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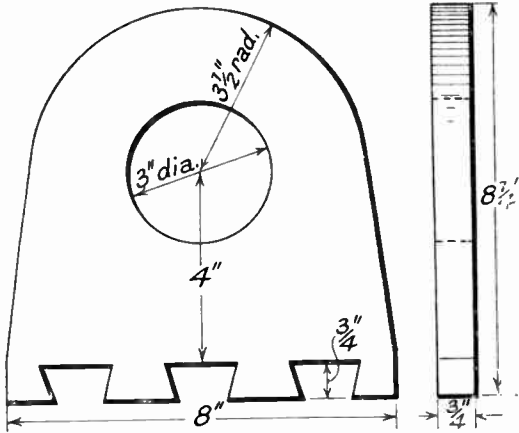


Fig. 4.—THE COIL TUBE END. Two are needed, cut out of teak.

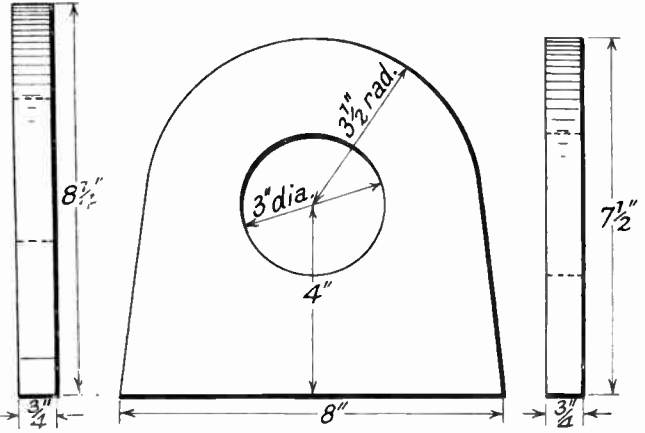


Fig. 5.—THE COIL TUBE CENTRE SUPPORT. This is also cut from teak.

Fig. 6 (Right).—DETAILS OF THE BASEBOARD.

The ends are dovetailed to take the tube ends.

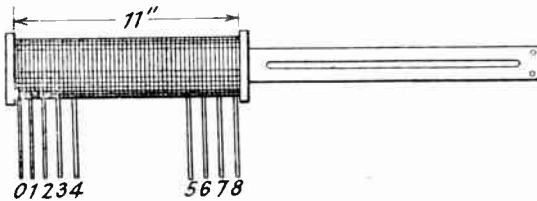
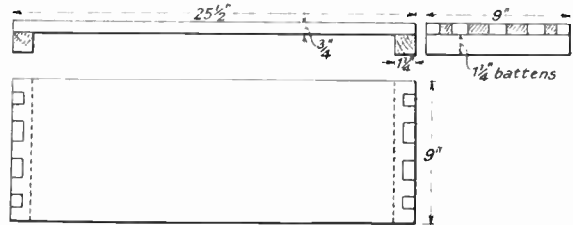


Fig. 7 (Left).—THE WOUND COIL WITH TAPPINGS BROUGHT OUT FOR CONNECTION TO THE REGULATING SWITCH.

Tapping No. 1—100 turns; 2—100; 3—200; 4—200; 5—200; 6—200; 7—200; 8—240. Total turns, 1,440; 12 layers, 120 turns per layer.

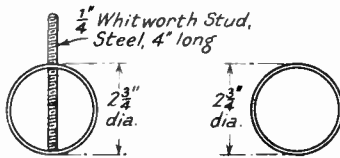
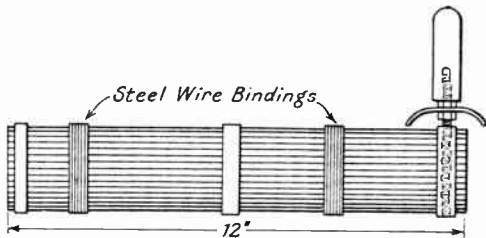


Fig. 8.—THE LAMINATED IRON WIRE CORE. The bindings are 1/4-in. wide.

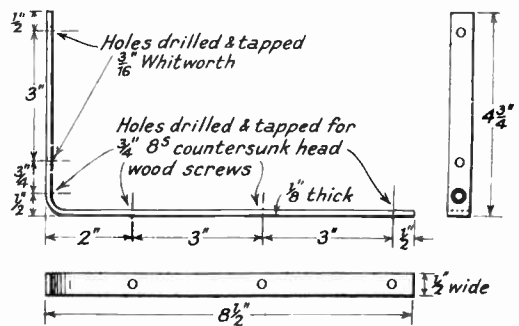


Fig. 9.—THE PANEL BRACKETS. Two of these are required, made from wrought iron.

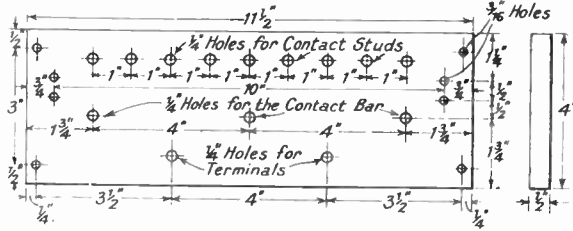


Fig. 10.—DRILLING DIMENSIONS OF THE SLATE PANEL.

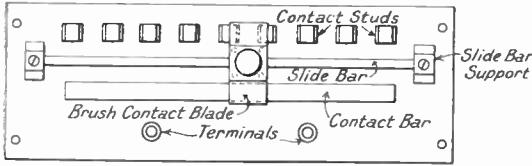


Fig. 11.—THE PANEL READY FOR MOUNTING ON THE BRACKETS.

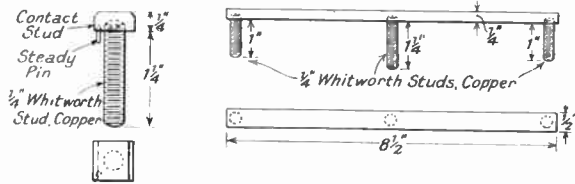


Fig. 12 (left).—THE CONTACT STUD AND STEM, OF WHICH THERE ARE NINE IN BRASS AND (right) THE CONTACT BAR.

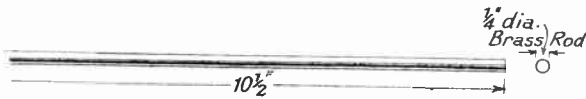


Fig. 13.—THE SLIDE BAR.

iron wire are cut up into 12 in. lengths, and each length straightened out.

Three pieces of 2 3/4 in. diameter thin iron pipe are cut to the given lengths. One of them is fitted with a 1/4-in. Whitworth screwed stud, which passes across the inside of the pipe, and projects for a distance of 1 1/4 in. above the surface. The stud is sweated securely in position.

The lengths of iron are packed tightly inside the three lengths of cut pipe, which are spaced apart from each other. The core is bound tightly with two bindings of soft steel wire which are sweated in position, the lengths of cut pipe are also sweated to the core to prevent the core humming when it is in use.

A suitable handle is made from hard wood and a flat piece of spring steel drilled through the centre and bent to the shape of an arc of a circle. The spring is fitted and fixed securely with nuts to the stud, so that its ends will bind along the surface of the tube when the core is fitted inside. The spring will prevent the core being sucked inside the winding, when it is adjusted to any definite position inside the tube.

damage and will give the completed coil a finish.

Connecting the Flexible Copper Connections to the Loops.

The loops are cut off to a distance of 1 in. from the surface of the cord binding, and the cut ends twisted together and soldered to the ends of the flexible copper connectors. The joints are insulated with empire cloth, and glass bead insulators placed over the flexible connections.

THE LAMINATED IRON CORE.

Sixteen pounds of No. 18 S.W.G.

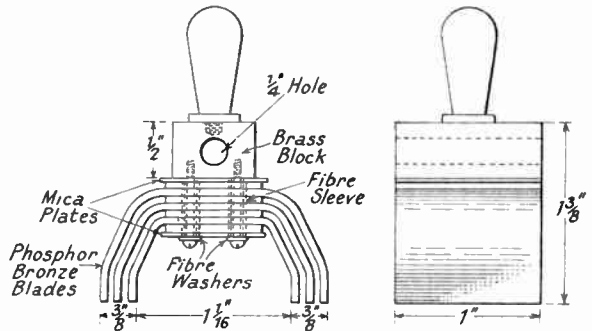


Fig. 14.—THE BRUSH CONTACT BLADE AND HANDLE.

The completed core is fitted inside the tube, and the wooden tube end fixed in position at the end with three $\frac{3}{8}$ in. 5's copper headed screws, testing the edges for alignment with the tube end and centre support.

REGULATION SWITCH AND PANEL.

The various parts of the switch are now made to the dimensions as shown in the drawings. Particular care should be paid to the fitting of the brush contact blade and good contact is essential between the blade and the stud contacts and slide bar.

The brush contact blade is insulated from the brass block with mica plates, and fibre sleeves insulate the fixing screws from the contact blade.

The panel, which should be made of good slate, is drilled and the various parts of the switch assembled on it. The contact studs should be fitted with steady pins to prevent them from turning when the brush contact blade moves over them, and each of the assembled parts on the panel securely locked to it with two nuts.

The Panel Fixing Brackets.

Two of these are made from a length of wrought iron strip $\frac{1}{2}$ in. wide and $\frac{1}{8}$ in. thick. Each bracket is drilled and tapped to admit $\frac{3}{16}$ in. Whitworth studs, which hold the panel to the brackets, and holes are drilled and countersunk for the fixing screws, which secure the brackets to the baseboard.

The Baseboard.

This is made from a piece of $\frac{3}{4}$ in. thick teak cut to the given dimensions and strengthened with two $1\frac{1}{2}$ -in. square

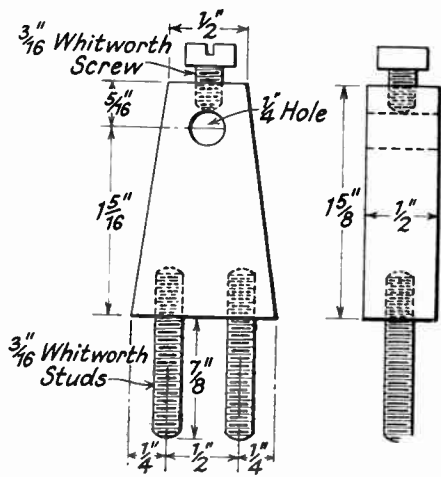


Fig. 15.—THE SLIDE BAR SUPPORT. Two are required, in brass.

battens fixed on the underside. The ends of the board are dovetailed to receive the dovetailed edges of the wooden tube ends.

Fixing the Coil and Panel Brackets.

The dovetailed edges of the coil tube are fitted into the dovetailed edges at the ends of the baseboard. In order to do this, remove the tube end from the core end of the tube, then fit the other tube and dovetailed edges into the end of the board; hold the core end of the tube in position and tap the dovetailed edges of the tube end, which has been removed, into the dovetailed edges of this end of the board, the tube entering the hole in the tube end. The dovetailed joints are glued and fixing screws are driven from the underside of the battens into the base of the tube ends.

The brackets are now screwed to the baseboard with $\frac{3}{4}$ in. 8's countersunk head brass screws, and the slate panel fixed in position on the brackets, a nut is screwed over the end of each fixing stud to hold the panel secure.

Connecting the Tappings.

The ends of the flexible copper connectors from the tappings of the coil are connected to the contact studs and terminals, as shown in the diagram of connections. Make sure all the connections are made to the right contact studs.

The whole of the woodwork may be given a coat of shellac varnish.

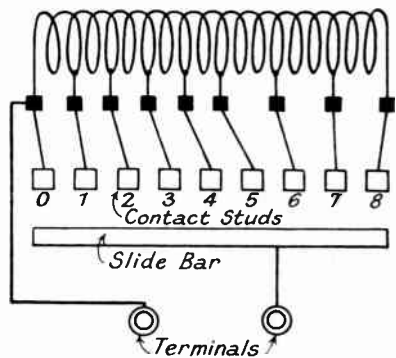


Fig. 16.—DIAGRAM OF CONNECTIONS FOR THE VARIABLE CHOKE.

USEFUL WIRING DIAGRAMS

SOME TYPICAL ELECTRICAL CIRCUITS IN THEORY AND PRACTICE

By T. LINSTEAD

THE circuits and connections shown in the following 20 pages are mainly theoretical, but where possible the practical application has been considered also. They are not intended to cover the whole scope of the circuits of the section to which they apply, but are given as a representative sample of the more commonplace connections required by the electrician in his daily round.

Transformers.

The diagrams on page 1837 deal with three methods of transforming the current from a company's supply where the pressure of that supply is in excess of the consumers' requirements, but there is sufficient in the transforming of electrical energy to fill a book with such diagrams, not to mention other sections, such as distribution, conversion, etc. It is sometimes necessary, however, for current to be so transformed in ordinary household requirements, and it is for this reason that they are inserted.

Lighting.

Pages 1838-1840 deal with typical lighting circuits in more or less common use, and from them the enterprising electrician should be able to adapt any circuit or method of switching to his individual requirements by studying the principles involved.

The circuit in Fig. 14 embodies the same principle as Fig. 13, but TS is a twin knob switch which when both sides are open switches S and T control only lamp No. 1, when the left-hand is closed switches S and T control lamps Nos. 1 and 2. With left-hand open and right-hand closed they control lamps Nos. 1, 3 and 4 and when both sides are closed they control all lamps, and thus we can operate 1, 3 or 4 lamps at will.

In Fig. 15 switches S are ordinary two-way with their straps removed. M is an ordinary single switch. When switch M is closed lamp No. 1 is on, when switch S is reversed it extinguishes No. 1 and lights

No. 2. S₂ reversed will extinguish No. 2 and light No. 3. Similarly will S₃ and 4 operate the respective lights. This control is only suitable for long corridors having one entrance, because on the return journey the switches must all be again reversed to allow their being in the position ready for the next entry.

Heating Appliances and Their Switches.

So much is often taken for granted that one is apt to refrain from attempting to discover what happens when, say, a fire is switched on. Pages 1842 and 1843 endeavour to show you, while on page 1844, on the one hand, is depicted the correct method of making internal connections on a cooker control board and not, as is sometimes done, so that the cooker has to be rendered "alive" in order to use the subsidiary circuit.

Motor Control.

On pages 1845-1849 are shown the connections for different types of D.C. starters graded under series wound, shunt wound and compensated motors, and on pages 1849-1851 the simple starting connections for one, two and three-phase A.C. motors.

Methods of Charging Accumulators.

On page 1853 is shown one method of charging an accumulator installation often used in private plant.

The current generated by the dynamo is passed from the positive side to the regulating switches A and B, the former governing the number of cells on charge and the latter the number on discharge. C is an automatic switch to close the charging circuit when the dynamo voltage exceeds the battery voltage, and for breaking when the condition is reversed. D is a two-way switch to enable the voltage to be read in a charging or discharging circuit. E is a similar switch allowing the current to be read in the same circuits according to its position.

This method allows distribution to take place while charging is in operation.

DISTRIBUTION.

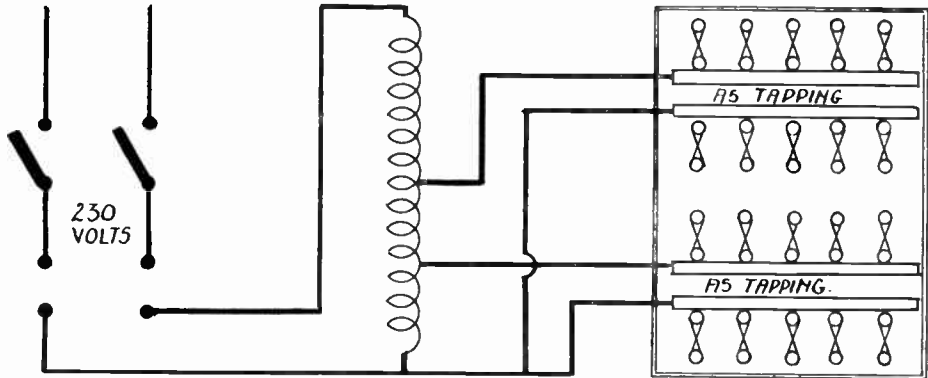


Fig. 1.—METHOD OF DISTRIBUTING CURRENT AT TWO PRESSURES BY MEANS OF STEP-DOWN TRANSFORMER.

The above circuit diagram explains how it is possible to step down a supply of, say, 230 volts and take off two pressures at, say, 100 and 50 volts respectively.

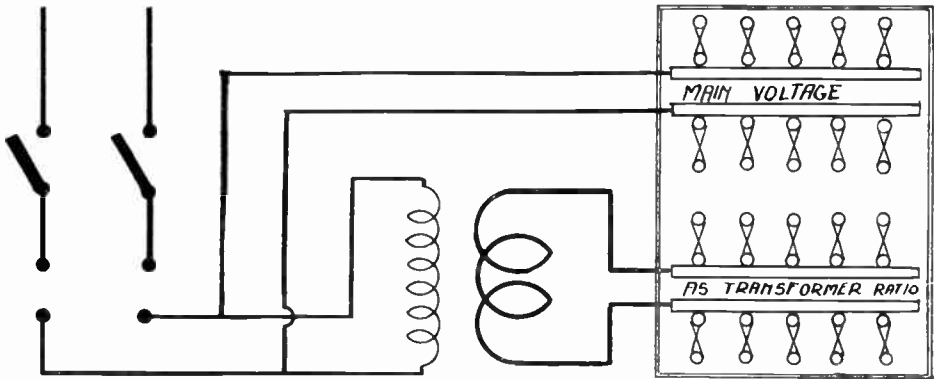


Fig. 2.—METHOD OF DISTRIBUTING CURRENT AT TWO PRESSURES BY MEANS OF STEP-DOWN TRANSFORMER.

This circuit shows the possibility of feeding one distribution board at full pressure and one at a lower pressure by means of a step-down transformer.

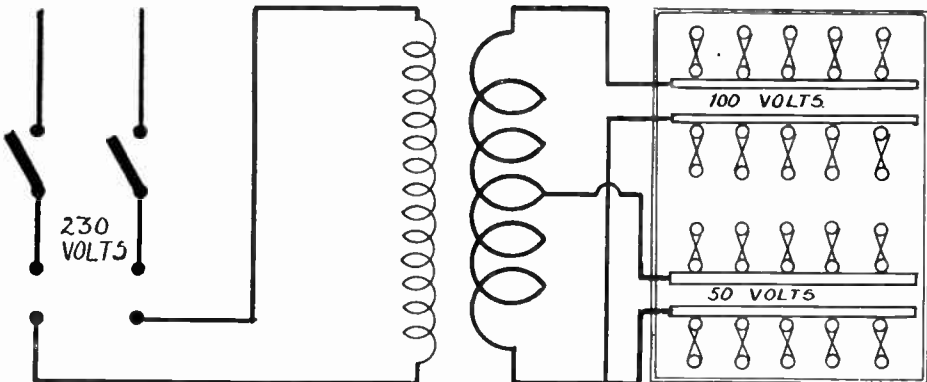


Fig. 3.—METHOD OF DISTRIBUTING A SUPPLY AT TWO PRESSURES BY MEANS OF AN AUTO TRANSFORMER.

