signalling apparatus to be reduced. It can be used on any railway, whatever the type of traffic, but it is most advantageous on surburban lines where the intensive service makes manual signalling very complicated and expensive to maintain.

An outstanding example is the London Underground Railways, where automatic signalling enables each track to accommodate over 40 trains per hour. The basis of modern automatic signalling systems is the track circuit.

TRACK CIRCUITS.

Track circuits depend on the conductivity of the rails and the wheels and axles of the train. The track is divided into sections of any length up to about 6,000 ft., according to the density of the traffic. One or both rails of each track-circuited section are electrically isolated from the adjoining rails by insulation at the end joints, the intermediate joints being bonded to give electrical continuity. If steel sleepers are used they must be insulated from the rails.

Fig. 2.—Colour Light Signal, Fog Repeater and Track Circuit Apparatus Case.

How the Rails are Connected.

The rails are connected at one end of the track circuit to a D.C. or single phase A.C. supply, and at the other end to a track relay the contacts of which make or break the control circuits of the signals, points, indicators, and so on. When a train enters the track circuit the wheels and axles provide a path of low resistance across the rails, short-circuiting the relay; this opens the signalling circuits, the signal indications showing that the track is occupied taking placing by gravity. When the train leaves the track circuit the relay is energised and a clear signal is given. The signal governing the track-circuited section cannot show clear unless the whole of the section is clear, and as long as any part of the section is occupied the signal is placed and kept at danger.

When the Track Circuit Supply Fails.

Failures in the track circuit supply, in the rails, or in the cables have the same effect as if the track were occupied, either locking the levers or setting the signals at danger. The human element as represented by the signalman is eliminated, and safety is ensured.

Choice of System.

Single-rail track circuits are the simplest to insulate at points and cross-overs, but breaks in the non-insulated rail may not be detected. In double-rail track circuits the apparatus is better protected from extraneous currents.

Alternating current is used on most large modern installations; it reduces the cost of wires and cables as distribution can be carried out at a relatively high voltage through transformers instead of by heavy voltage D.C. lines or a large number of small batteries.

Steam railways may be track-circuited on one or both rails with either A.C. or D.C. supply. On electric railways the track circuit must be protected from stray traction current (due to faulty insulation in train equipment, power cables, or conductor rails), which may produce a false indication.

Electric Railways.

Where an insulated conductor is used for the traction return, either single or double rail-track circuits are permissible. Railways electrified on the D.C. system may be equipped with A.C. track circuits, the relays being arranged not to operate on D.C. On railways using alternating current the traction supply is usually at a much lower frequency than the track circuit supply; either A.C. or D.C. track circuits can be used, the relays being arranged, if A.C., not to operate at other frequencies or, if D.C., not to operate on A.C.

Where the traction return is through the running rails, A.C. track circuits are necessary. Either one rail may be insulated, leaving the other free for the traction current, or both rails may be insulated and fitted with "impedance" bonds, which maintain the continuity of the traction return. For short lengths and near points or cross-overs where sufficient traction carrying capacity can be obtained by cross bonding non-insulated rails, the single rail method is satisfactory. It is, however, limited by the voltage drop in the traction rail, which may cause large currents to flow through the relay and the transformer secondary windings with the risk of burning out. With both rails available for traction current much longer track circuits can be used.

Design Considerations.

Track circuits are insulated by means of fibre between the ends of the rails, behind the fishplates and around the bolts; the point rodding and other metal fittings crossing the track must also be insulated.

Some energy is wasted by leakage between the rails through the ballast and over the surface of the sleepers, especially when wet. For economical operation the voltage between the rails is limited by the ballast resistance and may vary from .5 to 2 volts at the relay end of the track circuit; the relay must therefore require only a small amount of energy.

Opening of Relay.

The intermediate rail joints are connected by copper bonds; the impedance of the rails is increased by worn rails, bad bondings, or fractures. Sanded, dirty, or rusty rails may introduce a contact resistance which prevents the wheels and axles (the "train shunt") from making a complete short circuit. The relay must, therefore, be arranged to open with some current still in its coils. For maximum efficiency the opening current should be as near as possible to the closing current.

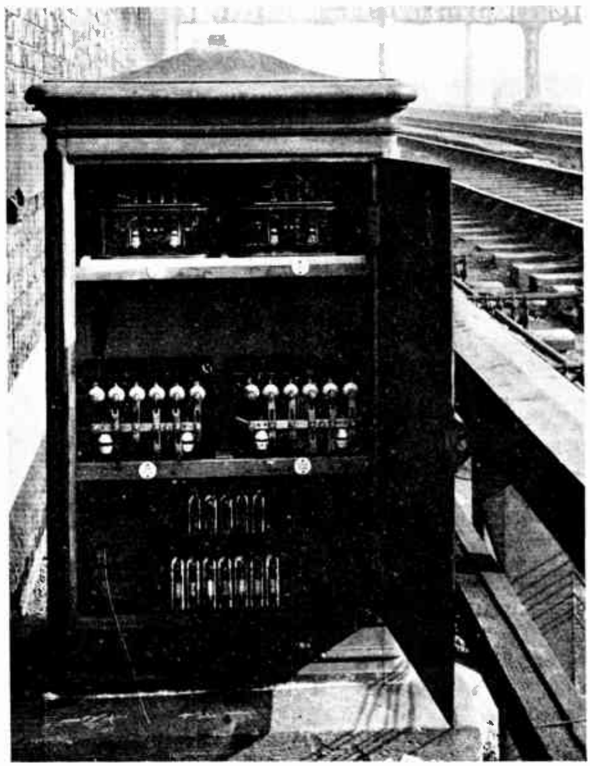

Fig. 3.—A.C. Track Relays, Condensers and Transformers in Cast Iron Cupboards.

The track relay has two sets of contacts, one set normally open and the other normally closed. The contact system

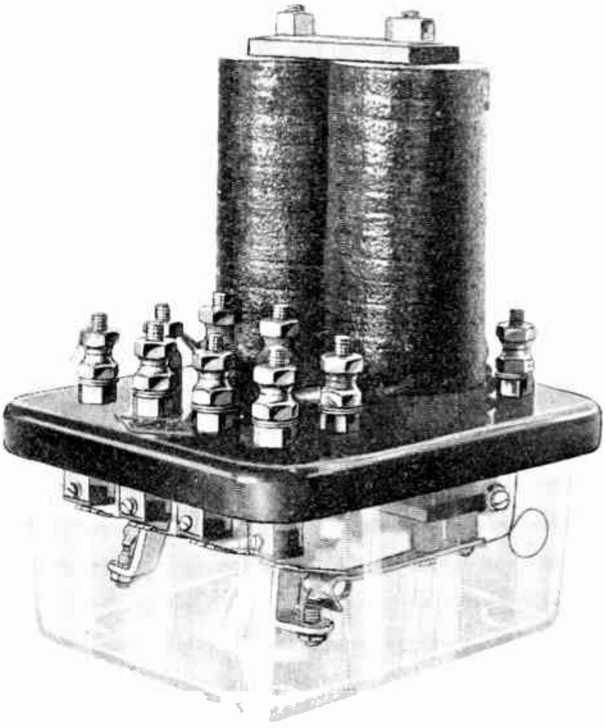

Fig. 4.—D.C. TRACK OR LINE RELAY.

high potential element, which is immersed in sal-ammoniac, is depolarised by contact with the air.

Accumulators may be maintained either by a trickle charge from a D.C. power supply or from a small rectifier supplied with A.C. through a transformer.

An adjustable resistance is inserted in the track feed and limits the current to a reasonable figure when the relay is short-circuited.

The D.C. track relay consists essentially of two large coils connected in the track circuit and an iron armature carrying the contacts. The resistance of the relay may vary from 2 to 10 ohms. The coils are normally energised, but when a train enters the track circuit they are short-circuited and the armature drops away, opening one set of contacts and closing the other.

is enclosed in a glass or glass-fronted case for protection.

Where more than four contact arms are required or where the track relay has to be placed some way away from the functions it controls, "line" or "repeater" relays are necessary. These considerably reduce the number of cable or line wires required and enable several controls to be grouped together.

D.C. Track Circuits.

D.C. track circuits may be fed from primary batteries, accumulators (where charging facilities are available), or rectified A.C. from a power supply.

Batteries usually have a caustic soda electrolyte with copper oxide and zinc elements. Alternatively, air depolariser cells may be used; in these the surface of the

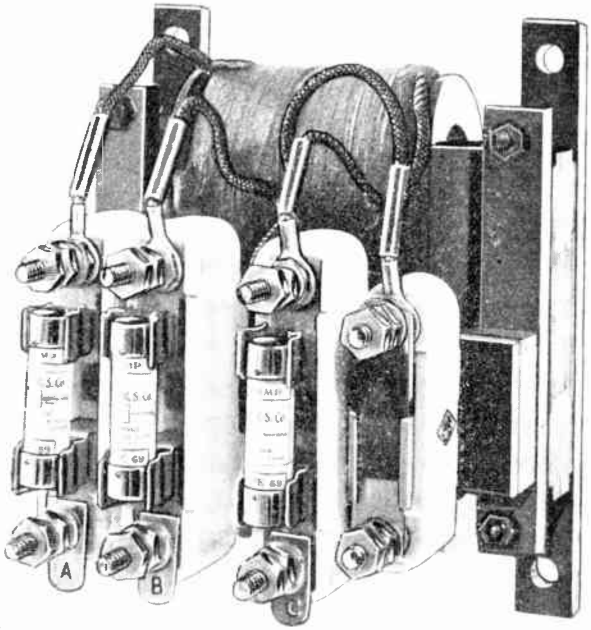

Fig. 5.—A TRACK TRANSFORMER FOR CONDENSER-FED A.C. TRACK CIRCUITS.

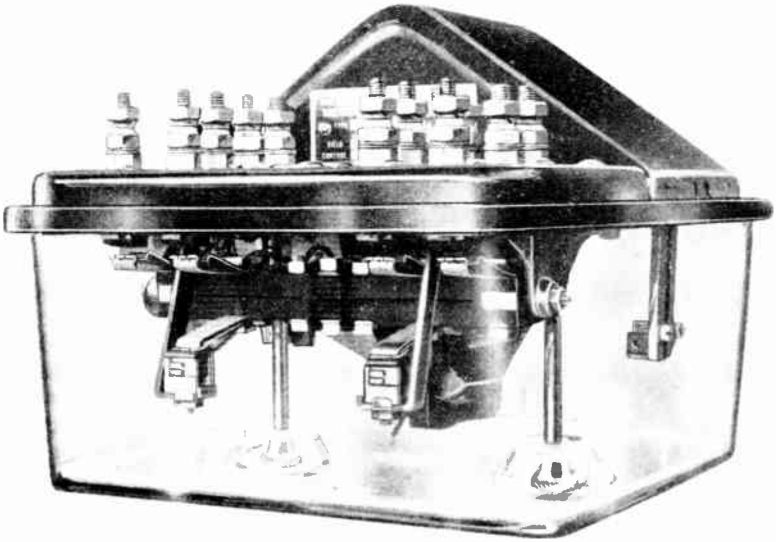

Fig. 6.—A.C. TRACK RELAY (TWO-ELEMENT TYPE).