By this means any given pressure can be determined by tappings on the auto transformer.

LIGHTING.

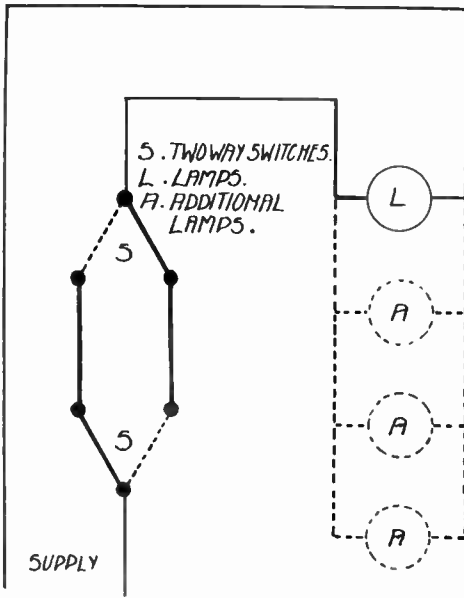


Fig. 4.—A SIMPLE TWO-WAY CIRCUIT. The solid lines comprise the most simple two-way circuit, while the dotted lines show how additional lamps may be added in parallel.

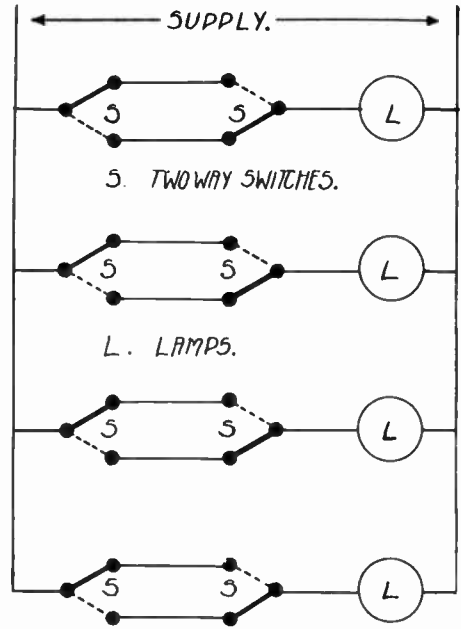


Fig. 5.—TWO-WAY CIRCUITS. In the above diagram each lamp is controlled by its own pair of two-way switches, although the lamps are in parallel.

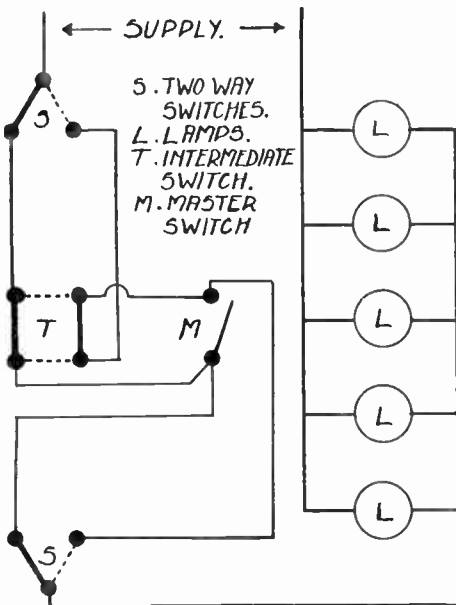


Fig. 6.—MULTI-POINT AND MASTER CONTROL. The lamps are independently controlled by the switches S and T, but when the master switch M is closed the lights cannot be extinguished except by this switch.

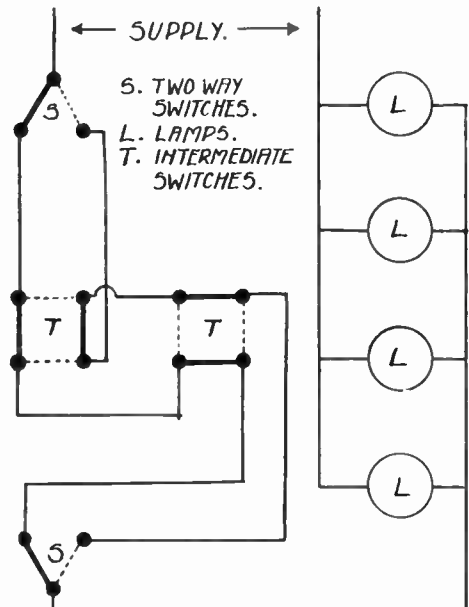


Fig. 7.—MULTI-POINT CONTROL. In this circuit the lamps can be operated from either of the switches S or T.

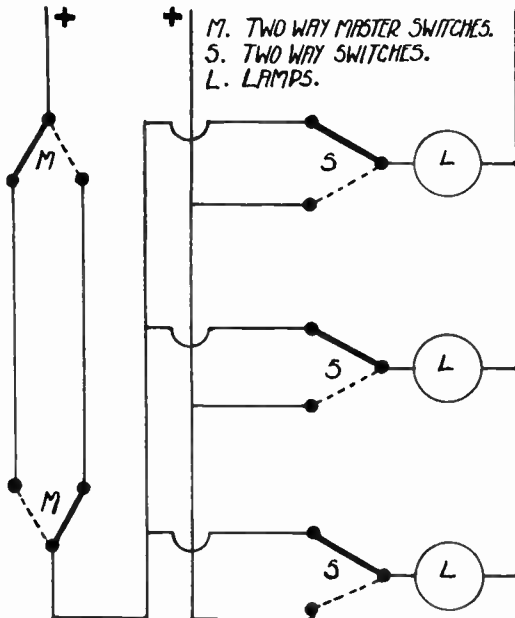


Fig. 8.—MASTER CONTROL.

By the use of a circuit and two-way switches such as this the lamps are controlled by their two-way switches S, but are subject to the two-way master control of the switches M. Two positive feeds are necessary, connected to either side of switches S.

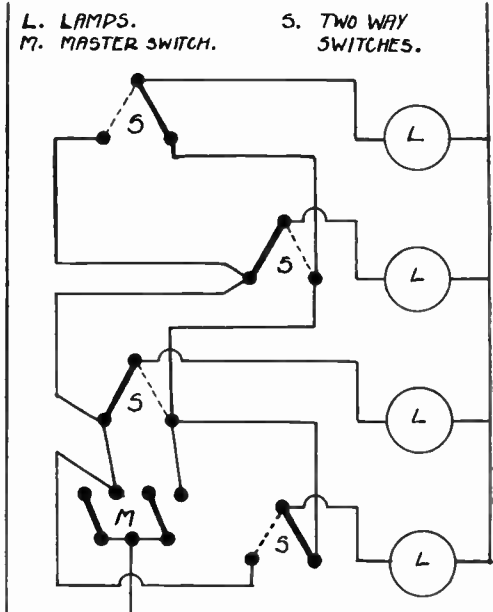


Fig. 9.—MASTER CONTROL.

When the switch M is off no lamps can be lighted. If any half of the switch M is placed on, any lamp may be controlled from its own switch. When both halves of switch M are on the lamps are not controlled by own switches.

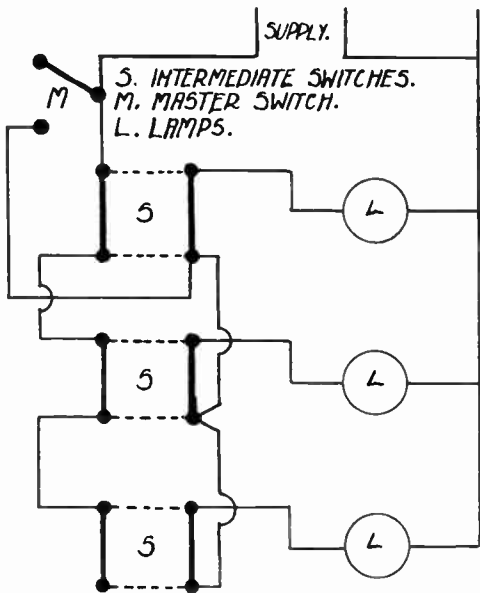


Fig. 10.—MASTER CONTROL.

The lamps L are controlled by separate switches, but the whole may be lighted and kept alight by the switch M.

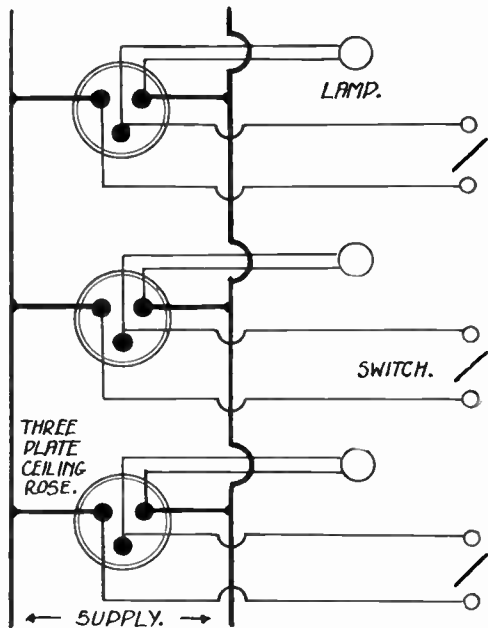


Fig. 11.—THE CONNECTIONS OF A THREE-PLATE CEILING ROSE.

To enable feeds to be looped in and out.

LIGHTING.

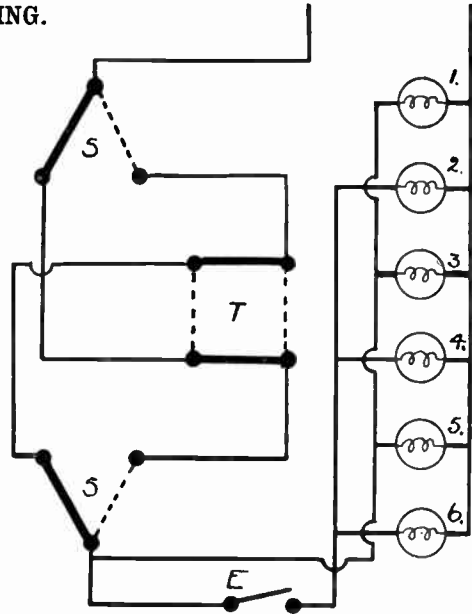
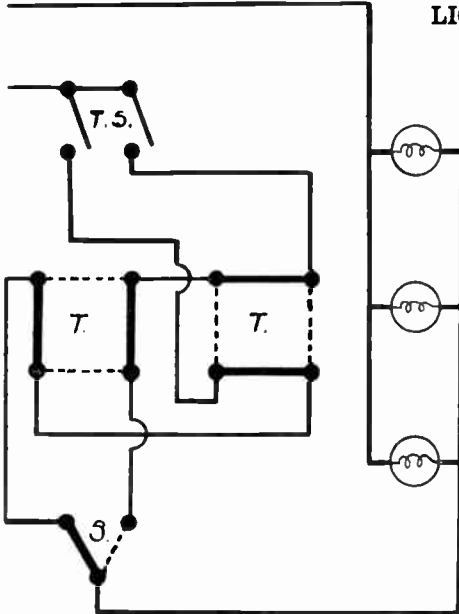


Fig. 12.—MASTER CONTROL FOR KEEPING LAMPS EXTINGUISHED OR ILLUMINATED.

Switch TS is a twin knob switch and when open all lamps are kept extinguished. If both sides are closed all lamps remain illuminated irrespective of the switches S and T. If one side be closed and one open switches S and T resume their normal control.

Fig. 13.—A TWO-WAY AND INTERMEDIATE CIRCUIT WITH VARYING CONTROL.

When the switch E is open the switches S and T control lamps Nos. 1, 3 and 5 only, but when E is closed they control all the lamps.

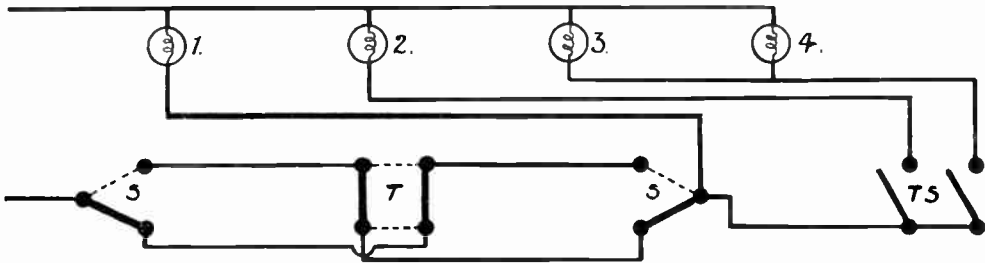


Fig. 14.—A TWO-WAY AND INTERMEDIATE CIRCUIT WITH VARYING CONTROL (see page 1836).

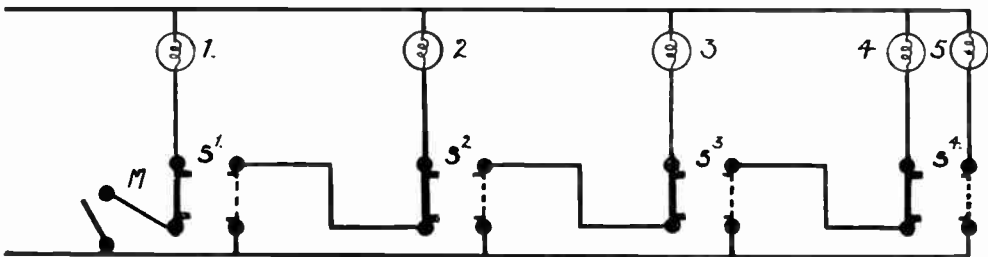


Fig. 15.—AN EXAMPLE OF RESTRICTED CONTROL (see page 1836).

BELLS.

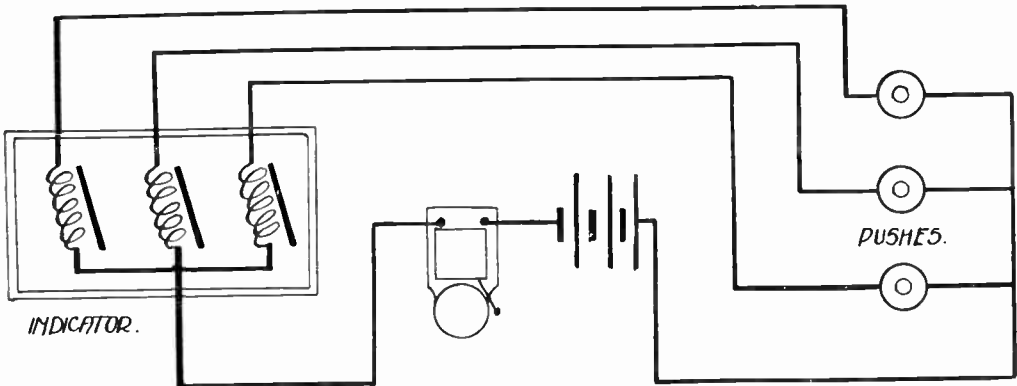


Fig. 16.—BELL CIRCUITS.

This diagram shows a simple bell circuit with pushes wired in parallel and connected to an indicator.

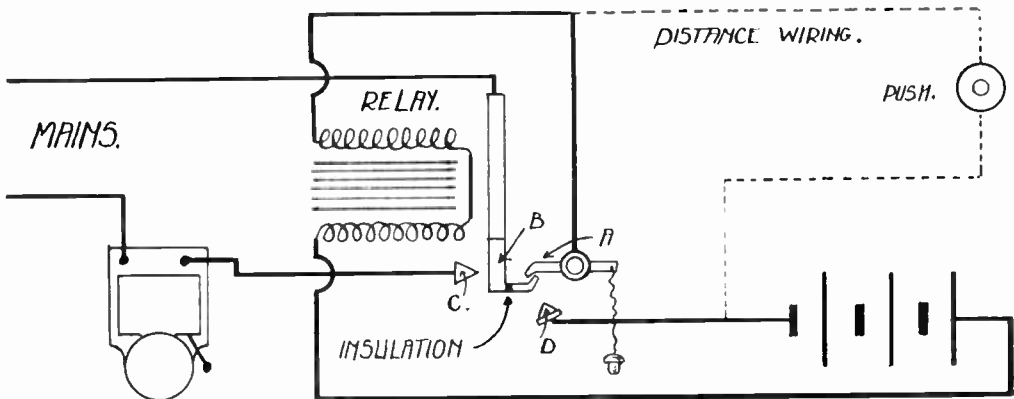


Fig. 17.—CONTINUOUS RINGING RELAY CIRCUIT WITH MAINS OPERATED BELL.

The object of this circuit is to enable a bell to be operated from a distance. When the push is pressed the circuit is *via* the battery and relay which attracts the armature B on to point C and completes the mains circuit. A then drops to B and forms a local circuit which keeps the relay in action irrespective of the push, and remains so until the trigger is set. It is important to note that while B must make contact with C the trigger portion must be insulated from A.

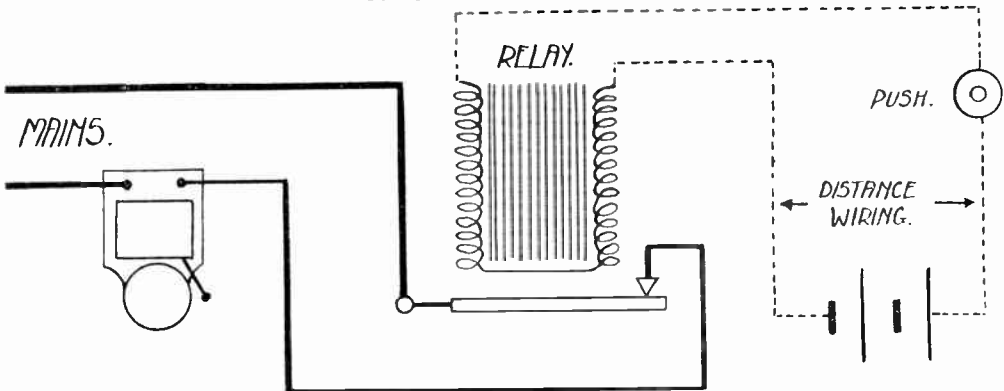


Fig. 18.—RELAY CIRCUIT FOR MAINS OPERATED BELL WITHOUT CONTINUOUS RINGING.