D.C. line relays may be either of the multi-contact type or exactly similar to track relays; the coils are wound for considerably higher resistance.

A.C. Track Circuits.

A.C. track circuits are fed from transformers, the primary (signalling mains) voltage being usually 110 or 440 volts, 50 cycles; the secondary voltage depends on the method of feed. The voltage across the rails may be 2-5 volts at the transformer end and .75-2 volts at the relay end.

A.C. track relays being fundamentally less efficient than D.C. relays require more power for operation. They are made with either single or double elements.

In the single element relay the whole of the energy (say 8 watts) is supplied from the track circuit. This is only economical on very short sections with high ballast resistance, such as for track locking and fouling protection at junctions; elsewhere it is wasteful and the train shunt is unsatisfactory.

In the double element relay less than .5 per cent. of the total energy consumed

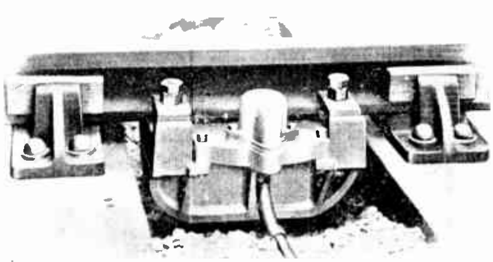

Fig. 7.—MERCURY TREADLE FIXED IN POSITION ON RAIL.
The construction of the treadle is shown in Fig. 13.

is used by the "track" winding, which is supplied from the track circuit at about 1 volt; the remainder (say 11 watts) is used in the "local" winding and is supplied at 110 volts from the signalling mains. Long and poorly drained sections can thus be track-circuited economically and satisfactorily.

For a double element relay to operate efficiently, the phase angle of the track winding current should be as nearly as possible at 90 degrees to that of the local current.

The correction of the phase angle of the feed current, the limitation of the current from the transformer when a train is on the section, and the adjustment of the track voltage necessitate feeding the track circuit by means of :—

(1) Through a resistance limiting the short circuit current, and a reactance adjusting the phase angle;

(2) Through a resistance adjusting the phase angle, the short circuit current being limited by the impedance of the transformer (and by the impedance bonds where these are used), or

(3) Through one or more condensers performing both functions.

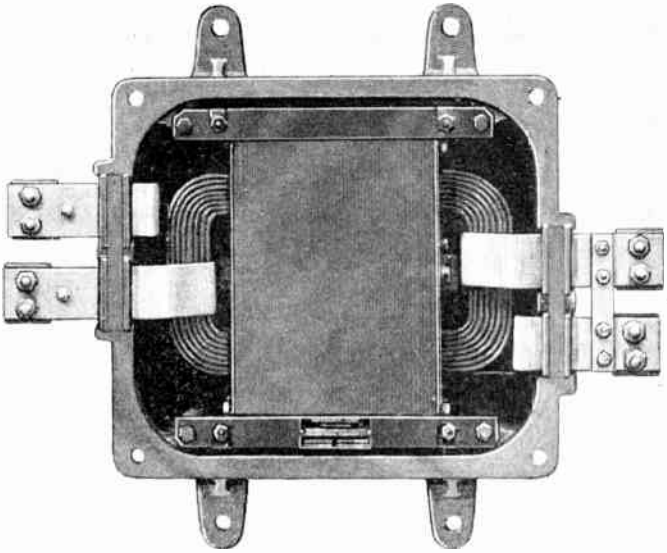

Fig. 8.—The Interior of an Impedance Bond.

required voltage at the rails.

Resistances may be fitted directly to the transformer; when used with reactances both are often combined in one unit.

Condensers are oil-immersed and housed in sheet steel cases; the capacities range from 3 to 20 microfarads. On electric railways they should be insulated to withstand the full traction voltage so as to allow for a leak or short circuit in the conductor rail. One or two condensers (one fixed and one adjustable) may be used.

Condensers can be used on all single-rail track circuits and on double-rail track circuits for steam lines; they can also be used on double-rail track circuits for electrified lines if special "auto" bonds are fitted. The "leading" current component helps to balance the "lagging" component of the current taken by much of the other apparatus, thus improving the power factor of the system and reducing the current in the main cables; the leading power factor of auto bonds is a further advantage.

Air-cooled transformers of the core or shell types are used. A number of tracks or track circuits can be fed from separate secondary windings on one transformer. With a resistance or resistance-reactance feed the secondary winding has tappings for 6, 8, or 10 volts; with a condenser feed it is wound for the full 110 volts, and the drop across the condenser gives the

The ordinary impedance bond consists of a laminated iron core wound with a few turns of copper wire or strip thick enough to carry the maximum traction current. The ends of the winding are connected to the rails, and the centre to a similar bond in the adjoining track circuit (or

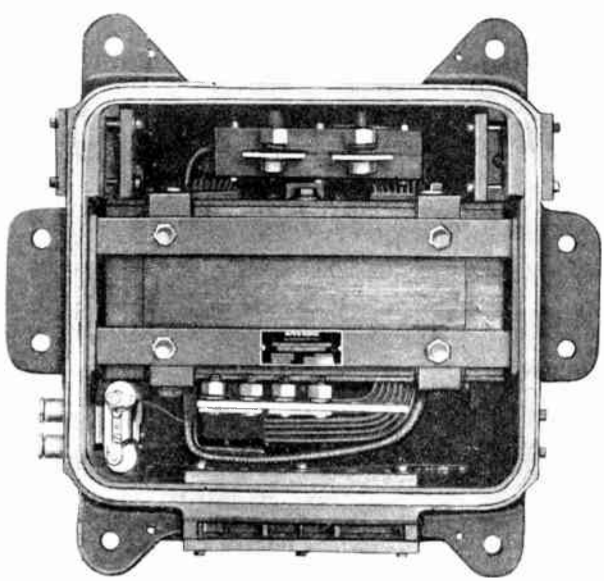

Fig. 9.—The Interior of an Auto-bond.

direct to the rails if not track-circuited). The traction current flowing from the ends of the winding to the centre or vice versa produces equal and opposite magnetic fluxes in the core, which is therefore not magnetised and provides a path of very low resistance for the traction current. The track circuit current flowing from one end of the winding to the other produces an alternating flux and, therefore, an inductive reactance; the impedance is about .5 ohm and is sufficient to prevent D.C. traction current from interfering with the working of the relay.

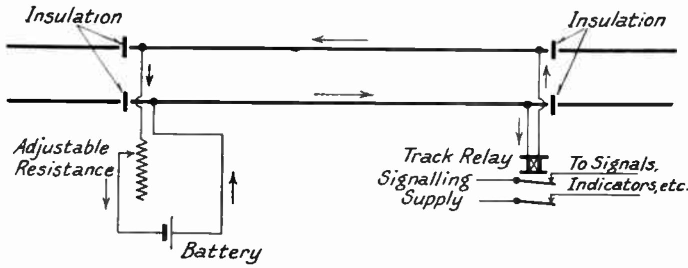

Fig. 10.—D.C. TRACK CIRCUIT.
Showing track clear.

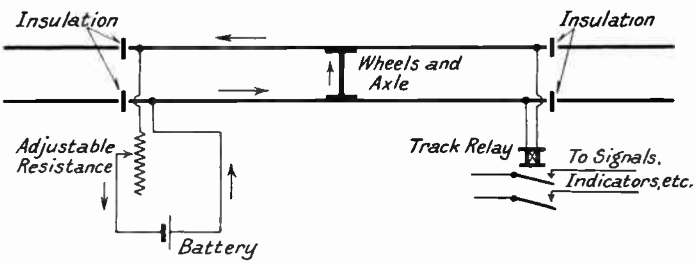

Fig. 11.—D.C. TRACK CIRCUIT.
Showing track occupied.

As the track circuit current lost in the windings of impedance bonds increases the energy consumption from, say, 5 to 74 watts per 1,000 ft. of track, special auto or "resonated" bonds are often used. With auto bonds the consumption per 1,000 ft. of track is reduced to 14.5 watts.

The auto bond combines the functions of an auto-transformer and those of an impedance bond. The main core has a fine wire auxiliary winding connected in series with the track circuit. The voltage is stepped down at the feed end and stepped up again at the relay end so that the relay works at a high voltage and low current, decreasing the effects of lead resistance. The core of the bond is magnetised by the auxiliary winding and not by the main winding; as the number of turns is in the ratio of about 1 to 50, only one-fiftieth of the current is required. Resonated bonds are somewhat similar in construction.

A.C. track relays depend for their operation on the induction of eddy currents in an aluminium vane or disc. The vane is mounted on a spindle so that it can move in its own plane to open or close the contacts. In the double element relay the local coil is continuously energised, inducing eddy currents with their reactive fields in the vane. The track coil flux is out of phase with the local flux, and the interaction between them causes the vane to move; the torque is greatest when the phase displacement is 90 degrees.

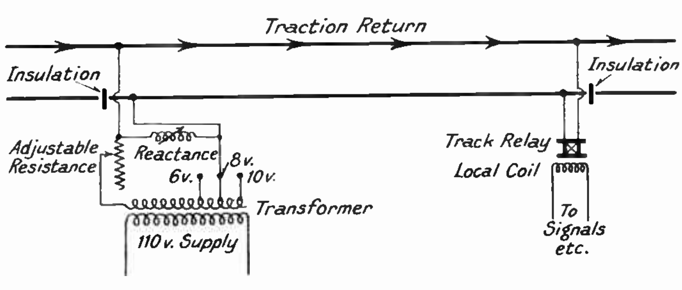

Fig. 12.—A.C. SINGLE RAIL TRACK CIRCUIT ON ELECTRIC RAILWAY (RESISTANCE-REACTANCE FEED).