On pressing the push the armature of the relay is attracted and completes the mains circuit as shown.

HEATING.

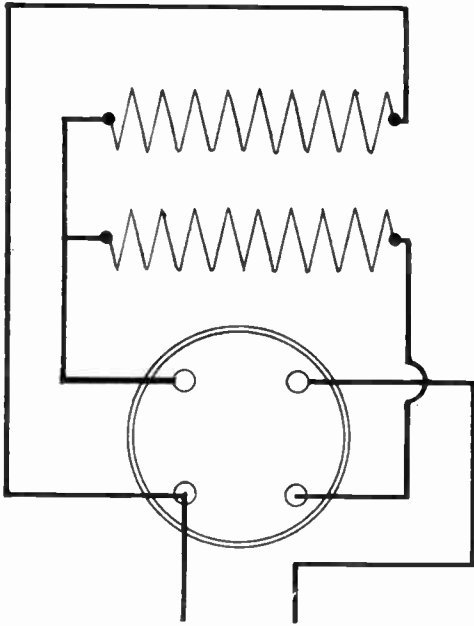


Fig. 19.—OFF POSITION.

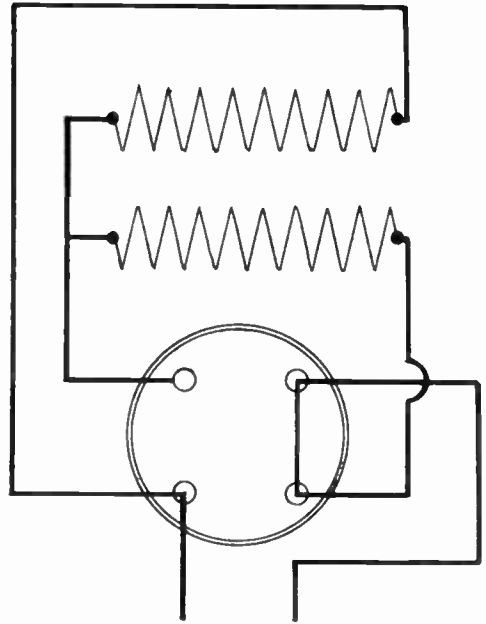


Fig. 20.—LOW. BOTH ELEMENTS IN SERIES.

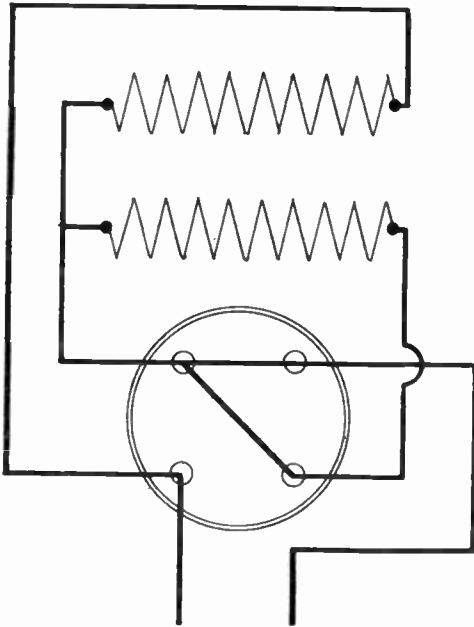


Fig. 21.—MEDIUM. ONE ELEMENT ONLY BEING USED.

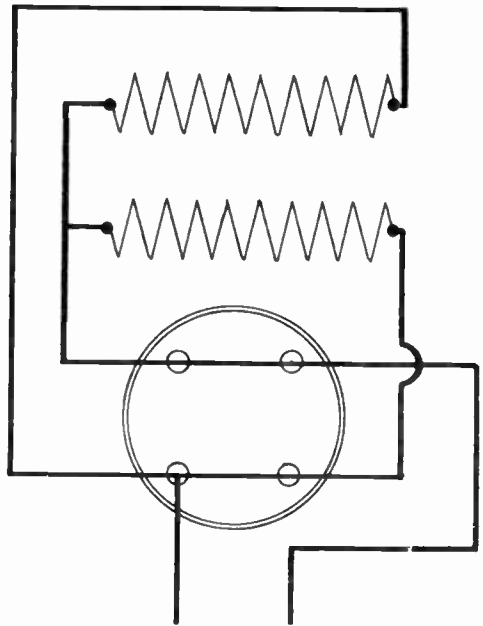


Fig. 22.—HIGH. BOTH ELEMENTS IN PARALLEL.

Heater Connections.

The above diagrams illustrate the method of wiring two elements and their switches for three degrees of heat.

HEATING.

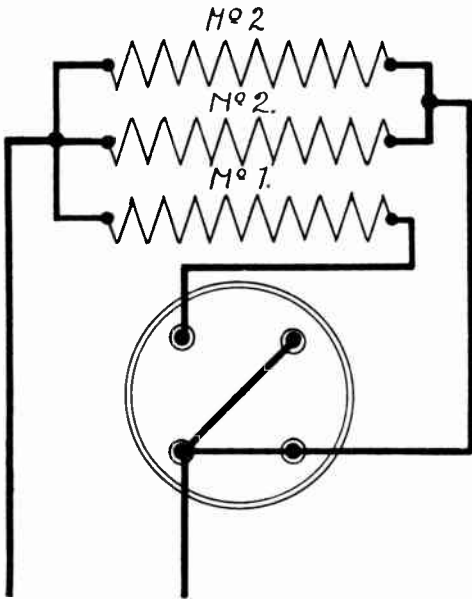


Fig. 23.—OFF POSITION.

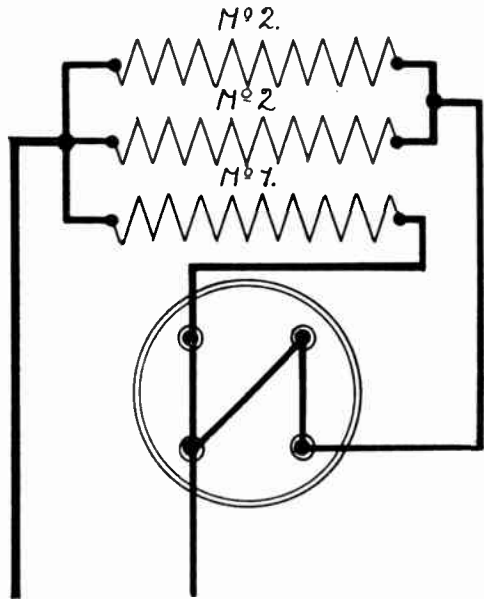


Fig. 24.—Low. No. 1 ELEMENT ONLY BEING USED.

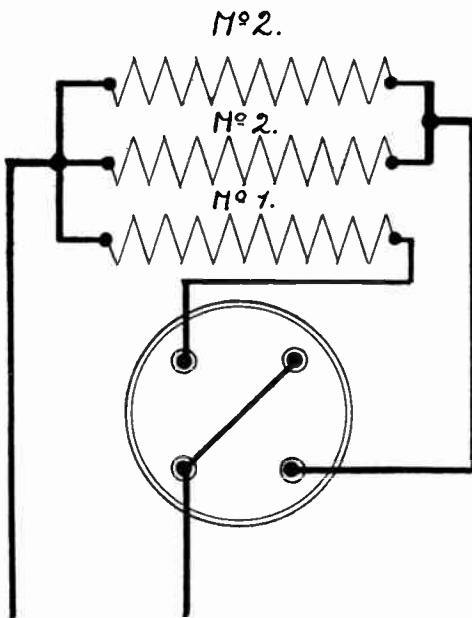


Fig. 25.—MEDIUM. NO. 2 ELEMENTS IN PARALLEL BEING USED.

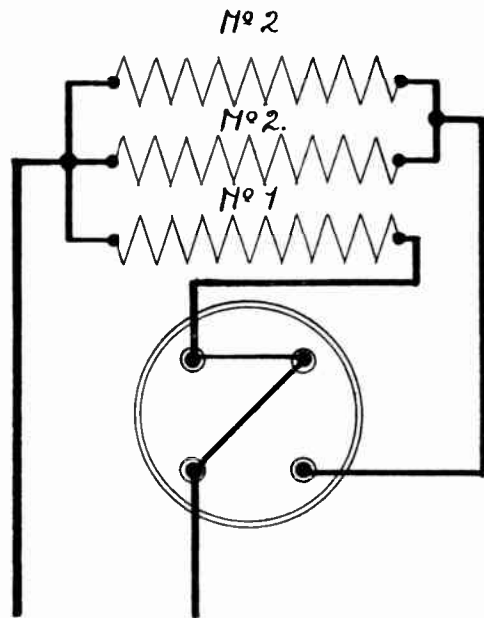


Fig. 26.—HIGH. THREE ELEMENTS IN PARALLEL.

Heater Connections.

The above diagrams illustrate the method of wiring three elements and their switches for three degrees of heat.

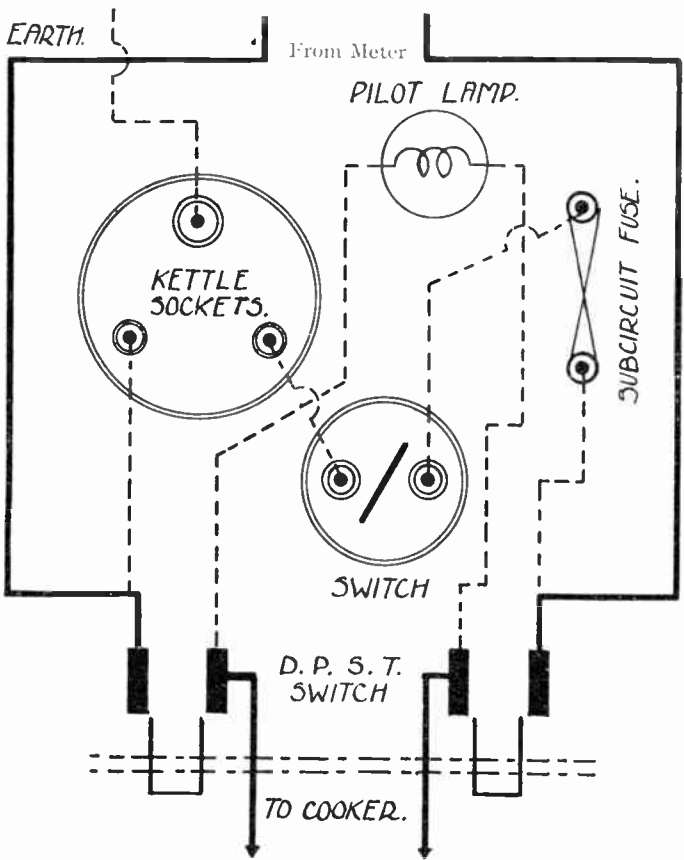


Fig. 27.—THE METHOD OF CONNECTING A COOKER CONTROL BOARD WITH SUBSIDIARY CIRCUIT FOR KETTLE, ETC., WITH PILOT LAMP.
 The subsidiary circuit is controlled by its own switch and fuse irrespective of the control switch, but when the latter is placed on, the pilot lamp is connected in parallel with the cooker and will remain alight so long as this switch is on.

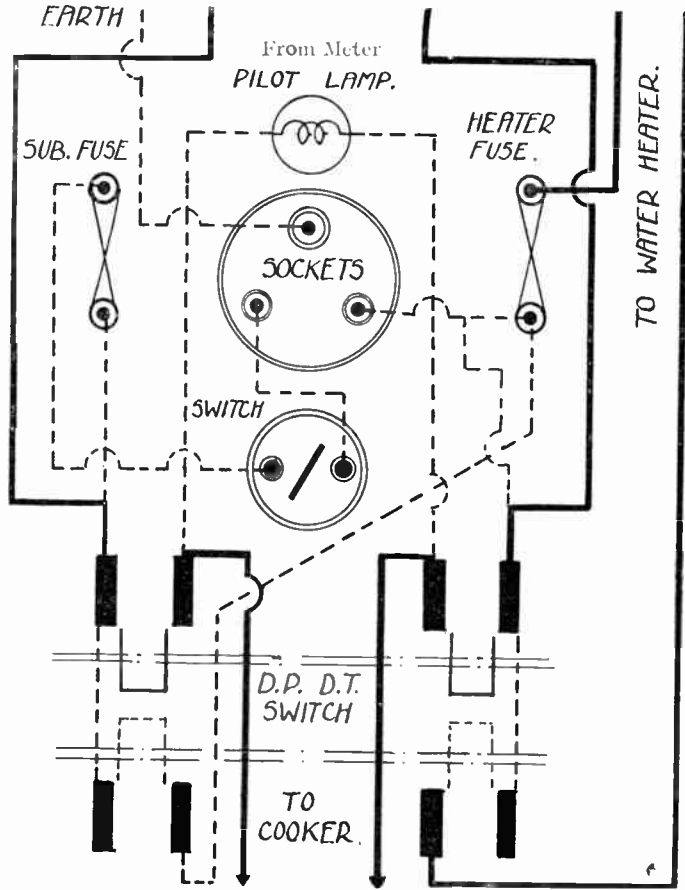


Fig. 28.—METHOD OF CONNECTING COOKER CONTROL BOARD WITH A THROW-OVER TO WATER HEATER.
 Some supply companies give a reduced rate if this control board is used in cooking and heating installation, as when the cooker is not in use the water heater is always connected and this water heater is controlled by its own thermostatic switch.

D.C. STARTERS.

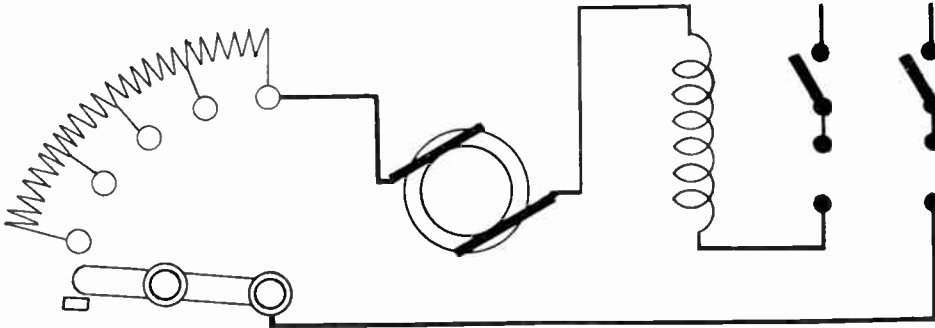


Fig. 29.—PLAIN FACE-PLATE STARTER CONNECTIONS FOR D.C. SERIES WOUND MOTOR.
The starter shown is a simple starter without no-volt release or over-load release. This means of starting can only be used for small motors up to, say, 1 h.p.

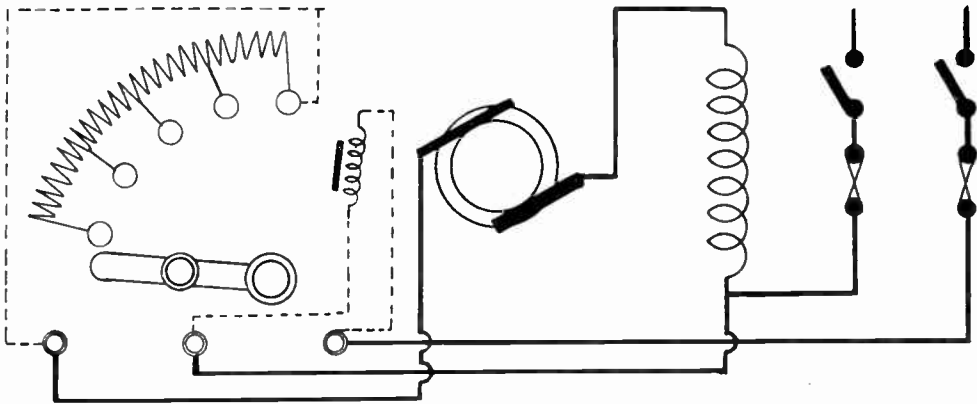


Fig. 30.—FACE-PLATE STARTER CONNECTIONS FOR D.C. SERIES WOUND MOTOR.
In this case the starter shown is similar to the above, but with the addition of a no-volt release and should be used only in similar cases.

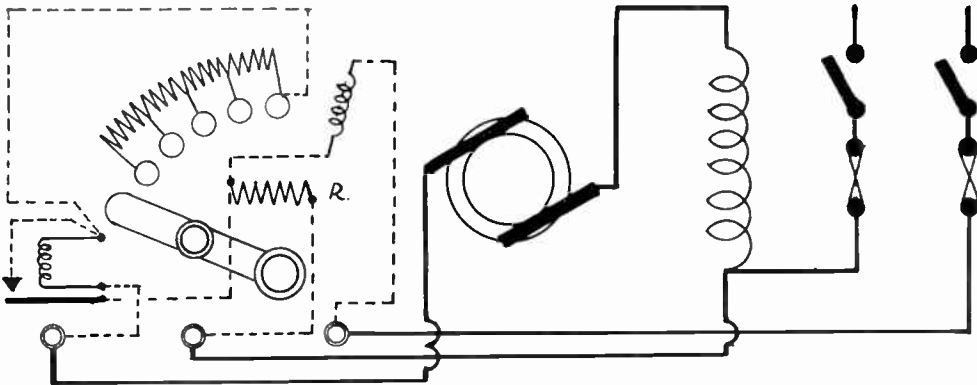


Fig. 31.—FACE-PLATE STARTER CONNECTIONS FOR D.C. SERIES WOUND MOTOR.
This starter is similar to the two above, but with the addition of an over-load release. R is a resistance in series with the no-volt release to eliminate the possibility of a dead short when the over-load release acts.

D.C. STARTERS.

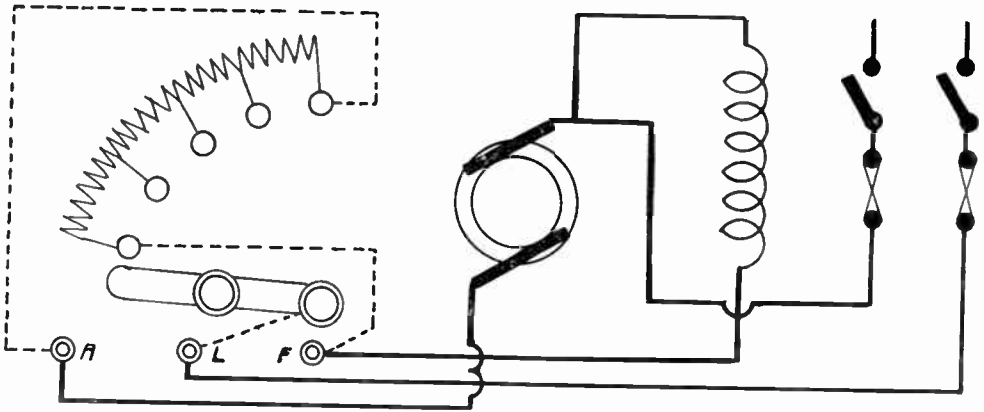


Fig. 32.—PLAIN D.C. FACE-PLATE STARTER FOR SHUNT MOTOR.
This type of starter has no over-load or no-volt release.

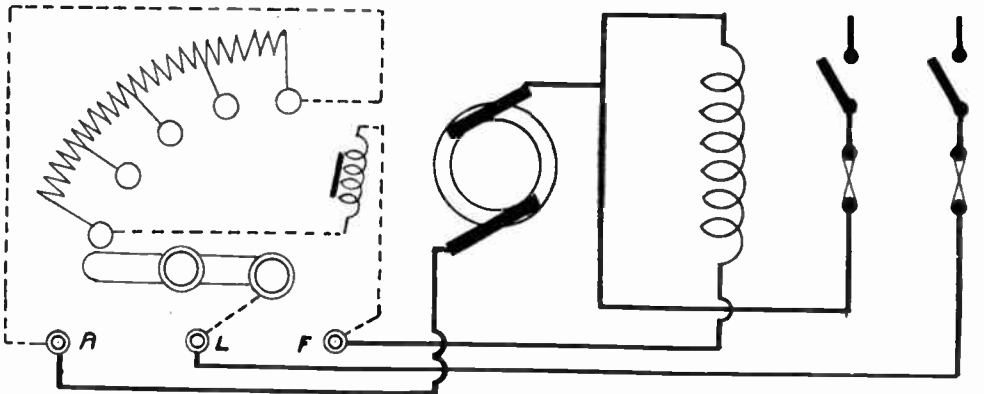


Fig. 33.—D.C. STARTER FOR SHUNT MOTOR.
This is similar to the above, but with the addition of a no-volt release.

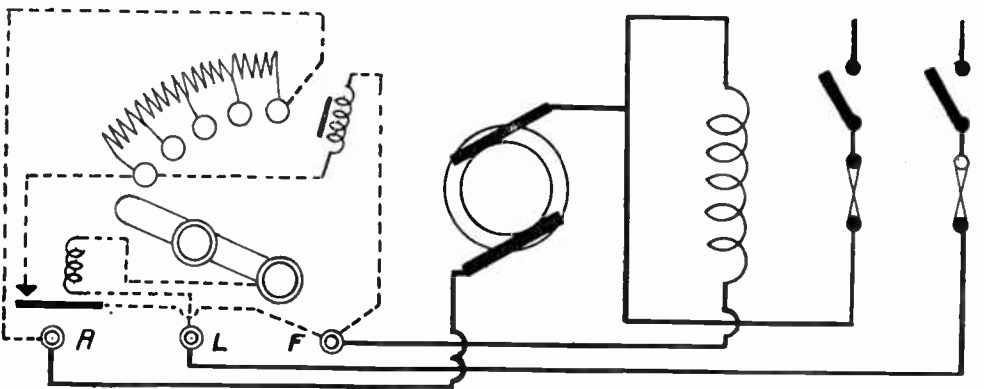


Fig. 34.—D.C. STARTER FOR SHUNT MOTOR.
This is similar to the two above, but with the addition of an over-load release.

D.C. STARTERS.

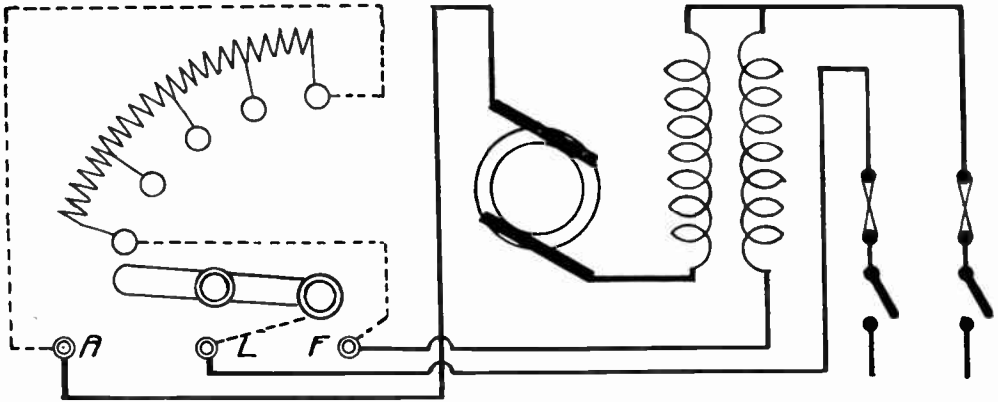


Fig. 35.—PLAIN D.C. FACE-PLATE STARTER FOR COMPENSATED MOTOR WITHOUT OVER-LOAD OR NO-VOLT RELEASE.

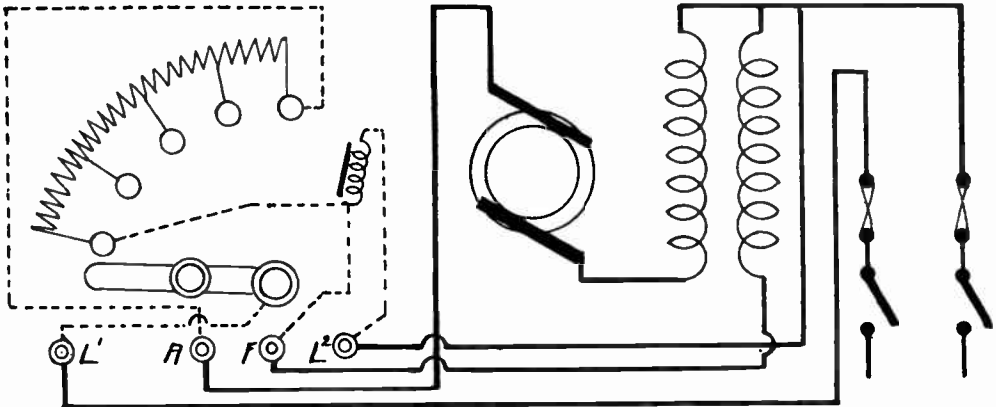


Fig. 36.—D.C. FACE-PLATE STARTER FOR COMPENSATED MOTOR WITH NO-VOLT RELEASE.

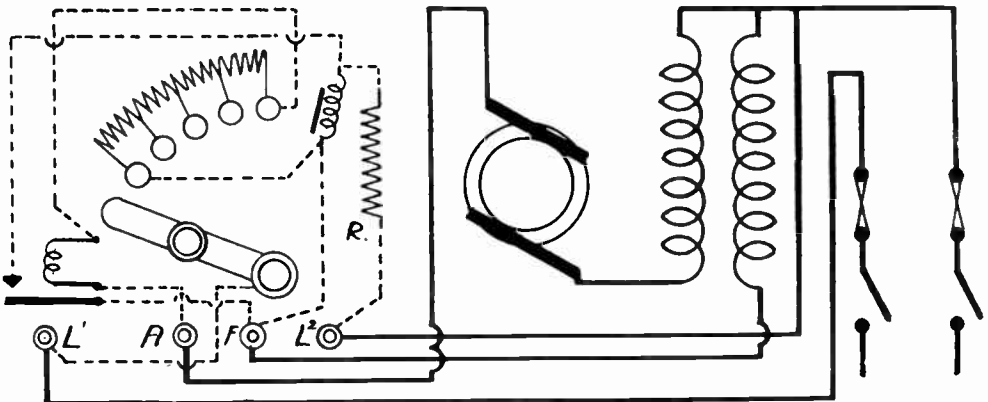


Fig. 37.—D.C. FACE-PLATE STARTER FOR COMPENSATED MOTOR WITH OVER-LOAD AND NO-VOLT RELEASE.

D.C. STARTERS.

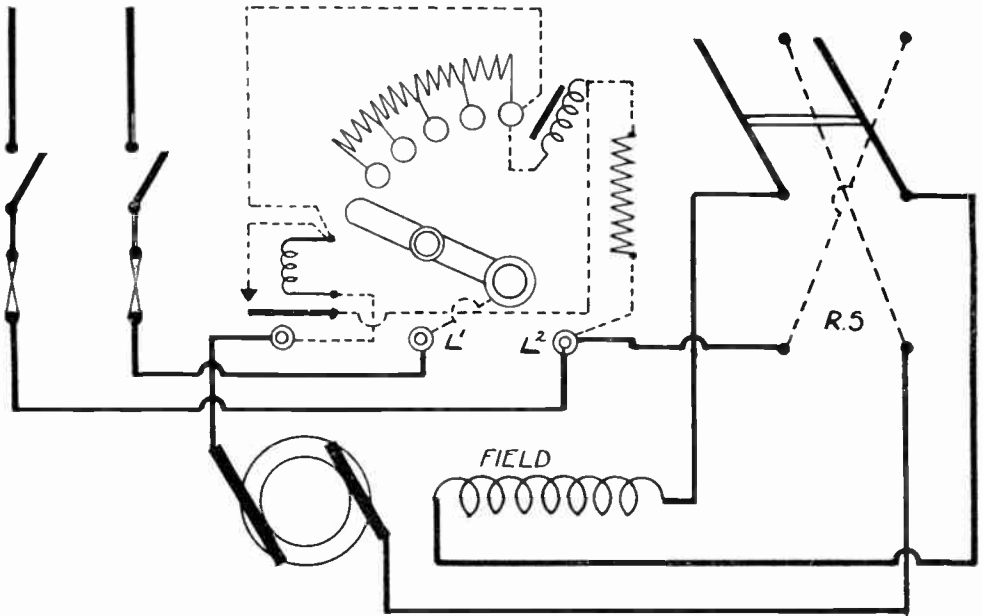


Fig. 38.—A D.C. FACE-PLATE STARTER WITH REVERSING SWITCH FOR SERIES MOTOR.

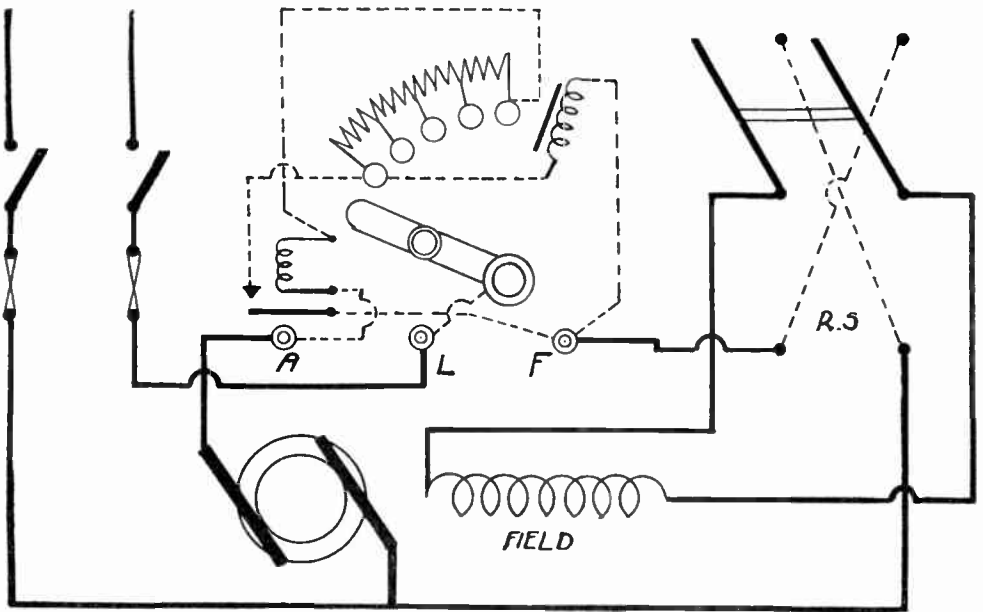


Fig. 39.—A D.C. FACE-PLATE STARTER WITH REVERSING SWITCH FOR SHUNT MOTOR.

D.C. STARTERS.

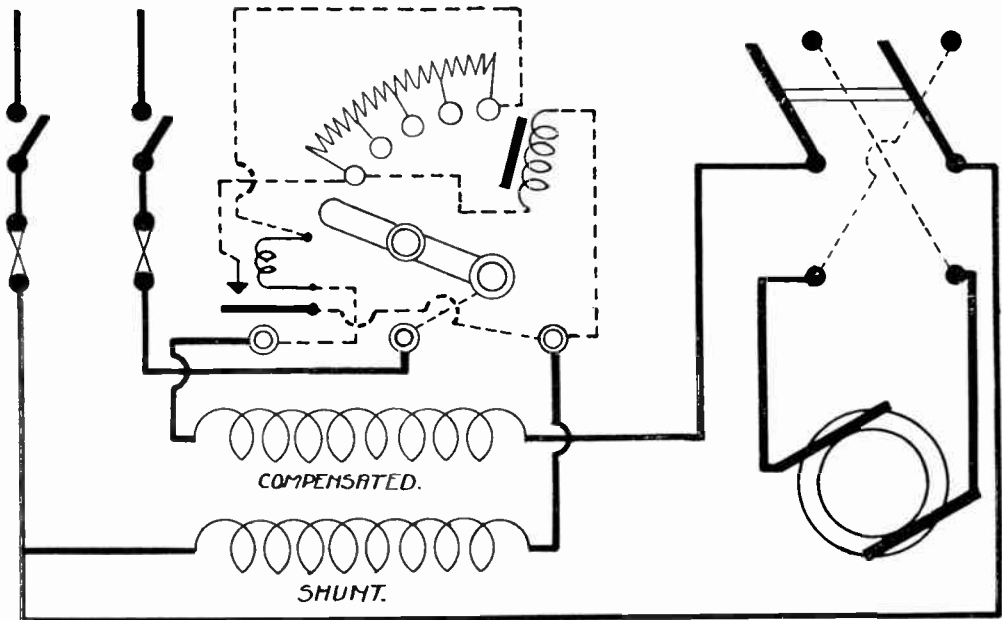


Fig. 40.—THE INTERNAL AND EXTERNAL CONNECTIONS OF A D.C. STARTER WITH REVERSING SWITCH FOR A COMPENSATED MOTOR.

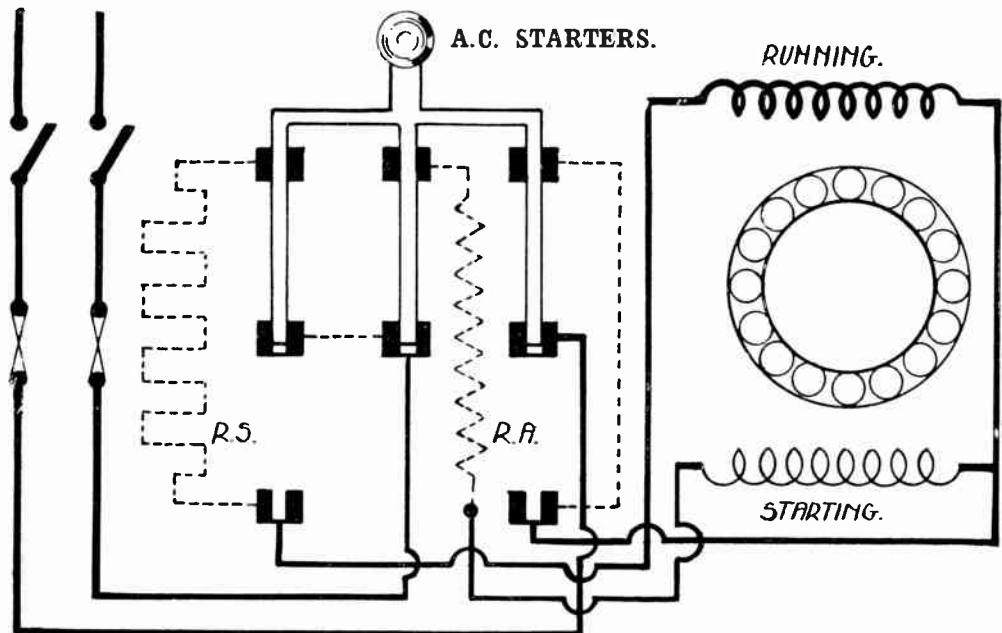


Fig. 41.—STARTING INDUCTION MOTORS.

The internal and external connections of starting switch with a single-phase induction motor. R.S. is the resistance and R.A. reactance.

A.C. STARTERS.

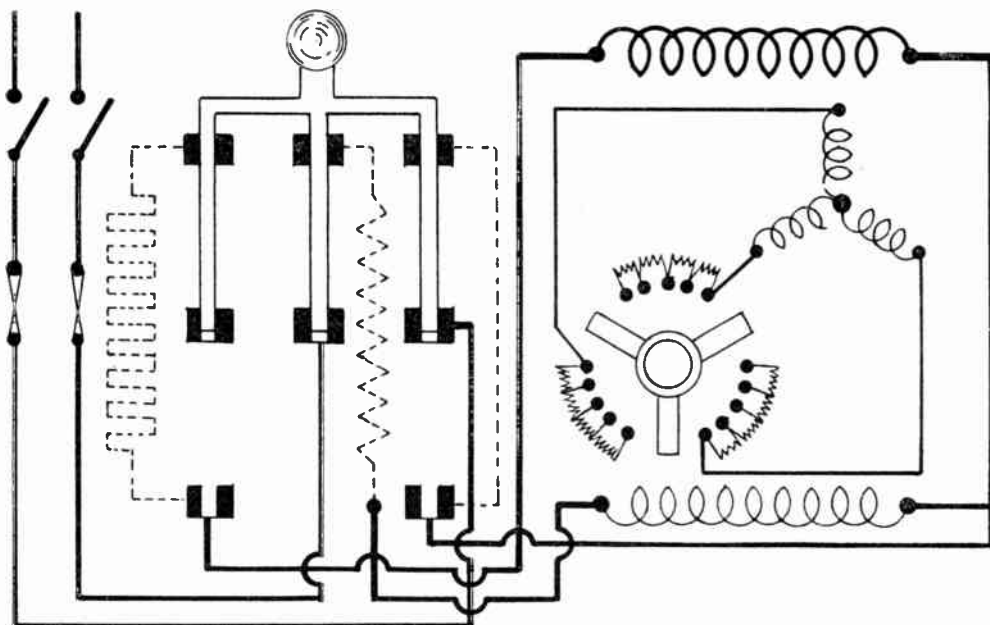


Fig. 42.—STARTING INDUCTION MOTORS.

A wiring diagram of starting switch for a single-phase induction motor with rotor and rheostat.