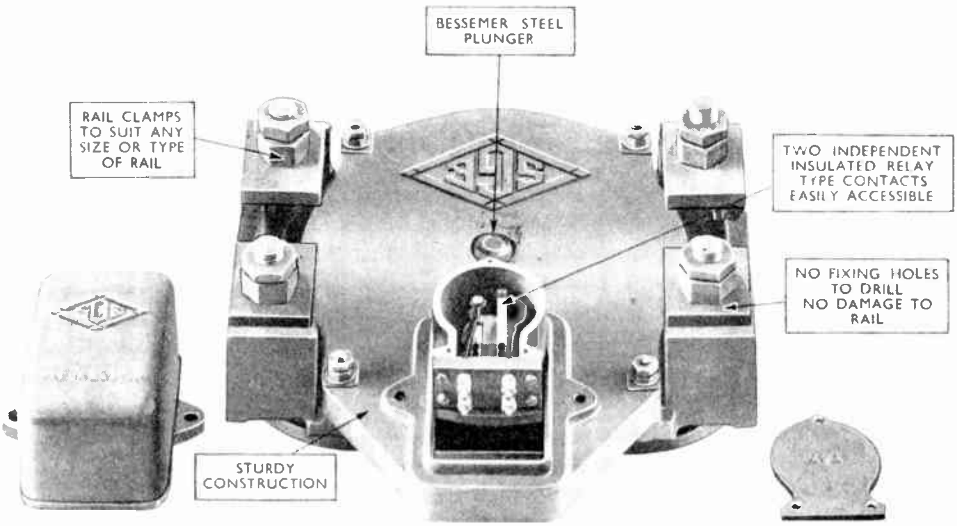

Fig. 13.—A Mercury Treadle with Covers Removed to show Construction.
The treadle is shown in position in Fig. 7.

A.C. line relays are similar to the single element track relays.

Track Circuit Applications.

In addition to the general use of track circuits in automatic signalling, the following are some typical applications :—

(1) To indicate to the signalman the presence of a train standing at signals out of sight of the cabin ;

(2) To replace mechanical fouling bars at facing points ;

(3) To control "route" locking in a manually or power-operated interlocking area ;

(4) To operate warning apparatus at level crossings, and

(5) To give fouling point protection in sorting or marshalling sidings.

TREADLES.

Treadles are primarily used for releasing lock-and-block instruments and are also employed for giving warning at level crossings, cancelling train descriptions, etc. They operate through the deflection of the rails between two consecutive sleepers due to the weight of the passing train.

The mercury treadle is bolted to the underside of the rail, and the deflection depresses a simple diaphragm, forcing mercury from a large chamber into a small chamber, where it makes or breaks contact in the signalling circuit.

The action is similar to that of a pump ; the contact-making part of the apparatus consists essentially of a steel container having valves and passages through

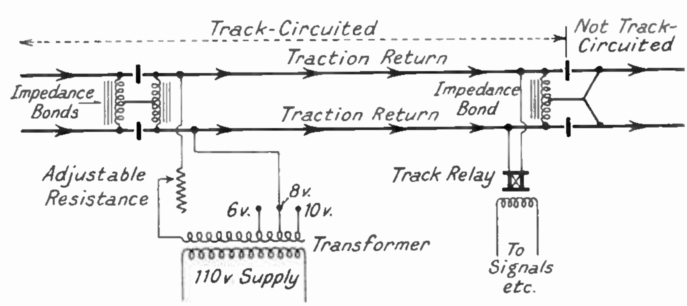

Fig. 14.—A.C. Double Rail Track Circuit on Electric Railway.
Using impedance bonds (resistance feed).

which the mercury is either forced or sucked.

Two types of treadle are made — with the signalling circuit normally open or normally closed. There are no levers and no wear of mechanical parts ; a deflection of 1 1000th in. is sufficient for operation whether the rails are light or heavy and whatever the weight of the train. Non-insulated treadles are suitable for circuits one side of which is earthed, and insulated treadles for making or breaking either or both of two insulated circuits.

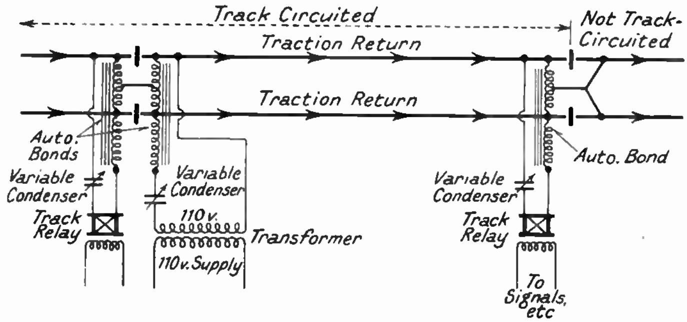

Fig. 15.—A.C. DOUBLE RAIL TRACK CIRCUIT ON ELECTRIC RAILWAY.
Using auto-bonds (condenser feed).

The Publishers are much indebted to the Siemens and General Electric Railway Signal Co., Ltd., for permission to use the photographs which accompany this article.

HOW AN ACCUMULATOR WORKS

WHEN an accumulator is fully charged it contains a certain quantity of sulphuric acid diluted with water, known as the electrolyte, one or more positive plates of lead peroxide and one or more negative plates consisting of pure lead in a finely divided condition. The colour of the positive plates is now puce, while the negatives are a grey colour.

As the battery is discharged the sulphuric acid reacts with the positive and negative plates. The positive plate is gradually converted into lead sulphate, and the negative plate also, at the expense of the strength of the acid, which is chemically hydrogen sulphate. The sulphate radical of the acid is used up by the plates and the hydrogen radical of the acid combines with the oxygen liberated from the lead peroxide plate to form water, which replaces the acid used up from the electrolyte.

Lead sulphate is white in colour, which explains the whitish appearance of the plates when a battery is discharged. It is not practicable to use up all the active material of the plates, so that the plates still retain a semblance of the puce and grey colours when the battery is discharged.

The same action takes place when a battery is left idle for an indefinite period. The lead sulphate deposit on the plates is then more noticeable and so hard as to be practically impossible to remove by charging. This explains why a battery is ruined when it is neglected, for if the lead sulphate cannot be reduced the active material is lost.

On charge the reverse chemical change takes place. The lead sulphate on the plates is reduced to lead peroxide at the positive plate and lead in a spongy state on the negative plate, while the sulphuric acid returns to the electrolyte and increases the specific gravity.

When an accumulator is nearly fully charged the current passing through the battery is no longer used to alter the chemical nature of the plates, so that it decomposes the water in the electrolyte to give hydrogen at the negative plate and oxygen at the positive. This explains why a battery gases when fully charged, although owing to the imperfect nature of the chemical actions during charging this is not a sure sign of the completion of the charge. The specific gravity of the electrolyte is a good measure of the state of charge, because the sulphate radical can only be supplied from the spent plates.

C

THE CONSTRUCTION OF A DOUBLE-CONE LOUD-SPEAKER

Materials Required.

14 feet of 1-inch square planed red deal.

3 feet 6 inches of 1½-inch by ½-inch planed red deal.

2 pieces of three-ply wood, each 20 inches square.

1 piece of unbleached calico sufficient to make two 24-inch squares.

4 6-inch lengths of $\frac{3}{16}$-inch Whitworth studding (brass).

16 $\frac{3}{16}$-inch Whitworth brass washers.

16 $\frac{3}{16}$-inch Whitworth brass nuts.

1 Blue Spot loud-speaker unit, type 66K, with an extension spindle, or other similar type of unit.

12 ounces of collodion solution.

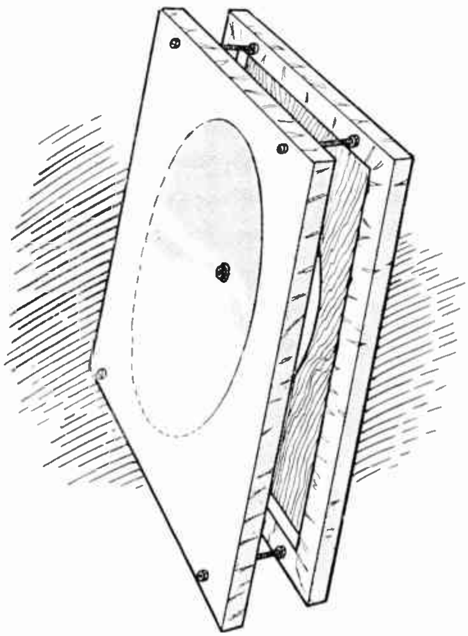

Fig. 1.—THE COMPLETED LOUD-SPEAKER.

Making the Frames.

Cut eight lengths of 1-inch square planed deal, each piece being 20 inches long. The ends of each piece should be carefully squared.

Mark off the ends of each piece for making the halved joint in the following manner: Square a line across the wood, 1 inch from each end, and continue the lines down each side for a distance of ½ inch. Set the marking gauge to mark a distance of ½ inch, and with it make a line along the sides of the wood from each end, to the lines which have been squared down the sides. These measurements should be carried out accurately to ensure a good joint when the frames are made.

Cut across the wood just outside the lines squared across the wood 1 inch from the ends, to a depth of ½ inch, using the tenon saw. The lines should be visible when the saw cut is made. In a similar manner cut along on the inside of the lines which have been made with the marking gauge, continuing the saw cut from the end of the wood till it meets the saw cut already made across the wood, thus removing a piece of wood ½ inch by 1 inch by 1 inch, which has to be cut away in preparation for the joint (Fig. 2).

Give the cut ends of each piece of wood a coating of thin glue, and arrange them to form two complete square frames having 20-inch sides. The joints are made quite firm with ¾-inch French nails (Fig. 3).

Cutting Out the Ply-wood and Fitting it to the Frames.

Determine the centre of each 20-inch square of ply-wood by finding the point of intersection of the diagonals of each piece.

On one of them draw a circle of 8½-inch radius with the compasses, using the point of intersection of the diagonals as centre. In a similar way draw a circle

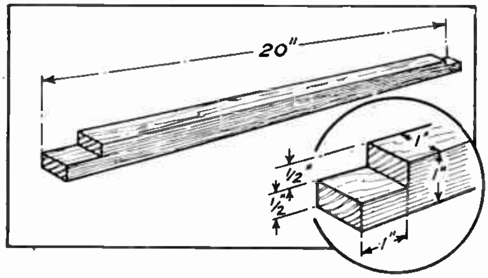

Fig. 2.—Showing Removal of Piece of Wood ½ inch by 1 inch by 1 inch.

of 6½-inch radius on the other piece of wood.

Drill a ¼-inch hole through the wood inside each circle, with centre ⅛ inch from the circumference. With the pad saw cut round the circumference of both circles. One piece will now have a hole 17 inches in diameter, and the other one 13 inches diameter, cut centrally. The edges of each hole must be carefully smoothed and rounded slightly with glass-paper.

Fasten a ply-wood square to each of the wooden frames with ¾-inch gimp pins, which are driven in at frequent intervals (Fig. 4).

Cutting the Calico and Glueing it to the Frames.