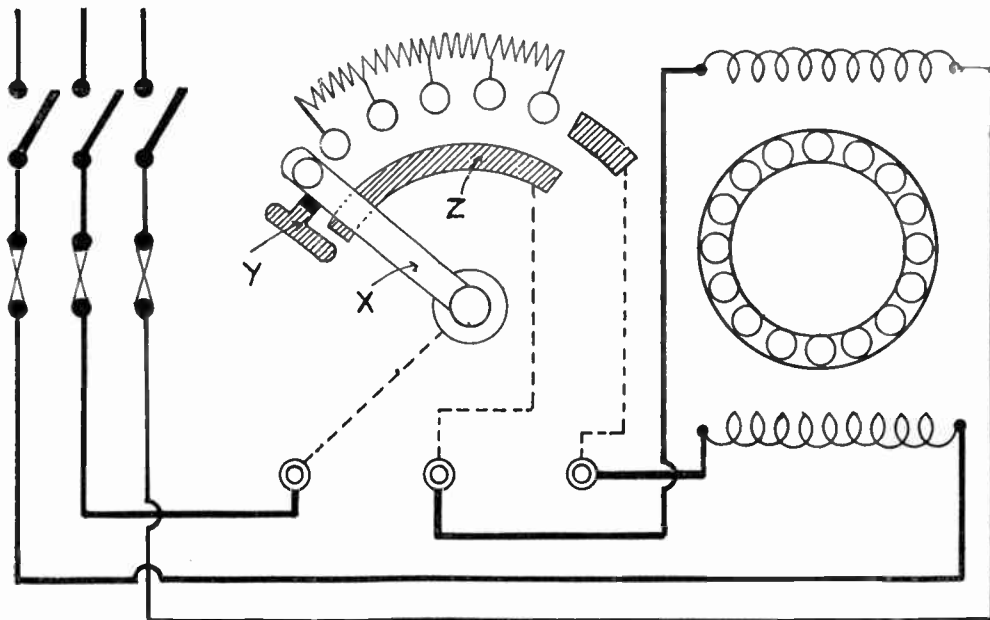


Fig. 43.—STARTING INDUCTION MOTORS.

A starting rheostat for a small two-phase motor. Y is a separate brush insulated from X, but making contact with segment Z.

A.C. STARTERS.

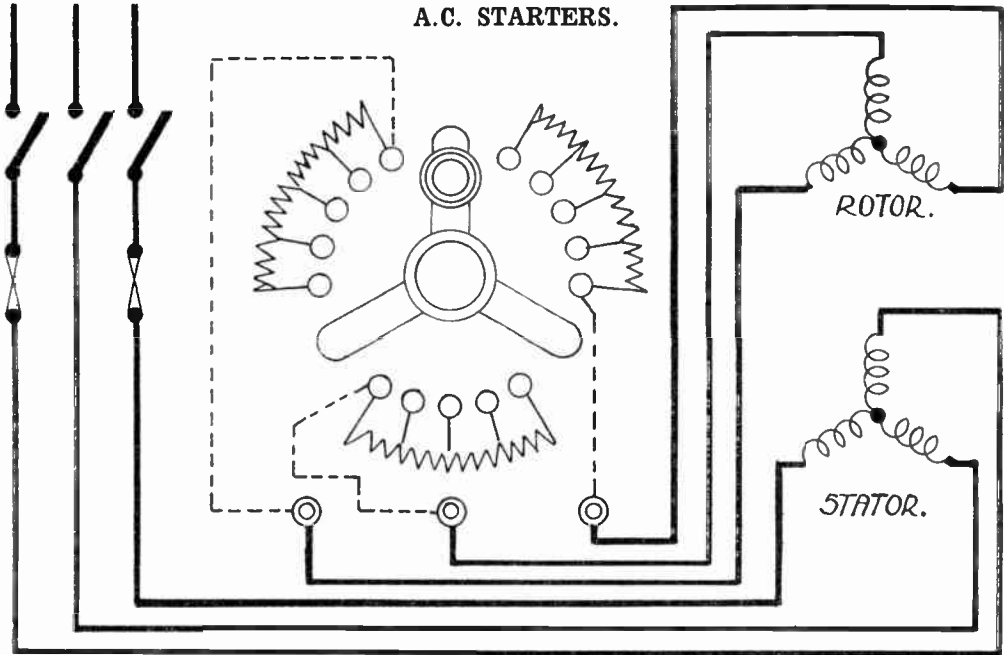


Fig. 44.—STARTING RHEOSTAT FOR A THREE-PHASE INDUCTION MOTOR WITH ROTOR RHEOSTAT.

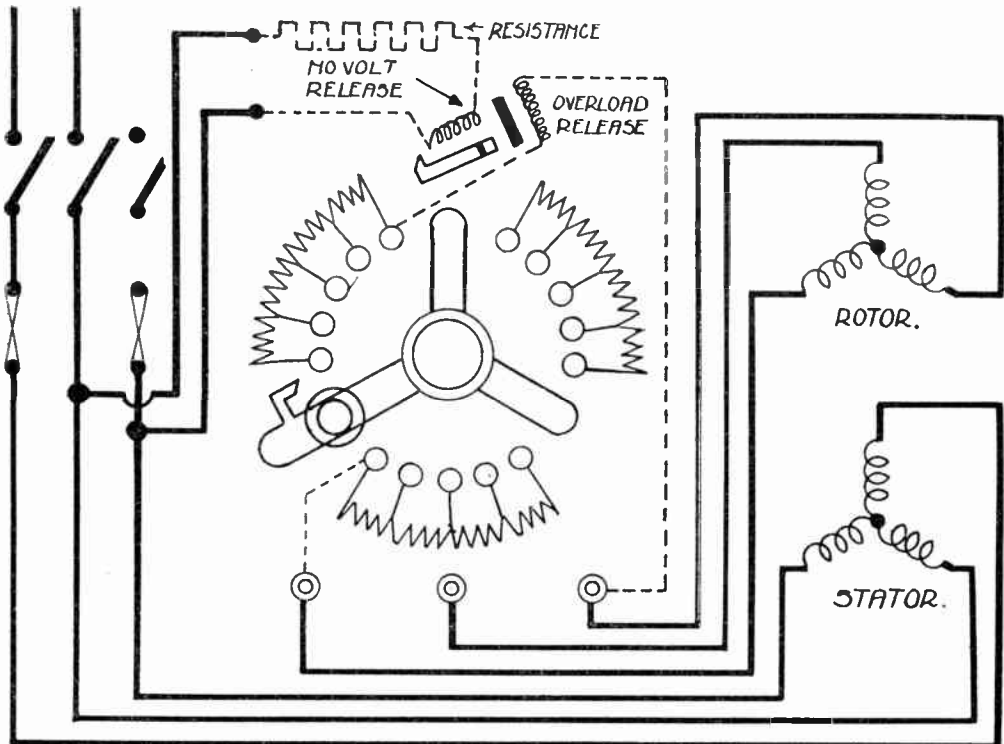


Fig. 45.—STARTING FOR THREE-PHASE MOTOR WITH ROTOR RHEOSTAT WITH NO-VOLT AND OVER-LOAD RELEASE.

USEFUL WIRING DIAGRAMS
ACCUMULATOR CHARGING.

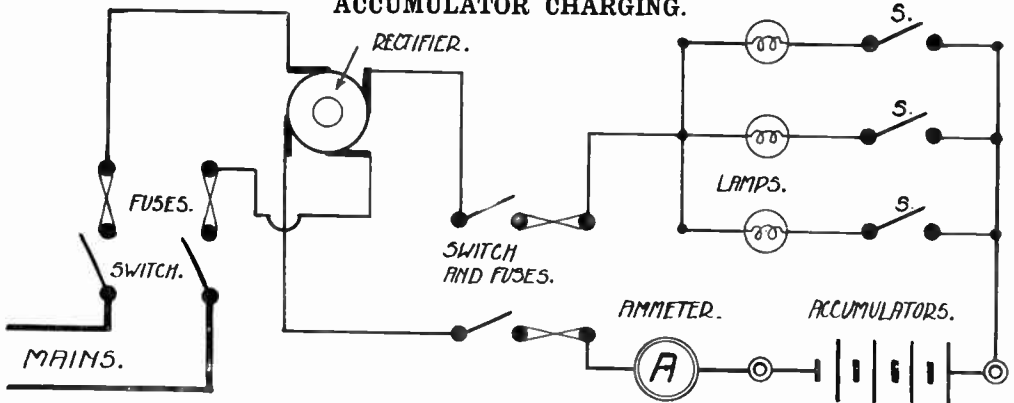


Fig. 46.—METHOD OF CHARGING ACCUMULATORS FROM AN A.C. SUPPLY.

The A.C. current is passed through a rectifier and the rectified current through resistance lamps and on to the accumulators. By the switches S 1, 2 or 3 lamps can be placed in resistance at will.

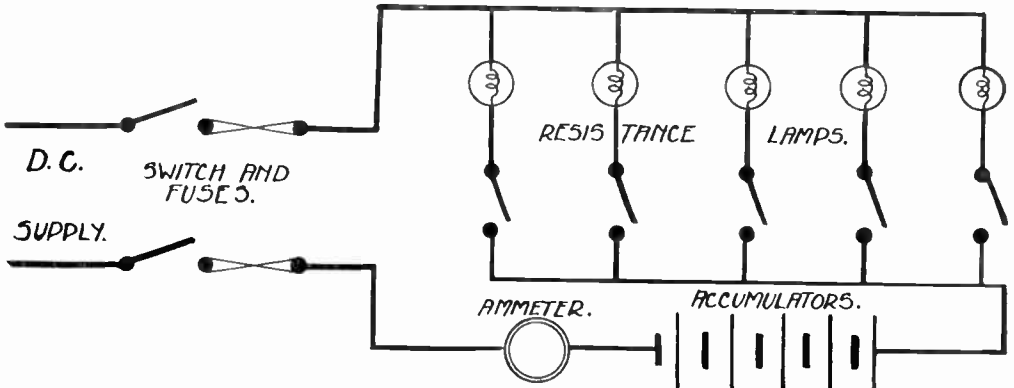


Fig. 47.—METHOD OF CHARGING ACCUMULATORS FROM A D.C. SUPPLY.

In this instance the rectifier is not necessary, the D.C. current being passed straight through the resistance lamps from the mains.

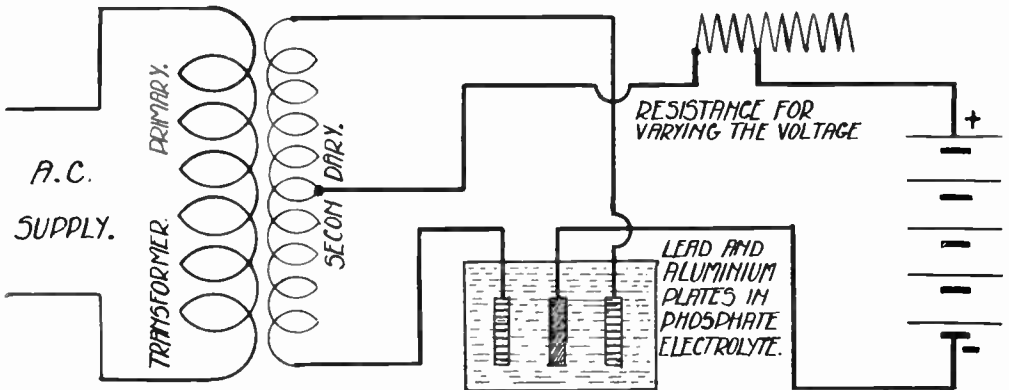


Fig. 48.—METHOD OF RECTIFYING A.C. CURRENT BY MEANS OF AN ELECTROLYTE.

The A.C. supply is passed through the primary of a transformer and the induced current in the secondary is passed through the electrolyte. While the resistance can be placed in either the A.C. or rectified circuits it is better to be placed in the latter, as the voltage can then be varied.

USEFUL WIRING DIAGRAMS
SIGN FLASHERS.

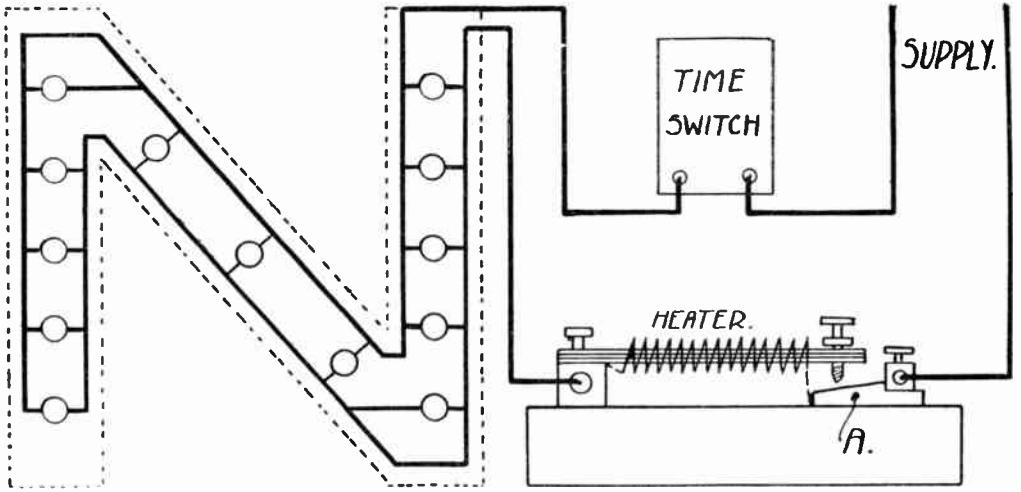


Fig. 50.—A SIGN FLASHER.

A simple flasher which is operated by heated element causing expansion and contraction and thus opening or closing the circuit at the point A.

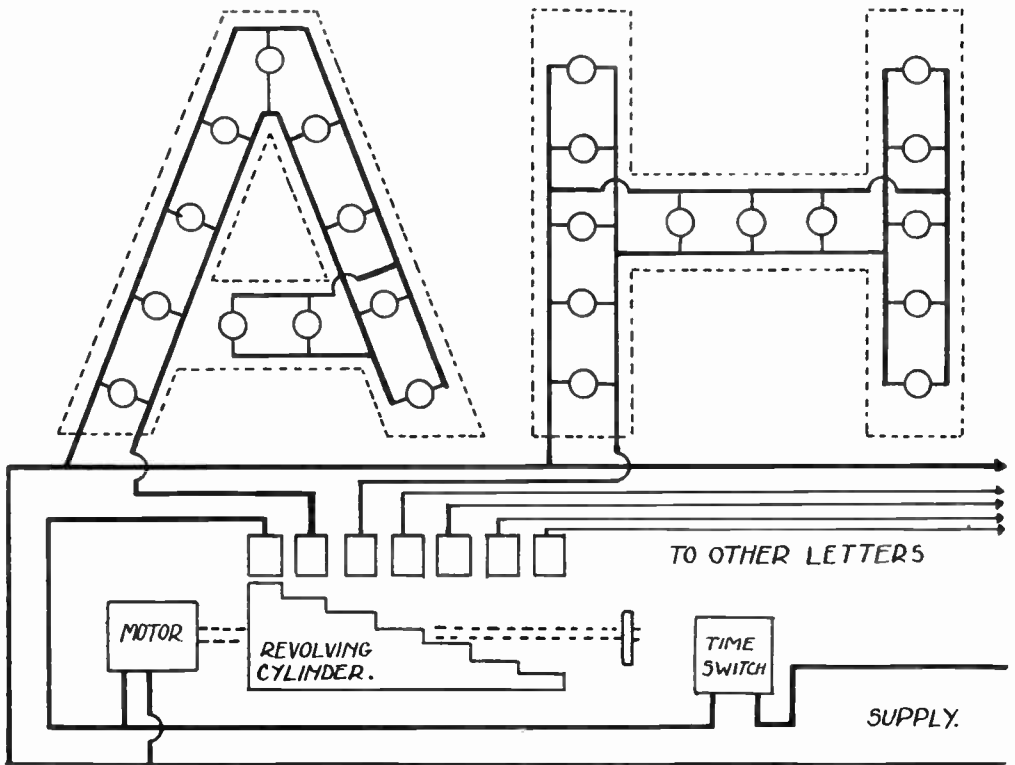
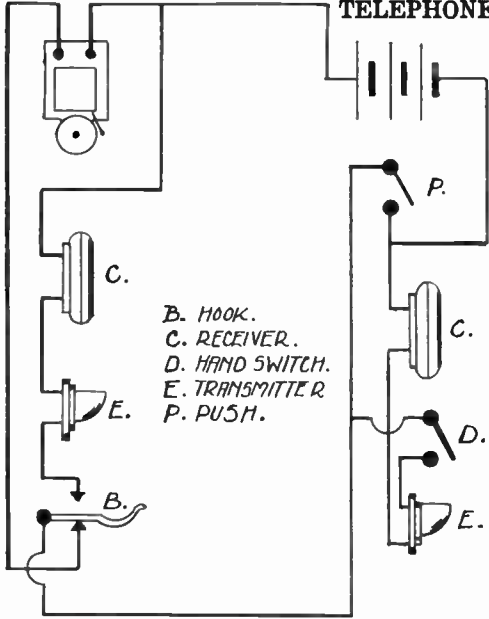


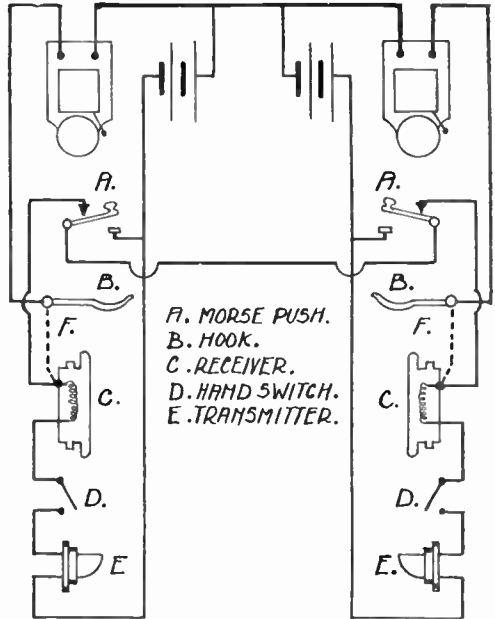
Fig. 51.—A SIGN FLASHER OPERATED BY MOTOR.

A cylinder having varying cams is revolved by an electric motor and makes consecutive contacts to small fixed points serving each letter or bank of lamps.

TELEPHONES.