From the piece of unbleached calico cut out two 24-inch squares. Cover one of the frames and the outer side of the ply-wood square fastened to it with a thin coating of glue, and quickly transfer one of the pieces of calico to it, so as to cover the frame completely, with an overlap of 2 inches on each side. Smooth out all creases from the calico. The overlap of the calico is pressed down tightly over the sides and back portion of the frame. Repeat the operation with the other frame and piece of calico. Allow the glue to set and harden for twenty-four hours.

Fitting the Frames Together and Forming the Cones.

Mark the exact centre of each calico square, which has been glued to a frame, by finding the point of intersection of the diagonals from opposite corners of the frames. With the scissors make a hole ⅛ inch diameter in the centre of each square, and buttonhole-stitch round the edge of each hole, to prevent the calico fraying. Four ¼-inch holes, for the reception of the 3/16-inch brass studs, are now drilled in each frame; two at the top and two at the bottom, through the calico, three-ply and 1-inch square wood at a distance of ½ inch from the edge and 2 inches from the corners (Fig. 5). Two 3/16-inch nuts are screwed to the centre of each stud, so that the backs of the nuts are adjacent. A 3/16-inch washer is placed against the face of each nut. The studs are now pushed through the holes drilled in one of the frames, so that the washers are flush with the back of the frame. The second frame is taken, and fitted over the studs so that its back is flush with the other four washers. The calico squares are now on the outside of the completed double frame.

Fasten the two calico squares together at the centre with the screwed sleeve and nuts, which are provided with the loud-speaker unit. The felt and brass washers are clamped between the calico and fixing nuts (Fig. 5).

Thoroughly soak the portions of calico

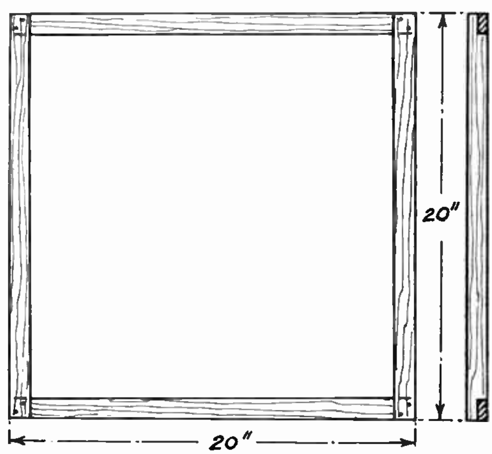

Fig. 3.—Arrangement of Complete Square Frame.

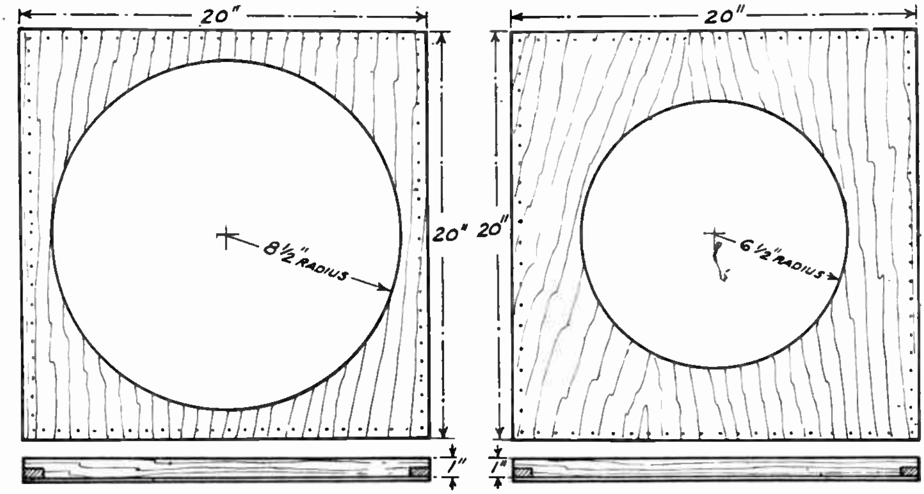

Fig. 4.—Front and Back of Loud-Speaker, showing Size of Circles and Method of Fastening Ply-wood Square to Each of the Wooden Frames with ¾-inch Gimp Pins, which are Driven in at Frequent Intervals.

which cover the holes in the ply-wood with collodion solution, using a soft varnish brush. *Great care* must be taken when using this solution, as it is *highly inflammable*, and must be kept and used well away from naked lights and the heat of the fire. When the calico squares are thoroughly soaked, screw each nut outwards for a distance of ½ inch. There will thus be 1 inch of bare spindle between each pair of nuts and the calico will be stretched, and will have begun to take on a conical form.

Again soak the calico with collodion solution and screw out each nut for another ½ inch. The soaking is repeated for a third time, and the nuts finally screwed out till the distance between the frames is 3½ inches. The cones will now be of the correct form (Fig. 5). They should be allowed a full day to dry before being touched.

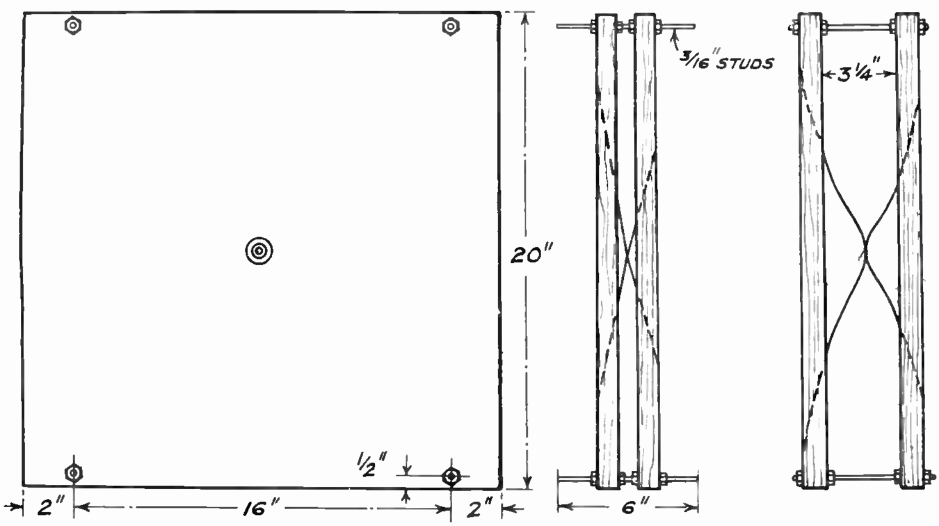

Fig. 5.—Fitting the Frames Together.

Fitting the Loud-speaker Unit to the Frame.

From the 3-foot 6-inch length of planed red deal cut two battens 20 inches long by 1½ inches by ½ inch. Half an inch from their ends drill two holes to take 1¼-inch by 7's countersunk screws. Fit the extension spindle to the end of the loud-speaker unit spindle with the connecting sleeve, and mount the unit on the battens. Two ¾-inch by 6's round-headed screws will secure the unit to the battens. The spindle must be exactly midway between the ends of the battens.

The end of the extension spindle should now be pushed through the screwed sleeve which fastens the two cones together, until the battens come against the wooden frame. The smaller cone should be nearest to the loud-speaker unit. The battens are secured to the frame with 1¼-inch by 7's countersunk head wood screws (Fig. 6). The screwed sleeve is now tightened up on the extension spindle with the locking nut, any excess of spindle now projecting beyond the sleeve is carefully cut off.

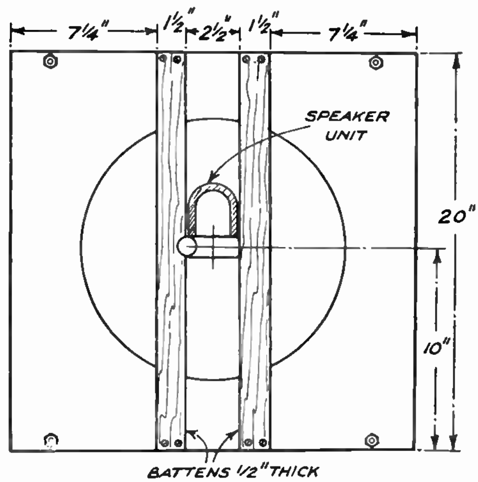

Fig. 6.—Position of the Unit.
Showing how battens are secured to the frame.

INSTRUMENT WIRE COVERINGS

THE wire used for winding coils of electro-magnets, relays, transformers and armatures may be obtained with several different kinds of insulation covering. The more common varieties are enamel, single and double silk and single and double cotton. The thickness of the covering varies with the gauge of the wire, being heavier for the larger gauges, and it is made in different thicknesses for the same gauge of wire.

Enamel-covered wire is used where the utmost number of turns have to be accommodated in a given space. Enamel covering has the advantage that it is non-hydroscopic ; that is to say, it does not absorb moisture. Single silk covering is only slightly thicker than enamel, but has the advantage over enamel that it is not so liable to mechanical abrasion and is therefore used for armature winding, where space is limited. A combination of enamel and single silk covering is ideal for certain types of coils because the enamel provides the necessary protection against moisture and the silk provides the cushioning and mechanical advantage.

Double silk covering affords higher insulation and mechanical strength than the foregoing coverings, but, of course, it takes up more room. Cotton covering is used primarily on account of its cheapness. Wire heavier than 16 S.W.G. is seldom used, other than cotton insulated, on account of the rougher handling necessarily involved in winding.

Coils of silk or cotton insulated wire should be dried and impregnated with insulating varnish whenever possible to prevent the ingress of moisture.

FAULT TRACING IN DYNAMOS, MOTORS AND ROTARY CONVERTERS

By H. E. J. Butler.