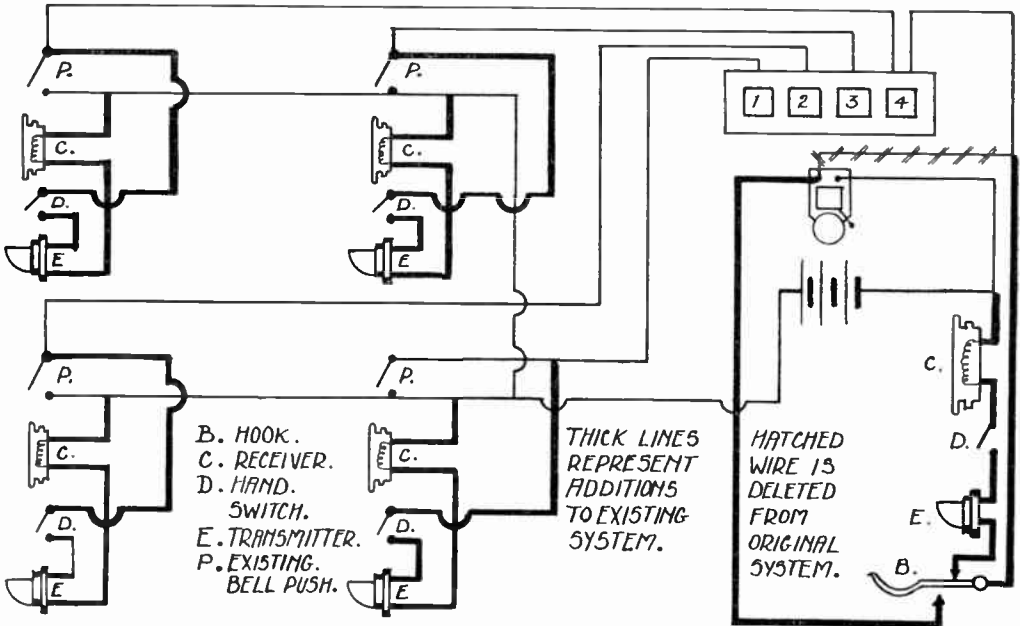
B. HOOK.
C. RECEIVER.
D. HAND SWITCH.
E. TRANSMITTER.
P. PUSH.



A. MORSE PUSH.
B. HOOK.
C. RECEIVER.
D. HAND SWITCH.
E. TRANSMITTER.
F. DOTTED LINE CONNECTION

Fig. 52.—A ONE-WAY CALLING CIRCUIT. When push P is pressed the bell is rung independently of the telephones, when P is open and D is closed and hook B making contact at top, speech circuit is complete.

Fig. 53.—TWO-WAY CALLING CIRCUIT. Dotted line F is connection made when metal case of receiver is resting on hook. When the speech circuits are closed both batteries are in use.



B. HOOK.
C. RECEIVER.
D. HAND SWITCH.
E. TRANSMITTER.
P. EXISTING BELL PUSH.

THICK LINES REPRESENT ADDITIONS TO EXISTING SYSTEM.

HATCHED WIRE IS DELETED FROM ORIGINAL SYSTEM.

Fig. 54.—METHOD OF CONNECTING TELEPHONES TO EXISTING BELL CIRCUIT WITH INDICATOR. The additions to an existing bell circuit are shown by the addition of the thick line.

TELEPHONES.

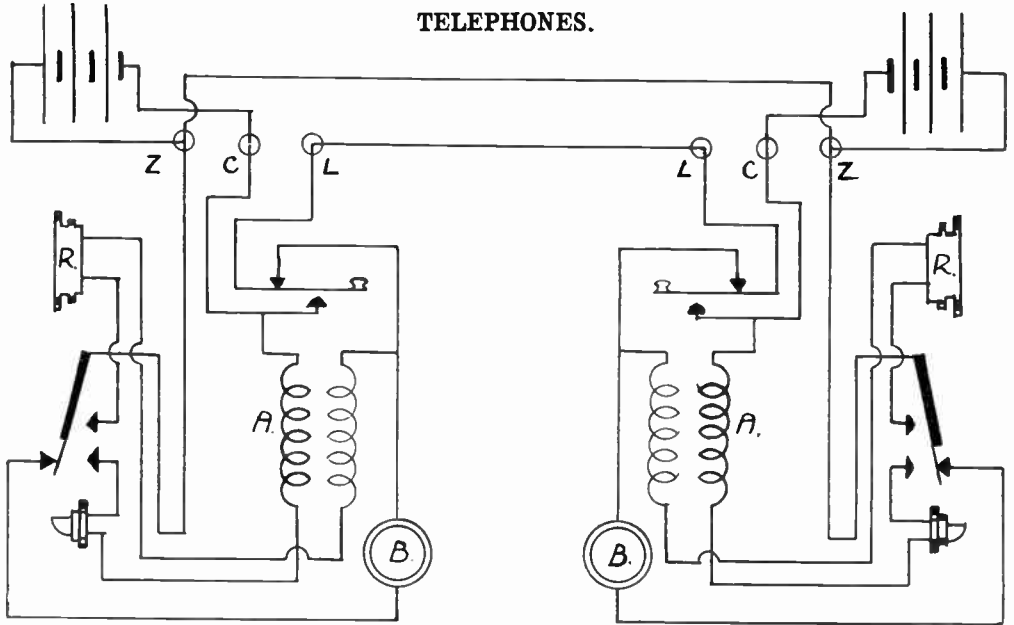


Fig. 55.—A Two-Way Telephone Circuit for Use Over Medium Distances.

This circuit employs induction coils and local batteries with hand microphones. R is the receiver; A the induction coil, and B the bell. The positions of the wires should be noted with regard to terminals Z, C and L, noting that the zinc and carbons of the batteries are connected in a special way and should not be reversed.

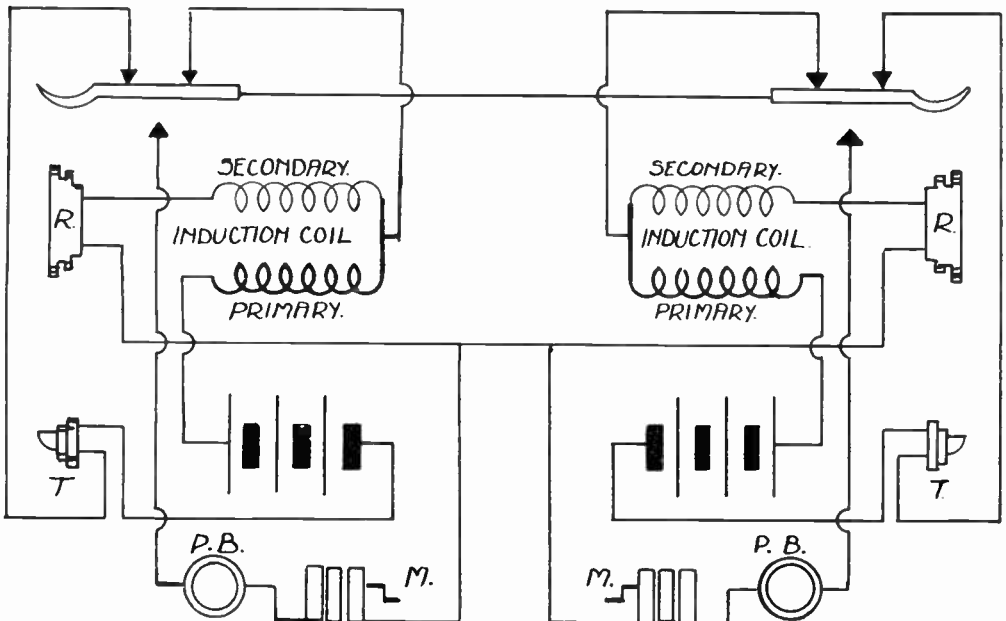


Fig. 56.—A Two-Way Telephone Circuit for Long Distances.

This circuit employs the induction coil also with magneto ringing. P.B. is a polarised bell. The magnetos are fitted with a short-circuiting device which is closed while speech is taking place, but opens the moment the handle is turned for ringing.

MODEL ELECTRIC RAILWAY SYSTEMS

By H. GREENLY, A.I.L.O.C.E.

THE model electric railway has developed mainly on what is known as the "third rail" system. The overhead trolley arrangement used for tramways and on some systems of high tension and three phase currents, is not altogether suitable to model work, as the wires are not only difficult to carry, but get in the way of handling the trains.

Third Rail System.

The centre conducting rail scheme is the most popular, the running rails acting as the return. The latter are bonded in some way and also cross-connected. In the case of the standard tinsplate tracks which are supplied in short made-up sections and used for model railways which are laid out in formations and taken up and packed away again after use, the third rail is either a strip of solid metal (tinned steel) or a section of the same hollow rail as is used for the track. The conductor rail is clipped on to the metal sleepers with insulating material intervening.

How Continuity is Obtained.

The electrical continuity between the sections is ensured by the spikes which socket into the hollow rail material of the next section, and where the

conductor rail is of the strip form, the ends are forked to engage with each other. The spiked running-rail connections, with the additional help of a spring clip, hold the track sections together. Sections of track with terminals are included in the range of components.

Points for Tinsplate Railways.

In all these tinsplate railway systems the centre conductor and the outer running rails are on the same level. To get over the difficulty of collecting shoes short-circuiting at points and crossings, the point-rails, which are normally on the negative side and would otherwise create such "shorts," are pivoted on to insulation materials (or on to an insulated frame), as shown in Fig. 1. The part of the track rail which is not run over is switched out of the way and does not make contact with the negative or running rail side of the circuit. When it momentarily touches the collecting shoe, which is, of course, on the positive or "flow" side, it is entirely disconnected from the rest of the circuit. In the other position of the track points the same thing happens to the opposite switch rail, i.e., to the one that was previously a part of the running track.

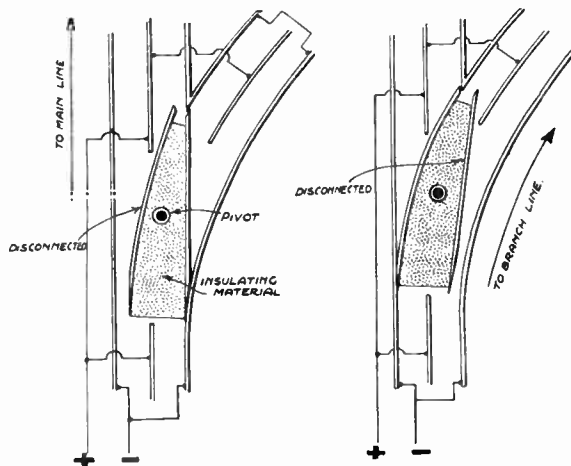


Fig. 1.—POINTS FOR TINPLATE MODEL RAILWAY TRACK.

Showing how the switch rails are pivoted on insulating material to prevent short-circuiting at crossing. The points on the left are set for the main line and those on the right for the branch line.

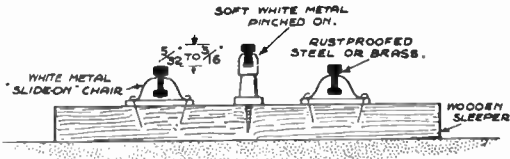


Fig. 2.—SECTION OF SOLID RAIL TRACK. Showing raised "third rail" conductor carried on a white-metal pillar (model insulator chair).

Double shoes are often used on model locomotives to maintain a continuity of supply to the motor in passing over crossings and should always be adopted if a choice is offered.

PERMANENT MODEL RAILWAYS LAID WITH SOLID RAILS.

A more advanced phase of model railway work is exemplified in the use of solid brass or rust-proofed steel rail, laid in chairs (die-cast or pressed steel) spiked to wooden sleepers, the whole line being permanently fixed down to a wooden sub-formation, generally raised 2 ft. 10 in. to 3 ft. 2 in. above the floor level.

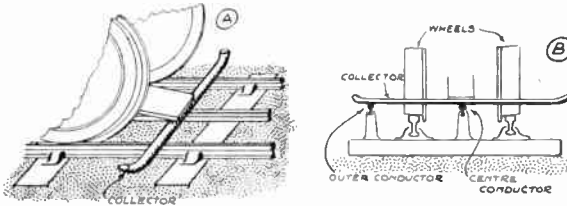


Fig. 4.—THE WIRE OR BOW TYPE COLLECTING SHOE USED FOR PREVENTING SHORT CIRCUITS AT CROSSINGS. The collector is always on one or both of the conductor rails and therefore cannot touch the running rails.

For these railways there are several makes of conductor rails, some of which are drawn sections; in all cases the component parts are supplied, so that the user can lay the track in any desired formation. For the most part the chairs carrying the conductor rails are of metal and in the matter of insulation the wooden sleeper is relied upon. Voltages are comparatively low and when used indoors in the dry such insulation is considered satisfactory. All rails are bonded with soldered-on wires, as shown.

Centre Rail.

Although there is an "all level" system

in use, the general practice is to raise the centre rail $\frac{3}{32}$ in. or $\frac{1}{16}$ in. above the running rails. At points and crossings two methods of preventing short-circuiting are possible. The shoe may be arranged with a limited lift, so that while it makes good contact with the conductor rail on the normal line of track, it is prevented by suitable stops from falling so low as to

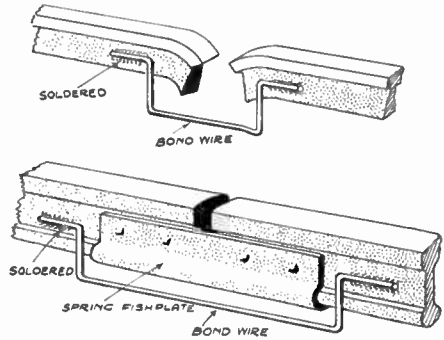


Fig. 3.—BONDING THE JOINTS. (Top) Conductor rails. (Bottom) Running rails.

engage the running rails at crossings. While this scheme is moderately successful with unsprung vehicles, difficulties occur when a pair of collecting shoes are widely spaced on a long locomotive.

The safest method is to fit a heavy brass wire shoe, made of, say, No. 10 or 12 gauge copper wire, extending outside the wheels on both sides, as indicated in Fig. 4. At points and crossings the conductor is transferred to the outside of the track and if these outer conductors are made to overlap the centre ones (in plan), the collector can never fall to the

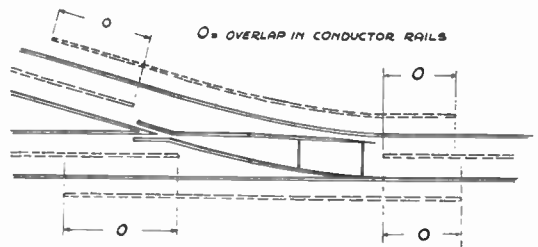


Fig. 5.—PLAN OF CONDUCTORS AT POINTS AND CROSSINGS. Showing overlap of outer and centre conductors.

rail level and cause a short-circuit. Further, it does not matter how long the engine or motor coach is, or whether it runs on springs, the collector height is entirely governed by that of the conductor rails.

Control Systems.

As the controlling of a model railway is almost exclusively accomplished by line-side switches, and it by commutating the current supply to the several sections of track the operator can effect a reversal in the direction of the train, as well as the speed control, shunting is quite an easy matter.

The methods of control adopted are governed by the type of motor.

The Series Motor.

The motor with a series-wound field is of course the best of all traction motors, but unless some form of polarised relay or magnetic trigger device is fitted to the engine which will obey either a change in the direction of the current supplied or acts in sequence impulses, reversal must be effected by a hand-switch on the engine or train.

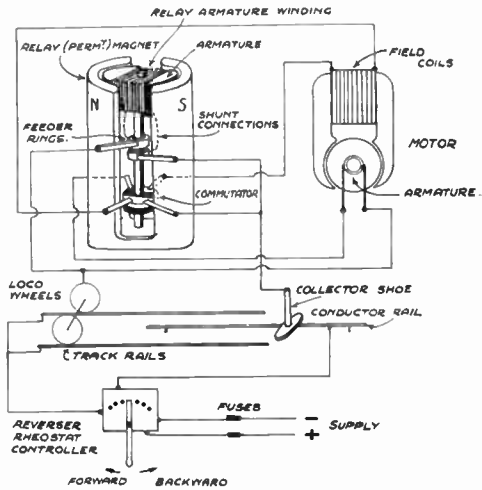


Fig. 6.—POLARISED RELAY SWITCH USED FOR REVERSING D.C. SERIES WOUND MOTORS FROM A LINE-SIDE REVERSER-CONTROLLER.

For a D.C. supply the usual arrangement is a polarised relay which obeys the direction of the current and switches over the fields, so that a reversal of direction is obtainable by maintaining a constant polarity in the fields. The fields can have a single or a double winding. In the double winding arrangement one set of coils is used for each direction. The relay device can be improved by the addition of a magnetic cut-out, so that the relay shunt circuit is broken after the first stop of the main controlling rheostat is passed and the reversal (if any) effected.

Motors for A.C. Supply.

The series motor is used in this case, but it has to have both a laminated field and armature to prevent overheating due to eddy currents. This system is employed by the majority of the Continental and American toy makers, as the same train equipment can be used for either A.C. or D.C. house supply circuits. For A.C., transformers are supplied and for D.C., a resistance or bank of lamps. The scheme is quite good and safe in the hands of a youngster. To the model railway enthusiast the drawback of the scheme is the fact that when the railway is used in an A.C. supply, reversing cannot be done

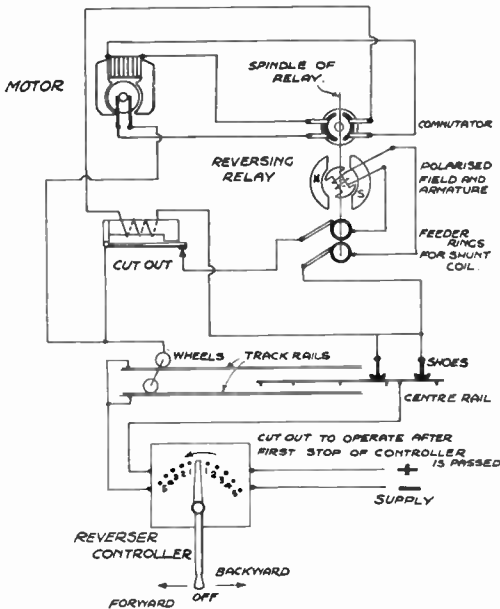


Fig. 7.—RELAY REVERSING SWITCH WITH AUTO CUT-OUT FOR THE SHUNT CIRCUIT.

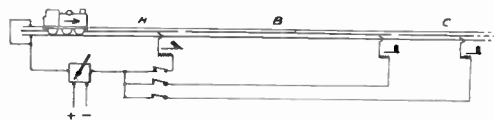


Fig. 8.—THE SERIES SYSTEM OF ELECTRICAL SIGNALLING WORKING ON A SECTIONALISED TRACK.

by any polarised relay switch on the loco.

“Bing” Reversing Scheme.

For alternating or direct current trains the “Bing” system depends for its reversal effects from the line-side control point on a magnetic impulse or “sequence of operations” device, in addition to a hand switch on the loco. The reversing switch is a spring and magnetic controlled rotating barrel switch. The latter is fitted with a ratchet which is moved by a pawl attached to an iron armature operated by the magnetism of the main fields of the motor. It is usually arranged so that on the stoppage of the current, by virtue of the spring, the barrel switch is pushed to a new position, forward or reverse, as the case may be. On the restarting the loco, therefore, goes the opposite way.

The system has the drawback that any temporary cessation of current to the engine actuates the reverser.

Transformer Supply Current Models.

The “KBN” makers have, among others, a range of models which are designed to work off the A.C. mains to a higher voltage than usual. The ordinary pressure is 4 to 8 volts, but the system just mentioned works through a transformer supplying current at 20 volts on the low tension side. This reduces the amperage

—always a trouble on model railways if large, owing to the comparatively low electric and mechanical efficiencies of motors and gearing—and at the same time 20 volts is quite a safe pressure.

Permanent Magnet Motors.

The magneto motor, as it is sometimes called, is used in the standard English system of model electric railways. It needs a D.C. current and two voltages are common, viz., 4-6 and 12 volts. Field magnets of really good quality (cobalt steel) are now made to suit locos of the smallest gauges. With the permanent magnet motor the characteristics are not particularly good from a traction point of view, but the simplicity and the ease with which reversal can be effected by changing over the line current has made it very popular.

Separately Excited Motors.

These are only used by amateurs who make their own motors. The drawbacks to the scheme are the same as in the case of magneto motors, except that devices can be added whereby the strength of field current can be varied with that of the armature current, in the attempt to obtain the characteristics of the series-wound motor.

Signals.

Signals can be worked by separate circuits, but the most satisfactory arrangement is that where the signal magnets are in series with the loco current circuit and the signals show “line-clear” when the current is being supplied from the control cabin to that section of the line occupied by the engine.

TELEPHONE ENGINEERING

By T. E. HERBERT, M.I.E.E.,

Superintending Engineer of South Lancashire District of Post Office Engineering Dept.

THE function of any telephone system is to provide speech channels. Sometimes it is only necessary to provide a telephone with suitable connecting wires between two fixed points, as for example, between a factory and the head office or from a house to the garage. Again, it is often convenient to provide a simple system which enables a number of private offices in a building to speak to each other at will. The arrangements required in these cases are, of course, of a very simple character. When, however, it is necessary to design a system which will enable any telephone subscriber to speak to any other telephone subscriber in any part of the world, the arrangements naturally become complex and planning involves the very highest scientific knowledge allied with that of the actuary to secure the best economic solution of the problem.

Sound and Hearing.

Appreciation of the physical facts which govern the nature and propagation of sound waves and the nature of the sensation termed sound is an essential preliminary to the consideration of telephony in general. Most of the requisite information is admirably set forth in J. I. Martin's article, entitled "The Recording of Sound," in Vol. II, p. 953.

Careful study of this article is earnestly recommended after consideration of essential facts summarized below.

How the Sound Waves are Formed.

Sound is produced by vibration of the



Fig. 1.—LATEST FORM OF TELEPHONE.

sounding body, as for example by the to and fro motion of the prongs of a tuning fork.

This results in alternately compressing and rarefying the layer of air in contact with the source of the sound. The effect is passed on to

the next layer of air, and this on to the next and so on; the disturbance of the successive layers of air spreads outwards in every direction in the form of a series of waves. The term wave is, in general, applied to any regular periodic disturbance.

Sound waves are longitudinal vibrations propagated outwards in straight lines from the sounding body, the air being carved into a series of waves of alternate compression and rarefaction. The air does not move bodily, and the condition may be likened to the passage of a wave over a cornfield, where the heads of corn move to and fro but are not, of course, translated from one end of the field to the other.

Volume, Pitch and Timbre.

The volume or loudness of a sound depends on the amplitude or vigour of the compression and rarefaction. Its pitch is determined by the rate of vibration, i.e., on the number of waves per second. The length of the wave is the distance through which the wave travels in the time required for a complete vibration, and is shortest for a high and longest for a low note. As the velocity of a sound wave in air at 60° F. is 1,120 ft. per second, the wavelength of any sound may be obtained by dividing 1,120 by the

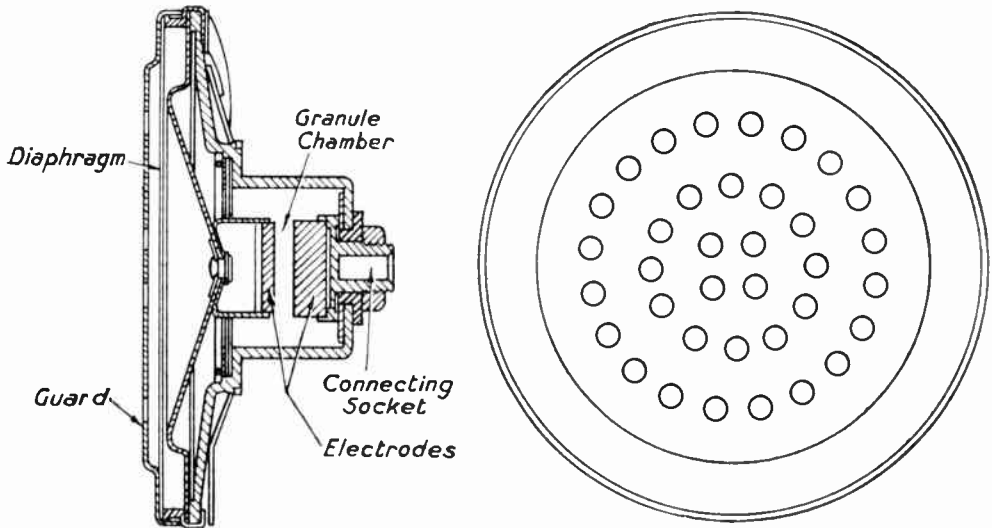


Fig. 2.—DIAGRAM SHOWING CONSTRUCTION OF THE TRANSMITTER OF THE TELEPHONE ILLUSTRATED IN FIG. 1.

frequency, e.g., the wavelength for middle C on a piano (256 vibrations per second) is $1120 \div 256 = 4.4$ ft. approximately.

The timbre of the sound gives to each musical instrument its distinctive peculiarity. The corresponding term to timbre is the German word *klangfarbe*, which may roughly be translated as "tone colour." It is determined by the small waves or harmonics allied with, or superimposed on, the fundamental or basic wave. It is upon the faithful reproduction of the complex wave at the distant end that the quality of speech and music depends. For the transmission of music a frequency ranging between 50 and 6,400 is essential, but excellent speech is obtainable between 300 and 2,400.

Transmission of Speech.

In the electrical transmission of speech the sound waves impinge upon a flexible

diaphragm which moves to and fro in precise accord with them. This mechanical motion controls the electrical energy sent along the line. At the receiving end mechanical movement of a similar diaphragm carves the air in contact with it into precisely similar sound waves to those produced by the movement of the diaphragm at the sending end.

Transmitters Used in Telephony.

All transmitters used in telephony consist essentially of a diaphragm which moves or vibrates in accordance with the sound waves and thereby varies the

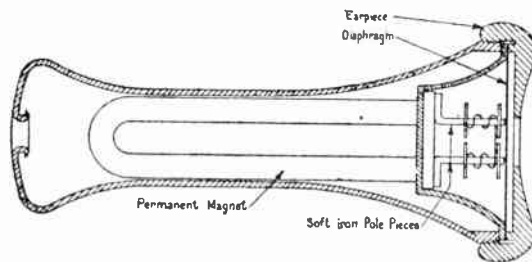


Fig. 3.—A DOUBLE POLE RECEIVER.
(Post Office Technical Pamphlets.)

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intimacy of contact between carbon granules arranged between the piston and the fixed electrode. When the piston exerts pressure on the granules in obedience to the compression half of a sound wave, the area of contact between the granules is increased and the resistance

between the piston and the fixed electrode, i.e., the resistance of the transmitter, is diminished. Conversely, outward movement of the diaphragm raises the resistance. Hence the transmitter resistance varies in accordance with the pitch, volume and timbre of the sound.

What the Battery and Receiver Do.

The inclusion of a battery and a telephone receiver in circuit with the transmitter translates the variations of resistance into variations of current corresponding to the originating sound waves. In the receiver these currents are reconverted into movements of the receiver diaphragm and consequently reproduce the original sounds.

The latest form of telephone used by the Post Office is illustrated in Fig. 1.

Post Office Telephone Transmitter.

The transmitter (Fig. 2) consists of a corrugated aluminium cone diaphragm with a small aluminium cylinder fixed to the centre. This cylinder carries a small circular carbon electrode facing a fixed carbon electrode in a chamber, which is filled with carbon granules. The distance between the two electrodes is rather less than one-tenth of an inch. The granule chamber is sealed by rings of silk. A protective perforated ebonite cover is fixed in front of the diaphragm. These transmitters are made up as units and are connected up by springs so that in the event of a fault it is only necessary to change the inset transmitter.

The Receiver.

The receiver calls for little comment. It is of the general form described by A. E. Watkins in his article on page 295. But, it may be interesting to remark that the polarising magnet is essential not merely to increase the efficiency of reception, but to preserve the pitch of the received sounds. A plain electro-magnet

acting on a diaphragm would increase the pitch of the sounds by an octave.

A skeleton sketch of an ordinary double-pole receiver is shown in Fig. 3.

The cradle which carries the micro-telephone forms a gravity switch which changes the connections required from the normal when the telephone is inoperative and the calling bell is joined up to the speaking condition. When a telephone is worked by means of a primary battery with magneto ringing the connections required are indicated in Fig. 4. When the receiver is raised from the switch-hook the circuit of a two-cell Leclanché battery is completed through the transmitter and the one ohm winding of an induction coil.

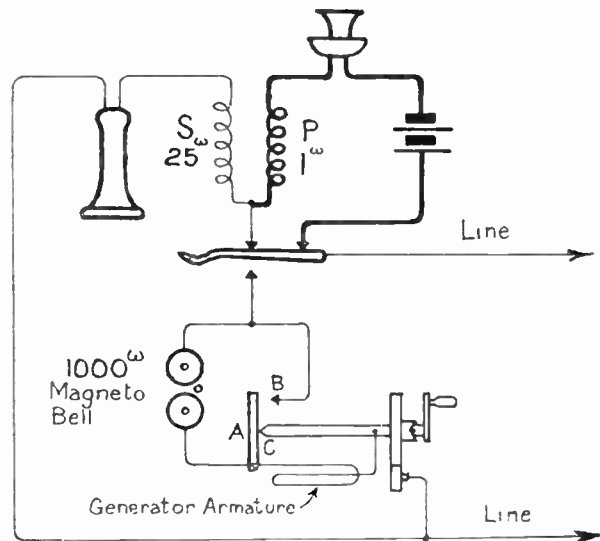


Fig. 4.—CONNECTIONS OF A MAGNETO TELEPHONE STATION.
(Post Office Technical Pamphlets.)

What the Induction Coil Does.

Variations in the resistance of the transmitter due to speech waves produce corresponding variations of current in the primary circuit. By induction, currents are generated in the secondary of the induction coil and passed through the receiver out to line. The function of the induction coil is to prevent the small variations in the resistance of the transmitter from being masked by the comparatively higher constant resistance of a line circuit. The pressure which can be

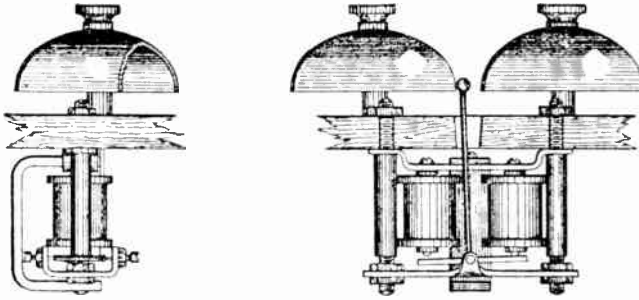


Fig. 5.—A MAGNETO BELL.
(Post Office Technical Pamphlets.)

This bell consists of an electro-magnet with a polarised armature which is vibrated by an alternating current.

applied across the terminals of an ordinary transmitter is very definitely limited to 3 volts owing to the loud hissing sounds which are produced when this value is exceeded. Hence the swamping effect of a large constant resistance in series with the transmitter cannot be compensated by a mere increase in the voltage used. It is for this reason that the induction coil is essential.

When a speech current is received it passes through the secondary of the induction coil and receiver.

Signalling.

When the receiver is placed upon the switch-hook, a magneto bell (Fig. 5) is in circuit across the two lines. This bell consists of an electro-magnet with a polarised armature which is vibrated by an alternating current. This current is provided by a generator of the Siemens H type of armature, revolving between poles of a permanent magnet. Normally, the armature of the generator is short-circuited, but the first operation of the turn of the handle causes the driving spindle to move laterally, thus permitting a contact spring to short-circuit the bell, thus cutting out much resistance and to send alternating currents direct to line.

Metallic Circuits Essential for Telephone.

At this point it is essential to appreciate that two wires are required for each telephone and that the use of a single wire with the return path via the earth is impracticable. If two single wires are run parallel to each other, the speech on

one will be heard on the other as the result of electro-static and electro-dynamic induction, the former being the principal cause. Then, too, a single wire will be affected by any electrical disturbance in its vicinity in addition to noises picked up via earth connections. Hence all telephone speech circuits consist of two insulated wires twisted together so that both wires are equally and oppositely

affected by any disturbance; this results in a balance and moreover that the two wires carrying current in opposite directions do not affect adjacent circuits.

In the case of aerial wires a complicated series of crosses between the A and B wires of each loop are made to bring about an approximate balance.

MAGNETO EXCHANGES.

To enable a number of telephone circuits to be connected together for speech at will, a switchboard to which the circuits are connected is required. On this switchboard there must be a means by which a calling subscriber can signal the exchange, a method by which the operator can ascertain the nature of the connection demanded, then make it, and finally can ring up the required subscriber. There must also be a method by which subscribers can indicate the conclusion of their conversation. If the subscribers' lines are connected to springs in the manner indicated in Fig. 6, connection with these circuits can be made by means of two plugs electrically divided into two sections.

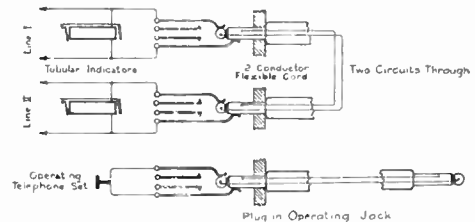


Fig. 6.—PRINCIPLE OF MAGNETO SWITCHBOARD.
(Post Office Technical Pamphlets.)

Indicator.

A form of indicator which can be used to this purpose is shown in section in Fig. 7. It consists merely of an ironclad electro-magnet with an armature which, when attracted, raises a releasing lever and permits a pivoted shutter to fall forward. Returning now to Fig. 6, it will be observed that an indicator is connected across each line. Hence, when a subscriber turns the handle of his generator, the indicator falls, thus calling the operator's attention to the circuit. By means of an operating telephone connected to a plug, the operator can ascertain the number required. She then inserts the operating plug in the jack of the required subscriber and rings him up with her telephone. Having secured his attention the two circuits are connected together by a pair of plugs and cords, as indicated in the upper part of the figure.

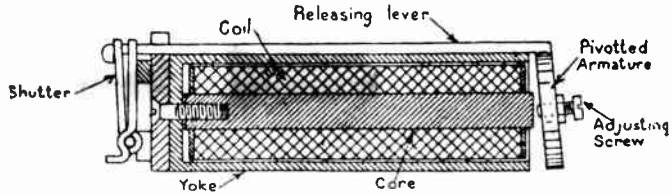


Fig. 7.—DIAGRAM SHOWING CONSTRUCTION OF AN INDICATOR. (Post Office Technical Pamphlets.)

On the conclusion of the conversation both subscribers turn the handles of their generators and the indicators fall, thus telling the operator that the conversation is concluded.

Where a large number of subscribers are involved, the arrangements naturally become more complicated and many of the functions are performed by keys consisting of levers operating a number of springs to make the requisite connections (Fig. 9).

Multiple Switchboard.

There is, however, one other complication which should be explained, and this is where the number of subscribers to be dealt with is beyond the capacity of a single operator. When the subscribers have to be divided up along a suite of

switchboards it is clearly necessary that any calling subscriber should be able to obtain connection with any subscriber on that exchange. Consequently the whole of the subscribers connected to the exchange must be within the reach of each operator, but the operator will only attend to the calls from the subscribers allotted to her. This involves the connection of each subscriber's circuit to several jacks in the exchange (Fig. 8), and it becomes necessary then to provide a means by which any operator in the exchange can ascertain whether the wanted subscriber's circuit is already connected. A switchboard in which the subscribers' circuits are repeated at several points so as to make each subscriber accessible to every operator is known as a multiple switchboard. By the aid of a plug having three sections, and by using the bush of the jack this condition is secured. The third point of the plug is connected to a small battery and immediately a plug is inserted in the multiple, the bushes of all the jacks allocated to that particular subscriber are connected to this earthed battery, with the result that if the operator taps the jack with the ball of the plug, a click is heard in her receiver. The necessary additions are made to the connections shown in Fig. 9.

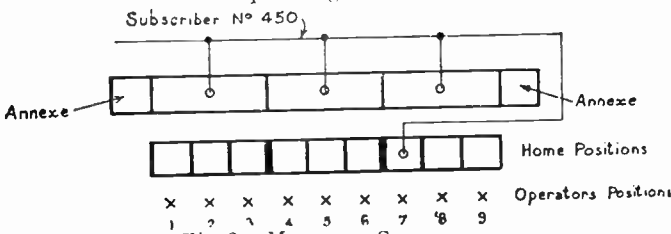


Fig. 8.—MULTIPLE SWITCHBOARD. (Post Office Technical Pamphlets.)

THE CENTRAL BATTERY SYSTEM.