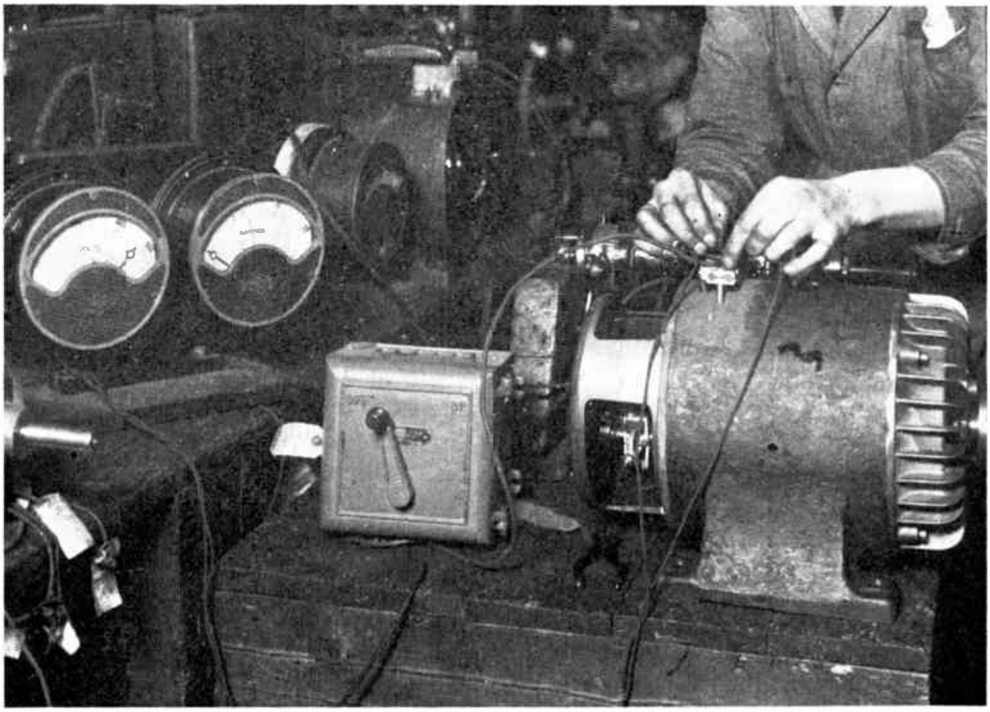

Fig. 1.—Testing the Voltage at the Motor Terminals. (*Lancashire Dynamo and Crypto, Ltd.*)
Note that this test must be made with the starter on the first stud.

FAULTS in electrical machinery usually manifest themselves by failure to operate, overheating or sparking at the commutator. More serious troubles give rise to excessive speed, smoke and mechanical vibration. For the diagnosis of the less obvious faults the practical electrician should equip himself with one of the modern types of multi-range A.C. and D.C. testing sets, although an ammeter and a voltmeter of the moving iron type, equally accurate both on D.C. and A.C., will serve for most purposes. An A.C. ammeter is essential for checking the correct working of two and three-phase motors, in order to verify the current in each phase. The correct working of a dynamo or alternator can usually be seen from its switchboard instruments, but a motor seldom has any measuring instruments, other than those of the supply company, in circuit. It is advisable to have an ammeter in series with a large motor because it enables the starting current to be kept below a dangerous figure, and serves as an indication of the load imposed on the motor while running.

Motor Fails to Start, Fuses Do Not Blow.

Cause.—Supply cut off, or power not reaching motor through faulty switches

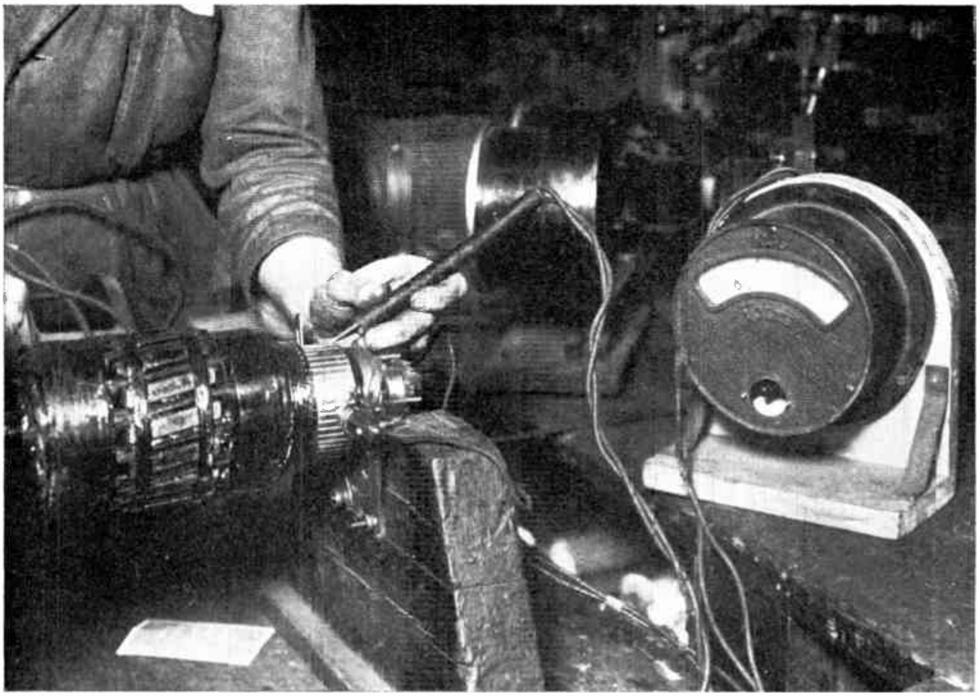

Fig. 2.—TESTING THE ARMATURE TO LOCATE A FAULTY COIL (*Lancashire Dynamo and Crypto, Ltd.*)
This picture illustrates the drop test being applied across the commutator segments.

or disconnection of a wire. Brushes not bearing on the commutator.

Remedy.—With a voltmeter or a lamp of suitable voltage, first check the supply at the main switch, then, if the mains are in order, test the voltage at the motor terminals with the starter on the first stud. Do not hold the starter in the full-on position, because if the fault is an intermittent one it may suddenly clear itself and the full voltage of the mains be applied to the motor. For a two-or three-phase supply, test each phase separately.

Motor Fails to Start When Loaded, Fuses Blow.

Cause (1).—Field winding of D.C. shunt motor disconnected or broken, with the result that the full voltage is applied to the stationary armature when the starter is moved to the running position.

Remedy.—Test the continuity of the field winding with a portable battery and voltmeter. If the field winding is in order look for cause (2).

Cause (2).—Short circuit in the motor or wrong connection of the motor starter. A short circuit to the frame of some live part of the motor is equivalent to a short circuit on the mains when one line of the mains is earthed. It is usual for one line of any type of power supply to be earthed.

Remedy.—If the starter connections are known to be all right from previous working, disconnect the leads at the motor terminals and test the different sections of the motor for a fault, with the brushes, if any, lifted from the commutator. Examine the terminal and brush gear bushings to see that they are not short-circuited in any way. If the fault lies in the armature it may be necessary to disconnect the wires from the commutator to determine whether the commutator or armature insulation has broken down.

Cause (3).—Motor seriously overloaded, bearings seized up, or bearings so badly worn that the armature makes contact with the field magnets.

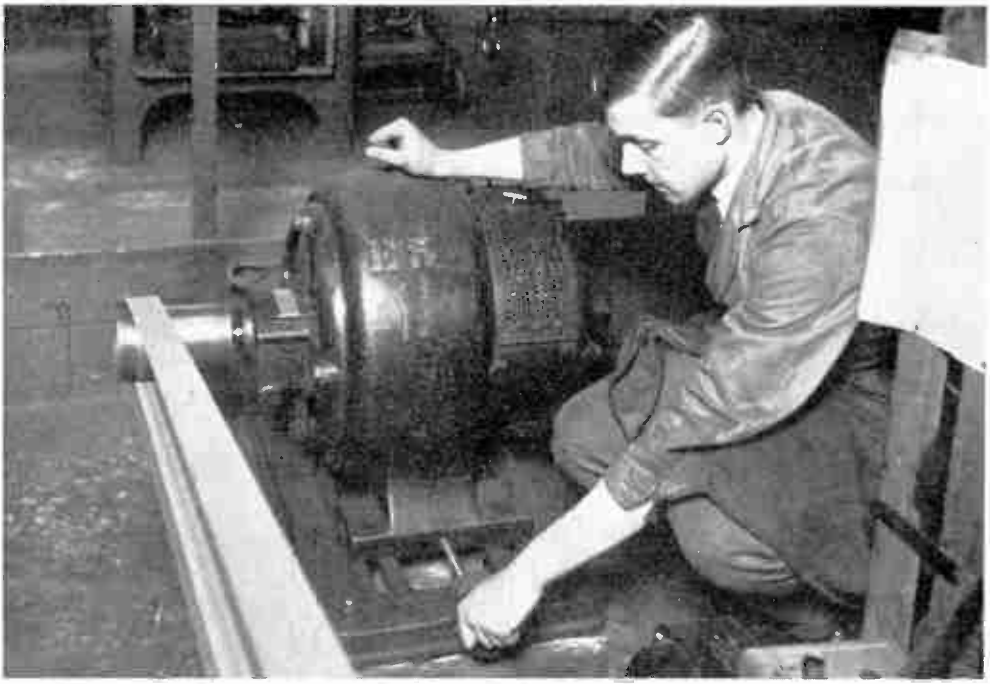

Fig. 3.—Tightening the Belt of a Motor by Moving the Machine on the Rail. (*Lancashire Dynamo and Crypto Ltd.*)
The belt should be adjusted so that there is no slipping under full load.

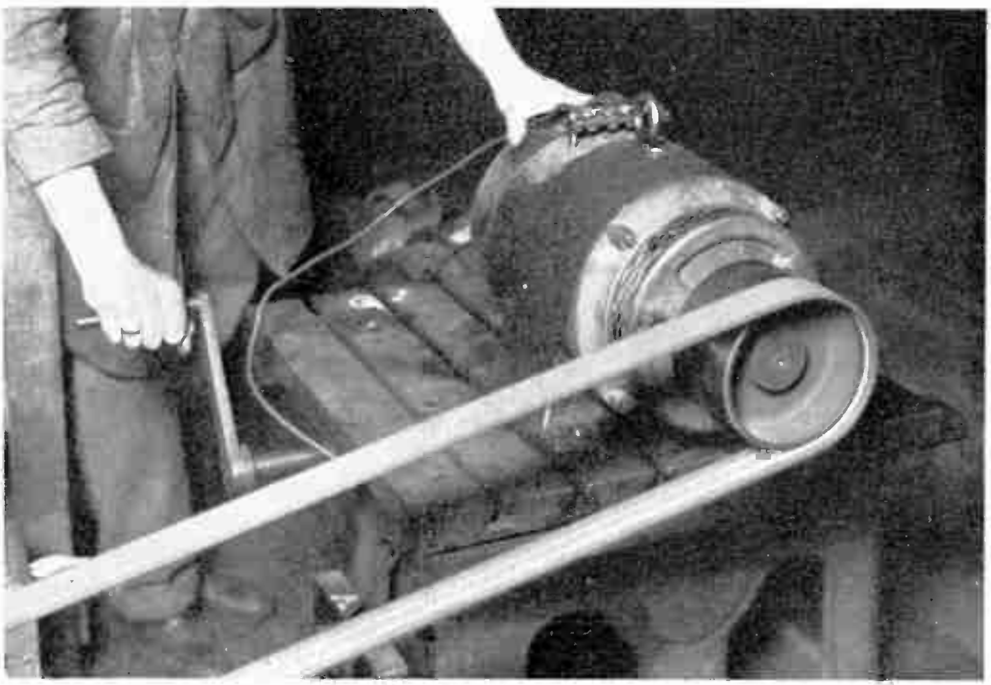

Fig. 4.—Adjusting Belt on Test Bench. (*Lancashire Dynamo and Crypto, Ltd.*)
When a motor or dynamo is tested for performance by the maker, special provision is made for adjusting the belt drive for tightness and alignment. The above picture shows good standard practice in this connection.

Fig. 5.—Changing Over the Field Windings When the Motor Runs in the Wrong Direction. (*Lancashire Dynamo and Crypto, Ltd.*) See page 770.

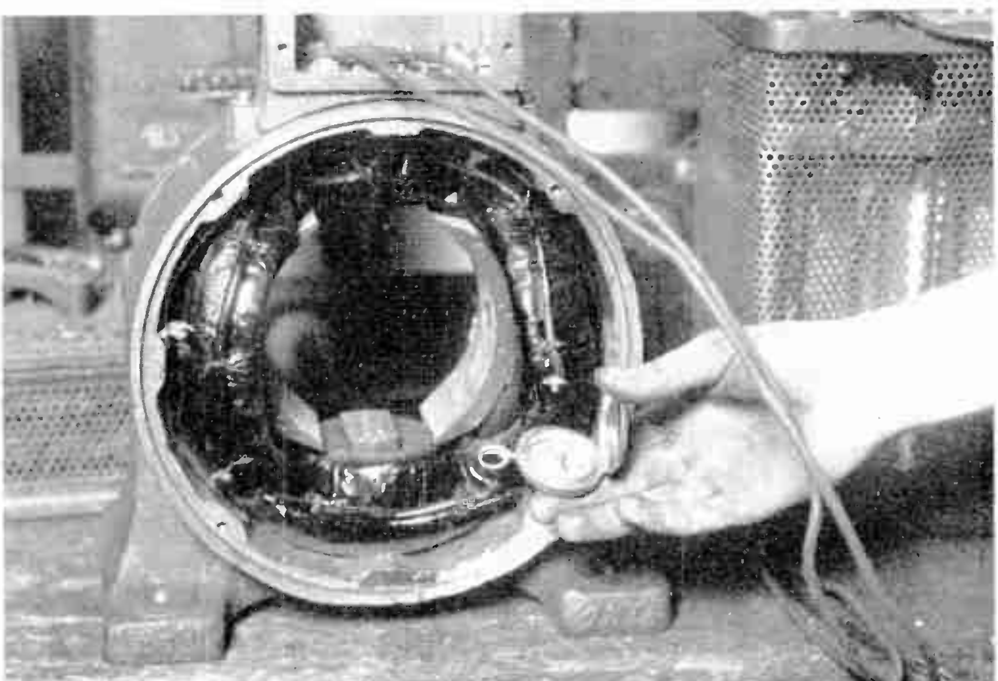

Fig. 6.—Checking Main Poles of Field Magnets with a Compass Needle. (*Lancashire Dynamo and Crypto, Ltd.*) See page 771.

Fig. 7.—Bedding in Brushes with Emery Cloth.(*Lancashire Dynamo and Crypto, Ltd.*)
The emery side should face the brushes. Take care that no emery dust remains between commutator segments.

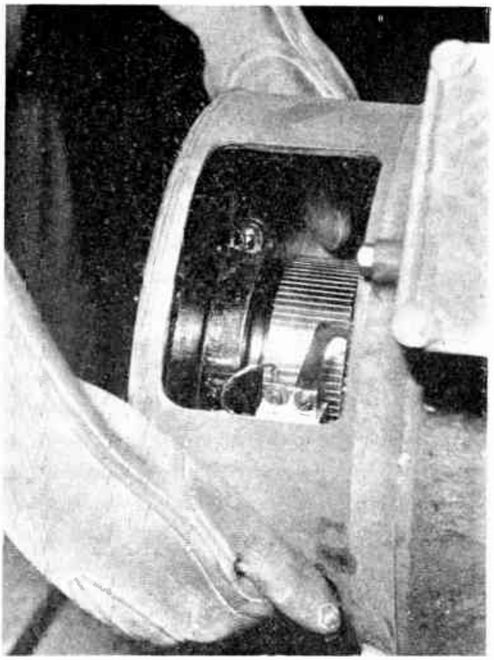

Fig. 8.—Adjusting a Brush Rocker. (*Lancashire Dynamo and Crypto, Ltd.*)
As this can only be done accurately whilst the machine is running, rubber gloves should be worn.

Remedy.—Remove the motor chain or belt and turn the armature by hand. If the bearings are in order, then the fault lies with the load. Ball-bearings seldom seize up and this trouble is usually confined to machines with plain bearings which have been neglected.

Motor Runs in the Wrong Direction.

The direction of rotation of a D.C. machine may be reversed by changing over the field connections, for either a shunt or series machine. The connections to the interpoles, if any, remain the same. To reverse a four-wire two-phase motor change over the two wires of one phase, leaving the other pair the same. A three-wire two-phase motor is reversed by changing over the two outer wires, the phase common wire being thicker than the two outer ones. A three-phase motor is reversed by changing over two wires of one phase at the terminals of the motor or at the main switch.

Output of Motor Too Low.

Cause.—Voltage of mains too low. This causes the motor to run somewhat slower than it should. If the motor is connected to a main of much lower voltage than for which it is rated, the no-volt release of the starter usually operates.

Remedy.—Test the mains pressure with a voltmeter, preferably with the motor running. There may be a high resistance contact in the system causing a drop. This will be located by the heat evolved from that part.

Belt of Dynamo or Motor Slips When Machine is Loaded.

Cause (1).—Belt loose or glazed.

Remedy.—Tighten the belt by moving the machine on the rails. If this is not possible, the belt is shortened. A glazed belt is treated with resin or castor oil.

Cause (2).—Machine overloaded by the machinery or bad alignment of the shafting bearings.

Remedy.—Check the load current of the armature, and, if it exceeds the maximum, investigate the condition of the shafting and the possibility of overload through too much machinery on the motor.

Cause (3).—Driving pulley on motor and main pulley on shafting too small,

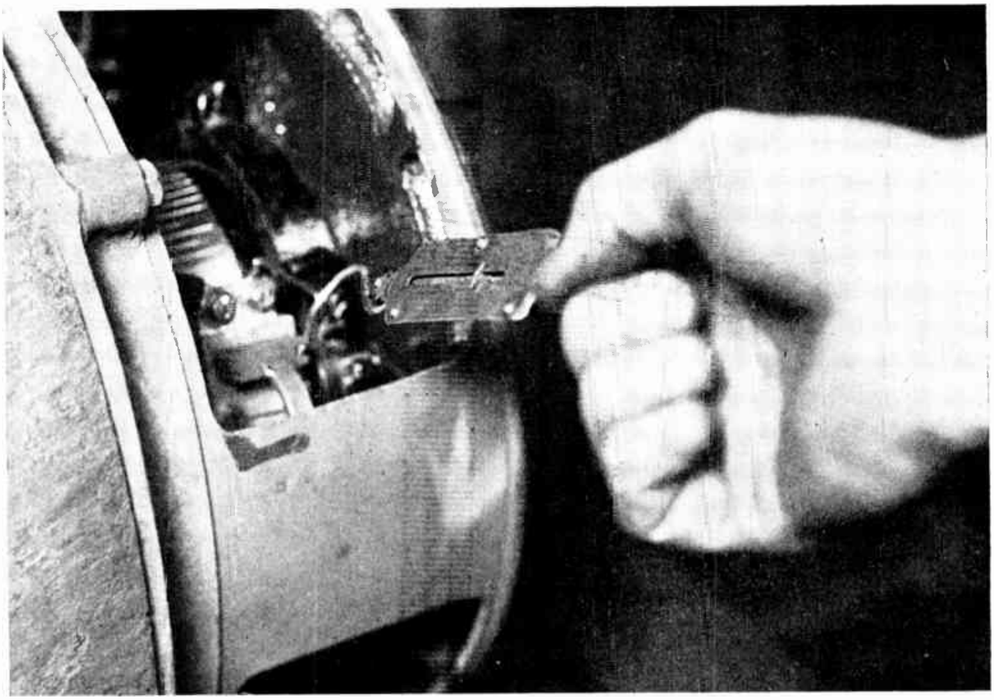

Fig. 9.—TESTING THE BRUSH PRESSURE WITH A SPRING BALANCE. (*Lancashire Dynamo & Crypto, Ltd.*)
The normal brush pressure should be about 2 lbs. per square inch of brush section for commutators, about 2¾ lbs. per square inch for slip-rings, and 8-10 lbs. for car starter motors.

with the result that the driving belt has not sufficient surface on which to grip.

Remedy.—Fit new driving pulleys to motor and shafting, taking care not to alter the ratio of the diameters, if the speed of the driven member is to be the same as before.

Motor Races.

Cause.—Unless the voltage of the mains is higher than it should be, this condition can arise only when the motor load is light. If the machine is a series one it will race dangerously if the load is entirely removed. A shunt motor will race if there is a break in the field windings, if there is no current in the field through a wrong connection or the fields wrongly interconnected.

Remedy.—A series motor, except in the smallest sizes, must not be used when there is a possibility of the load being entirely removed. Where it is necessary to have the high starting torque characteristics of the series motor, with safety on no load, a compound-wound field is used. The adjacent main poles of the field magnets must be of opposite polarity. This is checked with a compass needle. Do not hold the needle too close to the field magnets or the polarity of the needle may be reversed.

Dynamo Fails to Generate.

Cause (1).—No residual magnetism, or residual magnetism very weak.

Remedy.—A dynamo should give a reading up to 5 per cent. of its usual voltage when the machine is run with no field current. If it does not, and the magnets do not exhibit any signs of magnetism when tried with a piece of iron, the field is remagnetised by passing a current through the field coils, taking care to connect the positive of the magnetising current to the positive pole of the dynamo for a shunt machine and the positive to the negative for a series-wound dynamo. The simplest way is to run the machine for a few seconds as a motor, but where the supply is not available a battery of E.M.F. about 10 per cent. of the dynamo voltage will be usually sufficient to re-establish the residual magnetism.

Cause (2).—Direction of rotation reversed. This causes the dynamo to build

Fig. 10.—TESTING WITH A MEGGER FOR LEAKAGE FROM WINDINGS TO FRAME. (*Lancashire Dynamo and Crypto, Ltd.*)
The megger voltage should be at least twice that of the machine under test.

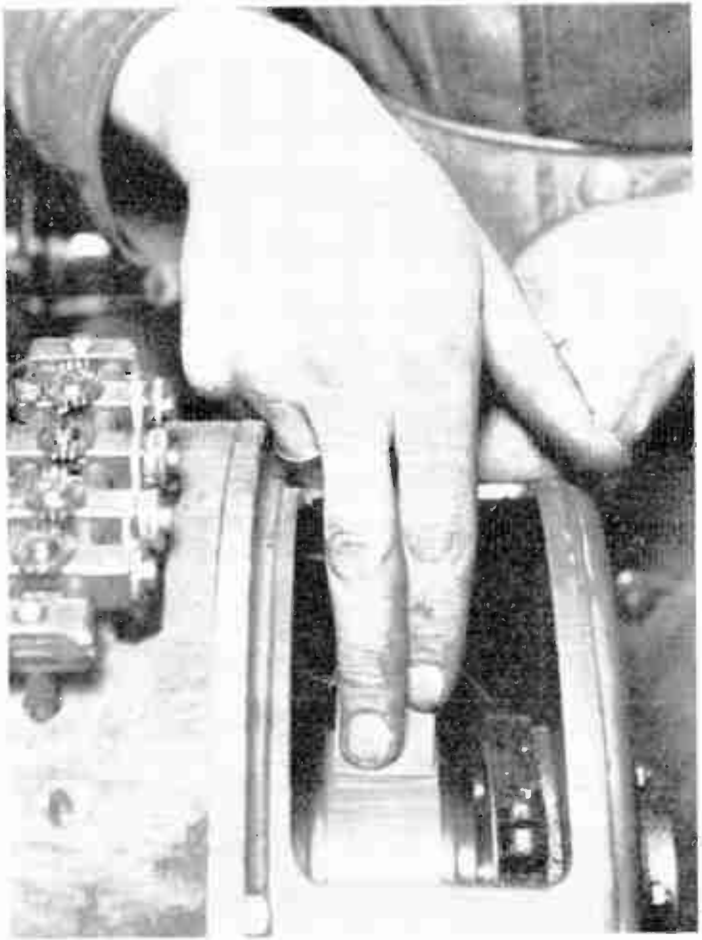

Fig. 11.—CLEANING THE COMMUTATOR WITH FINE GLASS PAPER. (*Lancashire Dynamo and Crypto, Ltd.*)
Emery cloth should never be used for this purpose.

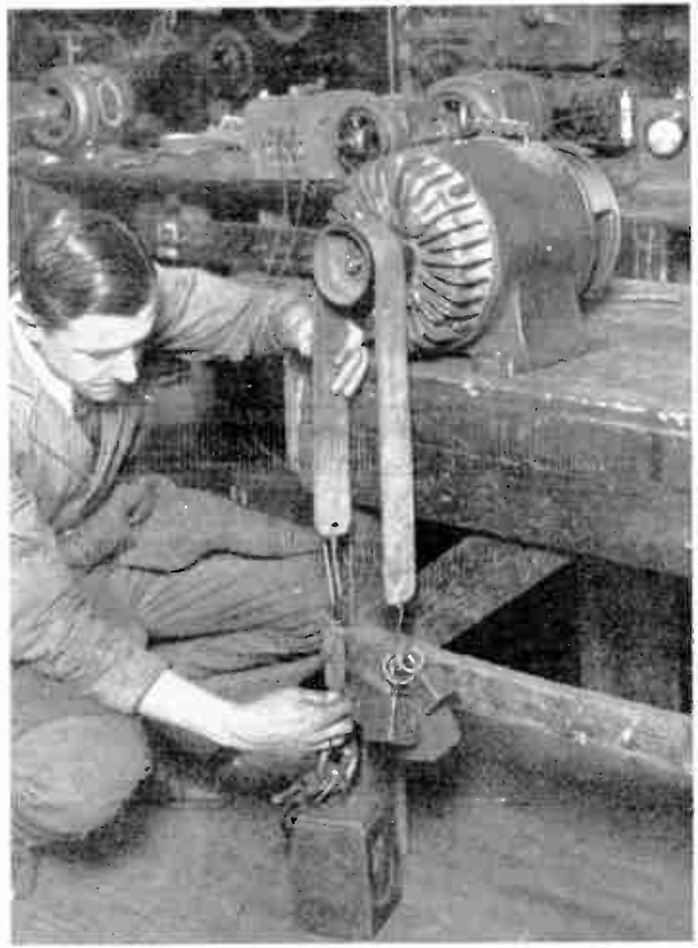

Fig. 12.—BENCH BRAKE TEST. (*Lancashire Dynamo and Crypto, Ltd.*)
This method enables the starting torque to be measured fairly accurately. It can also be used for short b.h.p. tests on small motors.

up in the opposite direction, with the result that a current is sent round the field which neutralises the residual magnetism.

Remedy.—Reverse the direction of rotation, or change over the field connections.

Cause (3).—Break in the field winding, or fault in the shunt regulator.

Remedy.—Locate the break by testing the exciting circuit of the dynamo with a cell and voltmeter. If the break is in one of the field coils, this one is removed and rewound. A series dynamo will not start to generate until the load is put on, because the field can be excited only by the load current.

Cause (4).—Short-circuit across the main terminals of a shunt machine will prevent the machine from generating.

Remedy.—Remove the short-circuit, which may lie in the machine itself, the switchboard or the external circuit. If the fault is in the external circuit, the dynamo will excite when the machine is disconnected from the load.

Dynamo Output Low.

Cause (1).—Speed too low or belt slipping.

Remedy.—Before increasing the speed make sure there is no other fault, which is recognised by overheating of some part. See that the engine governor is working properly.

Cause (2).—Field current too weak, or break in one of the field coils where there is more than one pair of field poles.

Remedy.—Verify the field current by inserting an ammeter in this circuit. Where the machine is a multi-polar one, test each field coil separately if they are parallel connected. If the coils are series connected the failure of one coil will cause a complete breakdown.

Cause (3).—Brushes not in correct relation to one another. On some types of machines the brush holders can twist out of position if the nuts become loose.

Remedy.—Reset the brushes so that they are equi-distant round the commutator, and, if necessary, re-bed them and adjust the rocker.

Alternator Fails to Generate.

Cause.—No D.C. current in the field magnets, or fault in the exciter machine itself.

Remedy.—Test the continuity of the field windings and examine the condition of the brushes and slip-rings to ensure they are in good condition and make proper contact.

Sparking at the Brushes.

Cause (1).—Brushes out of position on the commutator.

Remedy.—The brush rocker is moved round until the best position for the average load is found. A machine with interpoles does not require any adjustment of the brushes with a varying load. As a precaution, always use rubber gloves when adjusting a brush rocker.

Cause (2).—If varying the angle of the brushes does not improve the commutation, the brushes may not be bedding properly or the brush pressure on the commutator is too light.

Remedy.—Examine the bearing surface of the brushes. If the surface shows imperfect contact, re-bed the brushes. This trouble may arise through reversing the machine where the brushes are not too good a fit in the brush holders. Test the brush pressure with a spring balance. The normal brush pressure is at least 2 lbs. per square inch for commutators, $2\frac{1}{2}$-3 lbs. for slip-rings, and 8-10 lbs. for car starter motors.

Sparking at Brushes, Commutator Blackened.

Cause (1).—Open circuit or short circuit in part of the armature.

Remedy.—This may be located by some bars being more badly burned than the others. When a short circuit develops it may loosen the soldered connections of the commutator and cause further trouble to the sound coils. Test the armature by the drop-test method and rewind the faulty section, and clean the commutator.

Cause (2).—Machine overloaded.

Remedy.—Although a good-class machine will stand about $1\frac{1}{4}$ times full load for a good period, it is not advisable to run a machine on a permanent overload. Install a larger machine, or an extra one and split up the load.

Fig. 13.—BRAKE TEST ON BEARER MOTOR. (*Lancashire Dynamo and Crypto, Ltd.*)

This system of weights, lever and brake band provides a simple method of testing the torque and output of a motor geared to run at a slow speed.

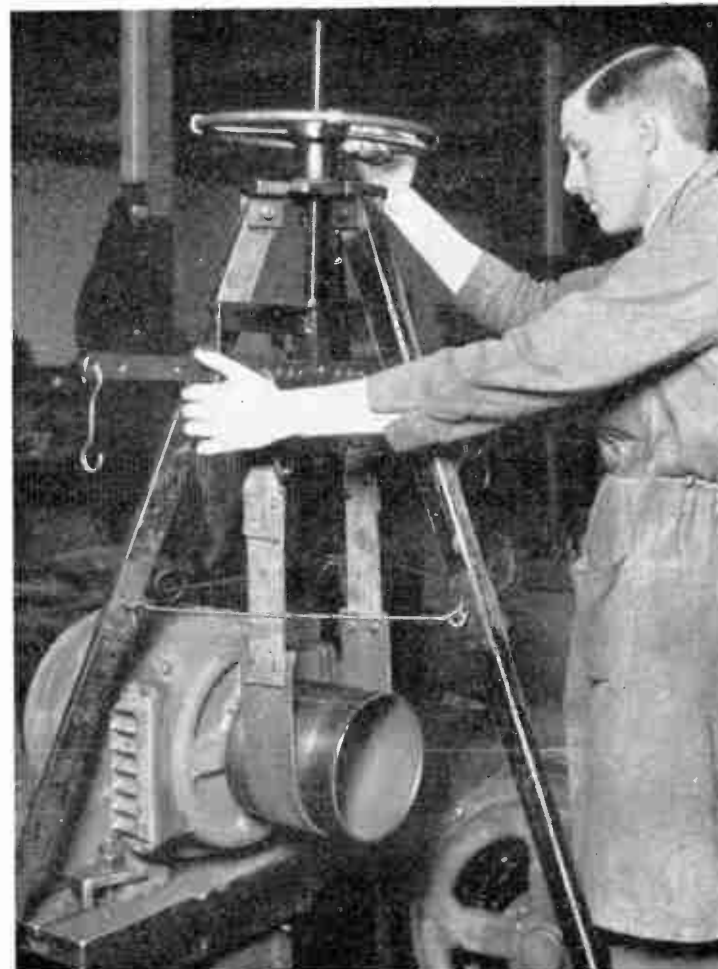

Fig. 14.—BRAKE TEST ON SMALL MOTOR. (*Lancashire Dynamo and Crypto, Ltd.*)

In this picture it can be seen that the brake lever can be pivoted at various points, according to the load which it is desired to put on the motor during the brake test.

Commutator Blackened, Sparking Round the Commutator.

Cause (1).—Brushes too soft, or brush pressure too great.

Remedy.—Clean the commutator with fine glass paper, or one of the special commstones made for this purpose. Check the brush pressure and the grade of brushes.

Cause (2).—Micas project above the commutator bars.

Remedy.—Most commutators and brushes work best with the micas undercut, so that it is necessary to periodically undercut the micas. Special machines and tools are made for this. Do not attempt to smooth down the micas with glass paper, because glass paper does not cut mica as easily as it does copper.

Machine Overheats.

Cause (1).—Overload.

Remedy.—In a shunt machine or an alternator the excess heat is generated in the armature. Check the load with an ammeter in the main circuit, and arrange to keep the load within the capacity of the machine.

Cause (2).—Bearings tight or out of line. This is located by the fact that the bearings are hotter than any other part.

Remedy.—Overhaul the bearings and arrange to lubricate at regular intervals.

Cause (3).—Some cause associated with sparking at the commutator (*q.v.*).

Cause (4).—One field coil of a bi-polar shunt machine short-circuited, with the result that the field resistance is halved and one coil carries twice its normal current.

Remedy.—Rewind the faulty coil, which is the cold one, and make sure that the insulation of the other coil has not been damaged by the excess current.

Cause (5).—Ventilating fan, if any, not working.

Remedy.—Tighten up the fan on the armature shaft, or replace fan if it is broken or has been removed.

Pipe-ventilated Machine Overheats.

Cause.—Blockage in ventilating pipe, especially at the entry, where loose material may be sucked on to the perforated inlet. Ventilation fan not working.

Remedy.—Clear away the obstruction in the pipe and check the working of the ventilating fan.

Machine Vibrates Badly When Running Up to Speed.

Cause.—In large turbo-alternator sets the machines must be run up to speed quickly or the machines vibrate badly when the critical speed is reached owing to whipping of the shaft.

Remedy.—When the critical speed is nearly reached, the machines must be rushed over this period as quickly as the conditions permit, or damage may be the result. The same rule applies when stopping. The machines must be slowed down quickly past the critical speed.

Machine Vibrates When Running.

Cause (1).—Loose or worn bearings. Armature out of balance due to the displacement of an armature coil.

Remedy.—Renew or adjust the bearings and examine the condition of the armature windings.

Cause (2).—Vibration transmitted from another machine when the motor or dynamo is direct coupled to it.

Remedy.—Uncouple the machines and run the driving one alone to ascertain which is at fault.

Shock is Felt on Touching Machine Casing.

Cause.—Machine frame not properly earthed, and breakdown of the insulation of some part of the windings or brush gear.

Remedy.—Renew the earth connection. Test each part of the machine with a megger having a testing voltage of at least twice the output voltage of the machine. Thus, use a 1,000-volt megger for a 500-volt machine. Breakdown of field windings is often caused by breaking the field circuit suddenly. On larger machines special safety devices are used to prevent a high voltage surge in the fields when the current is cut off.

PRACTICAL
ELECTRICAL ENGINEERING

Intended for Electric Lighting and Power Engineers. Electricians and Wiremen. Wireless Dealers. Students, Apprentices and Improvers in all Branches of the Electrical and Wireless Industries

General Editor
EDWARD MOLLOY

VOL. II

Contributors to Vol. II

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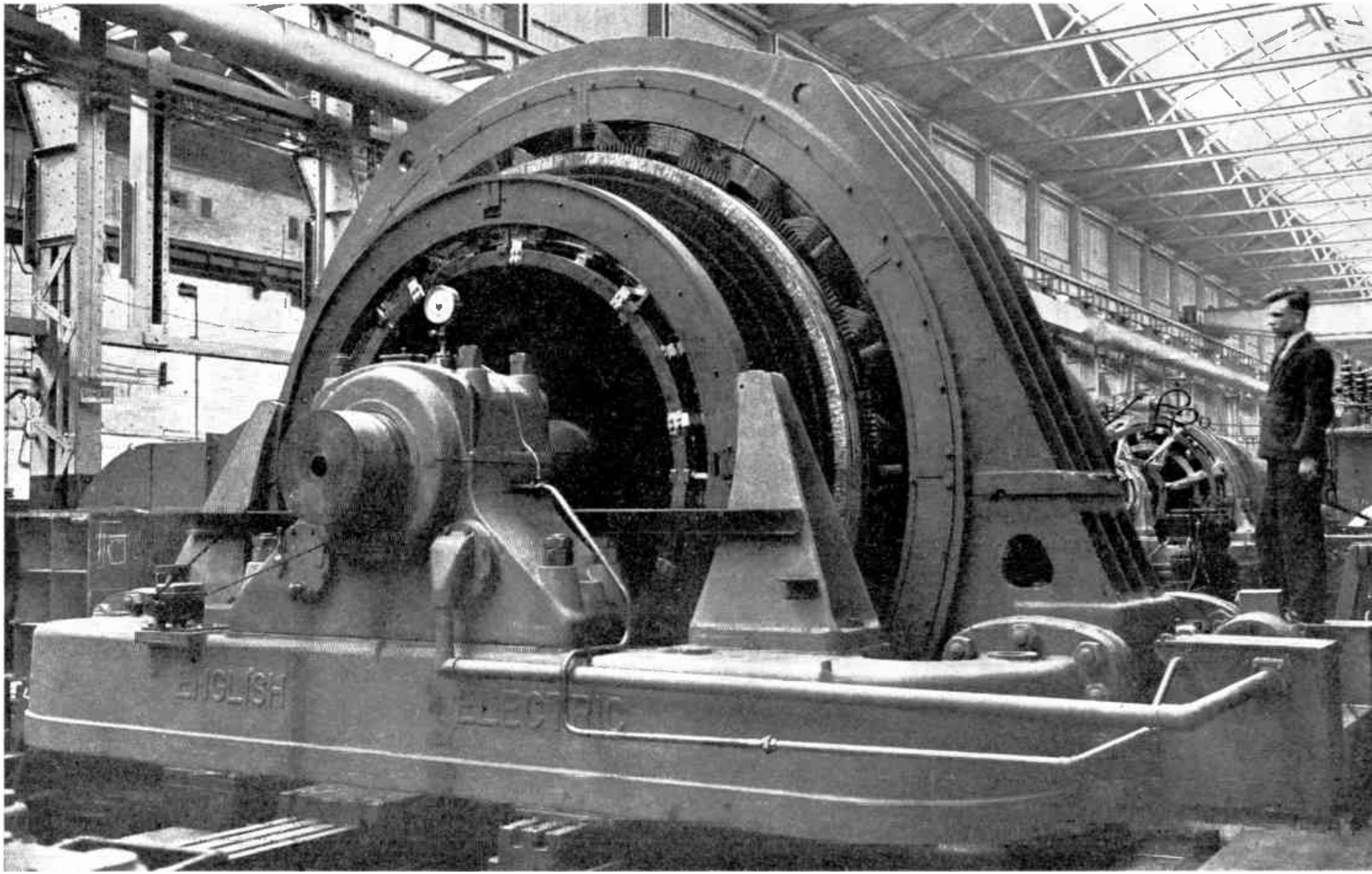

"English Electric" 12,000 h.p. Single-armature D.C. Motor for Driving a 27″ 3-stand Reversing Mill.

PREFACE TO VOLUME II

IT will be observed from the Title Page of this volume that the standard of distinction of the contributors has been well maintained. We are fortunate in having secured the assistance of so many able electrical engineers in the compilation of this work.

It will be noticed also that whilst the qualifications of the writers are beyond criticism, the style of treatment is still such that it can be appreciated by the man who has a practical rather than a theoretical turn of mind. Various aspects of Electric Lighting have been dealt with in the following articles :—

The Development of Electric Lighting.
Illumination and Design of Electric Lighting Schemes.
Fitting of Electrical Accessories.
How to Provide Adequate Illumination.
Fitting Additional Points of Supply.
The Planning of a Lighting Installation.
Theatre Lighting.
Shop Lighting and Wiring.

Another branch of electrical engineering which is becoming every day of greater importance to the man in the industry is that of Wireless Receiving. The following articles in this volume have a particular bearing on this subject :—

Fault Tracing Chart for Radio Sets.
High Tension Eliminators.
More Radio Receiving Circuits.
Making a Double-Cone Loud-Speaker.
Simple Battery Chargers.

In connection with the latter, it should be mentioned that the larger subject of Accumulator Charging on a commercial scale forms the subject of a separate article in a later volume.

Industrial applications of electricity have received their full share of attention. As examples may be instanced the articles on :—

Electroplating Apparatus.
Hairdressers' Equipment.
Electric Railways.
Electric Heat Treatment Furnaces.
How to Install a Power Transformer.
Installation and Erection of Electric Motors.

It will be seen that a considerable amount of space has been given to the hitherto somewhat neglected subject of Electric Clocks. This has been done deliberately because it is realised that this is one of the minor branches of electrical engineering which is likely to become of increasing importance in the near future.

Whilst the subject of Talking Picture Apparatus may at first appear to be rather outside the scope of PRACTICAL ELECTRICAL ENGINEERING, it will be seen on a perusal of this article that it is a subject of very great interest to the practical electrical engineer. Whilst this article has been written largely from the point of view of being directly useful to the man who may at some time be called upon to deal with this type of apparatus, there is no doubt that the information given will be appreciated by every electrical engineer who wishes to be reasonably well informed regarding the various developments which are taking place in his profession at the present time.

The same remark can be applied with equal force to the interesting article which has been contributed to this volume by the Engineer-in-Chief of the General Post Office, Col. Sir Thomas F. Purves, M.I.E.E. Here again the more detailed consideration of Telephony, as of its sister science Telegraphy, has been left for a later volume.

E.M.

CONTENTS

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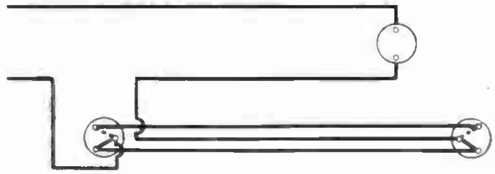
ERRATA FOR VOLS. I AND II

P. 28. Insert this diagram in place of Fig. 12B.



P. 49. In Fig. 4, terminal 2 of the S.G. coil and the moving plates of the reaction condenser should be connected to L.T. negative and not to L.T. positive.

P. 51. In Fig. 7, the coils DBG and DBA should be transposed.

P. 52. In Fig. 9, the lead from terminal 1 of the S.G. coil should be connected to the grid leak side of the grid condenser, and not to the grid side.

P. 380. In Fig. 13, a .0003 coupling condenser from the H.F. choke should be connected direct to the anode of the valve and not to the H.T. side of the H.F. choke.

P. 338. Transpose the captions under Figs. 14 and 15.

P. 587. Fig. 9. For greater safety it is recommended that the ebonite adaptor should be provided with sockets instead of pins. The pins should then be mounted on the kettle.

P. 590. In Fig. 1, the 60/70 Hys. choke from which the loud-speaker lead is taken should be of the iron core type.

P. 593. In Fig. 2, the 50/70 Hys. pentode choke should be of the iron core type.

A complete errata slip covering the work will be included in the final part.

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