The magneto system which has just been described has many disadvantages. Its efficiency depends largely on the condition of the primary battery at each station and these need periodic attention. Moreover, the finished, or

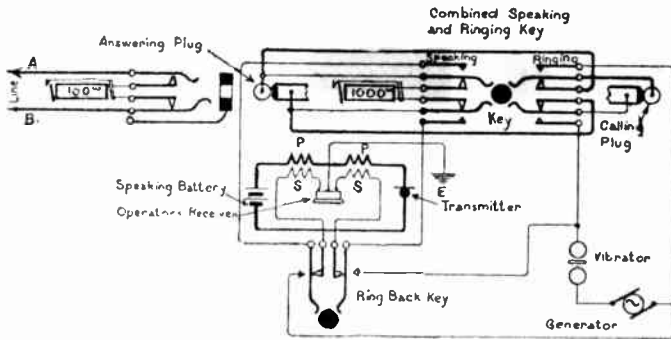


Fig. 9.—CORD CIRCUIT OF A MAGNETO SWITCHBOARD.
(Post Office Technical Pamphlets.)

winding of an induction coil and through the transmitter, with a 26-ohm winding a 2 microfarads condenser and the receiver as a secondary circuit. The object of this arrangement is to prevent the main current from the battery at the exchange from flowing through the receiver, the objection to this being that it is in such circumstances impracticable to obtain the best possible working of the instrument, since

clearing out signal is frequently omitted or, owing to the connection of junction and other circuits, becomes ineffective. In the central battery system the current for speaking and signalling purposes is furnished by a single large secondary battery at the exchange. Signalling is then automatic since the raising of the receiver lights a calling lamp at the exchange. When the operator plugs into the circuit this calling lamp circuit is cut away and a transmission system with speaking, calling and signalling facilities is substituted. The general principle will be clear from Fig. 10 and 10A.

the current flowing would depend to a considerable extent on the resistance of the transmitter. It will be observed that the battery at the exchange is applied to the subscribers' circuits through a repeating coil and that relays are included on each side of the coils.

How the Condition of the Circuit is Indicated

In this way it will be clear that the relays are operated when the subscribers are speaking and the circuit is therefore completed, and is not operated when the receivers are restored and the condensers brought into circuit. The armatures of these relays are used to light small lamps and consequently show the operator the condition on each side of her circuit. When both lamps are lighted it will be clear that both subscribers have restored their receivers and the conversation is at an end. The operator then disconnects the circuit by removing the plugs.

How the Central Battery System Works.

At the subscriber's end of the circuit, when the receiver is on the switch-hook the A and B wires are connected through a 1,000-ohm magneto bell and condenser to the line. This circuit is, of course, disconnected for direct currents, but permits the passage of the alternating current which is used to ring the bell. When the receiver is raised, the lines are connected together by the 17-ohm winding of an induction coil and the transmitter in series, i.e., the removal of the receiver, joins the A and B wires together through the speaking apparatus. The circuit is through the 17-ohm

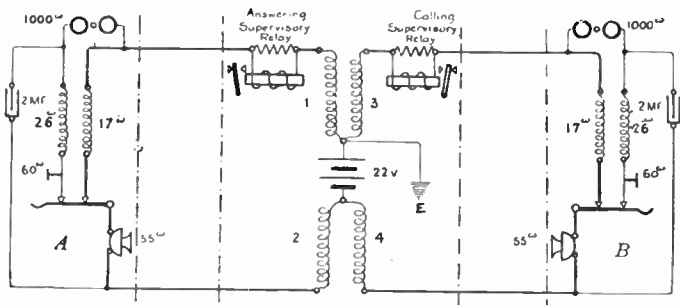


Fig. 10.—PRINCIPLE OF SPEAKING AND SIGNALLING CIRCUIT ON A C.B. EXCHANGE.
(Post Office Technical Pamphlets.)

Method of Transmission.

At this stage it may be useful to explain that the method of transmission described employs a 22-volt battery at the exchange and a repeating coil transformer with four equal windings. The object in using a repeating coil is to prevent the various circuits connected to the single battery from interfering with each other. If the internal resistance of the battery and leads, to the point at which the current divides is negligible, then the circuits operate without interfering with each other. If, however, the resistance of the battery and its leads is appreciable, then cross talk between the various circuits results. If the battery were connected to line directly, cross talk would at once result.

Using Supervisory Relays.

Another method of transmission consists in using the supervisory relays instead of the repeating coil and to connect the two sides of the cord circuit by condensers.

This is illustrated in Fig. 11 and is now the standard system. A 40-volt central battery is used and speech is transmitted between the two sides of the cord circuit by linking them together by 2-microfarad condensers.

Metering.

Calls are recorded on a meter (Fig. 12) operated by the meter key in connection with each pair of cords. Its depression increases the current flowing through the meter to a value sufficient to cause the armature to be pulled up and by means of a ratchet wheel to move the recording train forward. At the same time, the operator's meter lamp is lighted, thus indicating that the meter has operated. This is effected by the armature placing a low resistance winding across the meter and so increasing the current to a value sufficient to operate the meter relay.

Battery Room.

A typical battery room is shown in Fig. 27. The batteries are duplicated, so that one battery can be charged while the other one is connected to the exchange.

The size of the cells varies with the size of the exchange, but for a 10,000-line automatic exchange a capacity of 10,000 ampere hours is necessary. The heavy character of the leads will be noted.

Power Room.

The power room is illustrated in Fig. 13. Power supply is obtained from the local authority and by means of a directly coupled motor and generator provides current at the requisite voltage for charging the batteries. Ringing machines supplying alternating current at 17 cycles per second for ringing subscribers' bells are also installed.

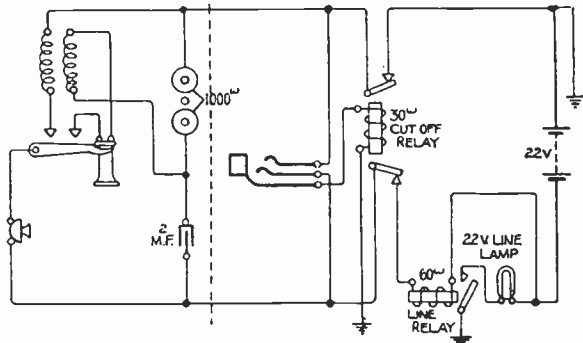


Fig. 10A.—DETAILS OF SIGNALLING CIRCUIT.
(Post Office Technical Pamphlets.)

Apparatus Room.

The apparatus room is shown in Fig. 14A. The cables from the street are connected to fuses on one side of the main frame, where the wires are laced up and permanently soldered to the connecting tags. It will be clear that the numbers of the subscribers served by any particular cable cannot follow the arrangement of the wires in the cable owing to changes and diversions rendered necessary by the growth of the system. On the other or apparatus side of the main frame, the subscribers are arranged numerically in order to facilitate cabling to the switchboard and to enable faults to be located and removed without delay. The connections between the line and apparatus sides of the main frame are made by single pairs of twisted wires.

In this way any changes, as, for example that caused when a subscriber removes to other premises or when cables are rearranged in the streets, merely involve rearrangement of these jumper wires without disturbance to the cabling on either side of the frame. A closer view of the apparatus racks in a large C.B. exchange is shown in Fig. 14.

PROTECTION.

The telephone circuit has dangers of its own for which suitable protection must be afforded. Open wires are, of course, liable to be struck by lightning discharges, or, alternatively, to be charged to high

fuses in the circuit, and in addition to this there is a small coil of wire known as the heat coil, which prevents an excessive current continuing over a long period from causing fire risk. The reason for the heat coil is that it is not possible to design a fuse which is stable and which will operate with a current of less than half an ampere. In this way all fire risks are eliminated.

Power Crossings.

Where telephone circuits cross tramways, which are usually worked at about 500 volts D.C., either covered wires are used for the telephone circuits or earthed

wires are erected on the tramway poles above the trolley wire, so that any telephone wire falling on to the tram route will be effectively earthed, and even if contact with the trolley wire occurs, the voltage will not be impressed on the telephone circuit owing to the fusing of the wire between the guard

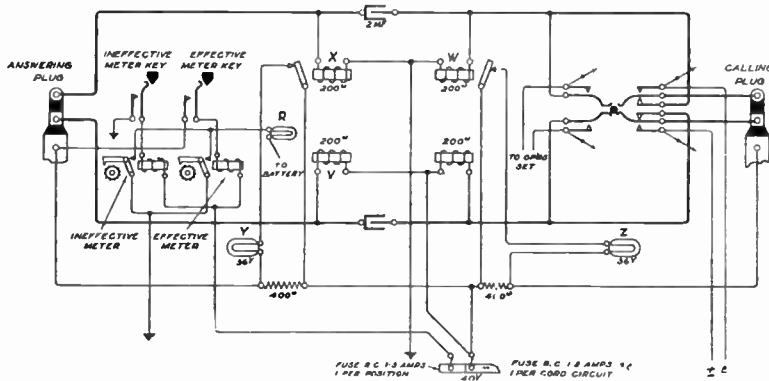


Fig. 11.—SUBSCRIBERS' CORD CIRCUIT.
Bridged impedance method of transmission.
(*Post Office Technical Pamphlets.*)

potentials during lightning storms. In order to prevent any possibility of damage to users, operators or to the apparatus itself, a lightning protector is added to each circuit. This consists of two small blocks of carbon separated from each other by a perforated mica disc. One of the carbons is connected to the line wire and the other to earth. Any voltage which exceeds about 300 sparks across from one carbon to the other, and the device is so efficient that there has never yet been a case where an operator or telephone user has been injured during a lightning storm.

Fuses and Heat Coils.

Then there is the case where contact with electric light and power wires would cause an excessive current to flow. This condition is safeguarded by inserting

the wire and the trolley wire. In the case of the Central Electricity Board, which is working at a pressure of 132,000 volts, much more elaborate arrangements are necessary. With ordinary telephone subscribers' circuits the telephone circuits are placed underground, but where an important open trunk line is involved a large cradle guard is constructed beneath the power wires.

Intermediate Distribution Frame.

Facilities are necessary also to vary the distribution of the lines between the various operators, otherwise it might happen that some of the operators were intolerably overloaded. This is the function of the intermediate distribution frame. On one side the circuits are arranged in numerical order and on the other in the

order in which they are connected to the various operators. The connection between the two sides is made by jumper wires, as in the case of the main frame, and consequently any rearrangement of load is made without disturbing any of the permanent cabling of the exchange.

The apparatus generally is mounted on racks in numerical order.

CENTRAL BATTERY SIGNALLING SYSTEM.

Small exchanges which are not likely to grow to more than a few hundred lines are catered for by the C.B.S. system (Fig. 15). This system, designed by Post Office engineers, provides precisely similar signalling facilities to the C.B. system, but at much smaller cost per line. Each subscriber's telephone is provided with a 2-cell Leclanché battery for speaking purposes and thus enables the power plant required to be reduced and simplified. Moreover, the relays and lamps may be substituted by electro-magnetically operated signals and the functions of the cut-off relays of the C.B. system are performed by using jacks which cut out the calling apparatus when a plug is inserted.

JUNCTIONS.

Thus far, only interconnections between subscribers on the same exchange have been considered. Exchanges in the same or adjacent areas are linked together by junction circuits, whilst distant towns and cities are connected by trunk lines.

It is only possible here to indicate the method of operating junction circuits in very general terms, since the arrangements required in practice are exceedingly varied and often somewhat complex. Add to this that it is frequently necessary to connect junction circuits together, as, for example, the case of a small suburban or rural exchange subscriber speaking to another such subscriber on the opposite side of the city. Here a junction circuit is used from the small exchange to the parent exchange and thence to the central exchange via, perhaps, one or more exchanges to the called subscriber. Naturally, everything possible is done to simplify the routing of such calls, but

questions of economics are often the dominating factor.

Call Wire Working.

The selection by the operator of a disengaged junction at a minor exchange presents no difficulty, since the absence of a plug in the junction jack shows that it is

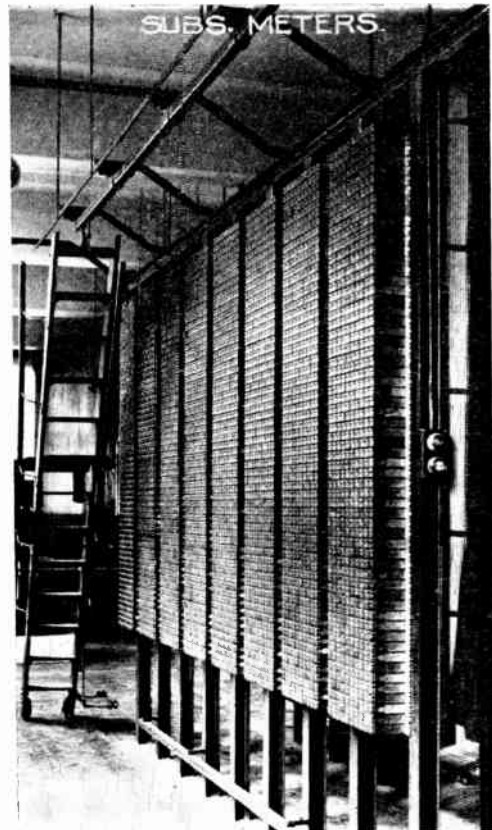


Fig. 12.—SUBSCRIBERS' METERS.

free. But at a large exchange it is necessary that any operator shall be able to reach any exchange demanded. This involves the provision of jacks for each junction circuit on each operator's position and consequently a somewhat different method of operating. There are two plans, the older one consisting in providing a special circuit, termed a call wire, to which each operator can connect her telephone by the depression of the appropriate key. At the distant end, each

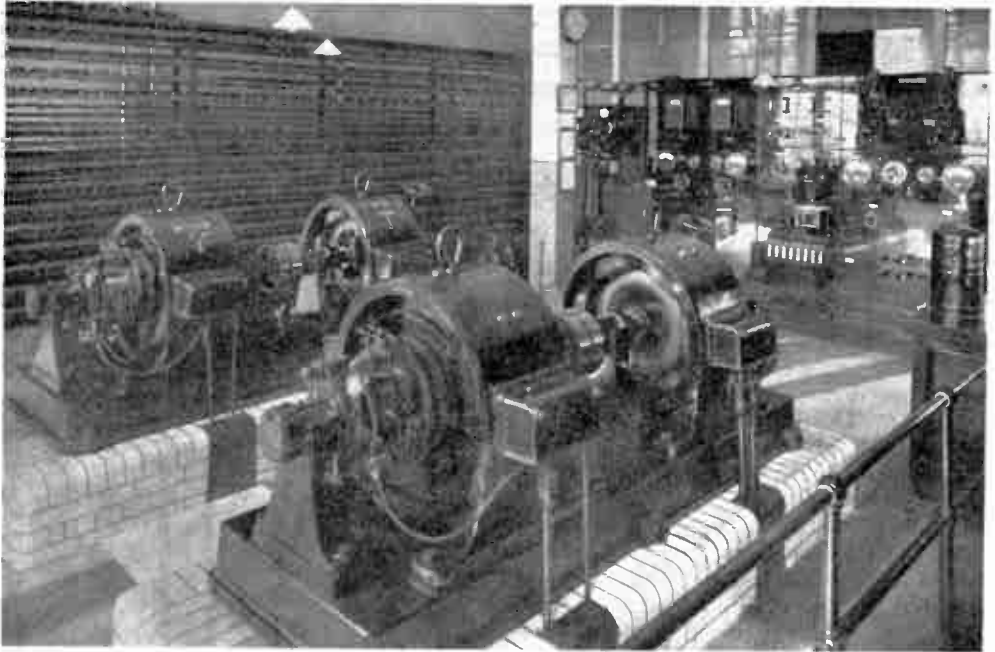


Fig. 13.—POWER ROOM AT A TELEPHONE EXCHANGE.

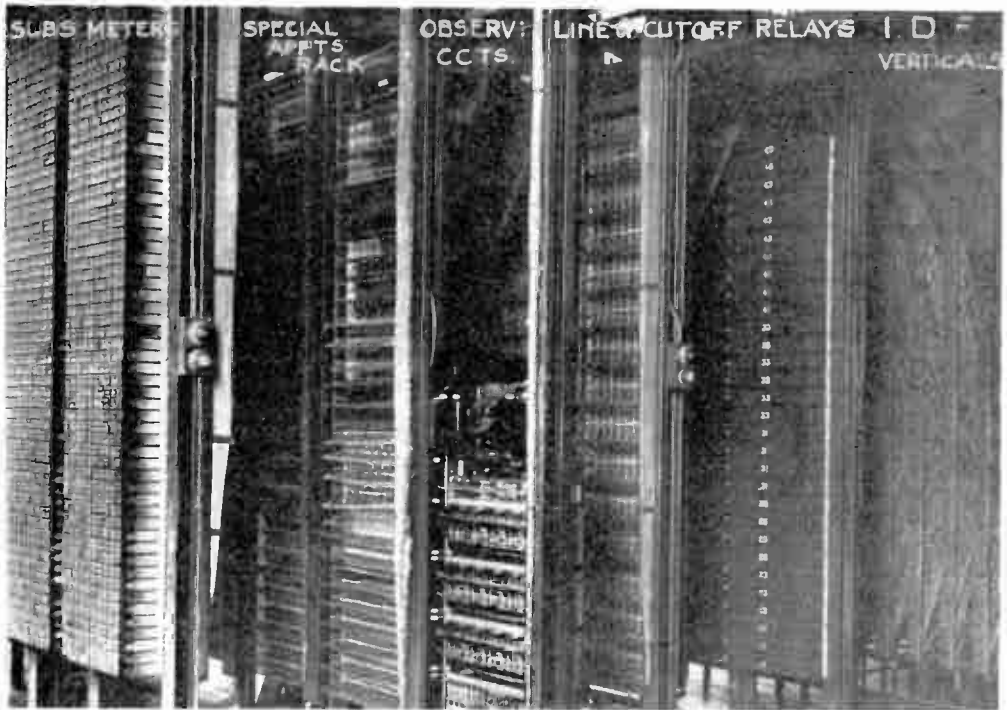


Fig. 14.—A CLOSE UP VIEW OF THE APPARATUS RACKS IN A LARGE C.B. EXCHANGE.

junction terminates on a plug and the operator there assigns the junction to be used.

Straightforward Junction Working.

The latest plan, known as "straight-forward junction working," consists in the abolition of the call wire and designation of the junction to be used in favour of an engaged test by the calling operator who, having found a disengaged circuit, plugs in, thereby calling in the distant operator and giving the number of the required subscriber over the junction circuit to be used for the completion of the connection.

In a large exchange the junctions are divided into outgoing and incoming groups. Those used by the A operator, i.e., the operator attending to and receiving the demand from the originating subscriber to make the required connection with another exchange are termed "outgoing junctions"

and are multiplied along the switchboard below the subscribers' multiple. "Incoming junctions" terminate on a special switchboard *en suite* with the A boards, and it is here that demands for connections on the exchanges are received from other exchanges. A view of a B board heads Col. Sir Thomas F. Purves's article.

JUNCTION SIGNALLING.

The principle of junction signalling between two exchanges Q and R, which is also adopted for trunk lines up to 60 miles in length, is illustrated in schematic form in Fig. 16. The A and B wires of the junction circuit are separated

for direct currents by condensers and signalling is effected by using the A wire for signalling from the called subscriber and the B wire from the calling subscriber.

Normally, the subscriber's line is disconnected for direct current by the condenser in series with the bell. This is indicated by the open contacts.

What Happens When a Call is Made.

The calling subscriber on exchange Q raises his receiver, thus lighting the calling lamp. The operator plugs in and

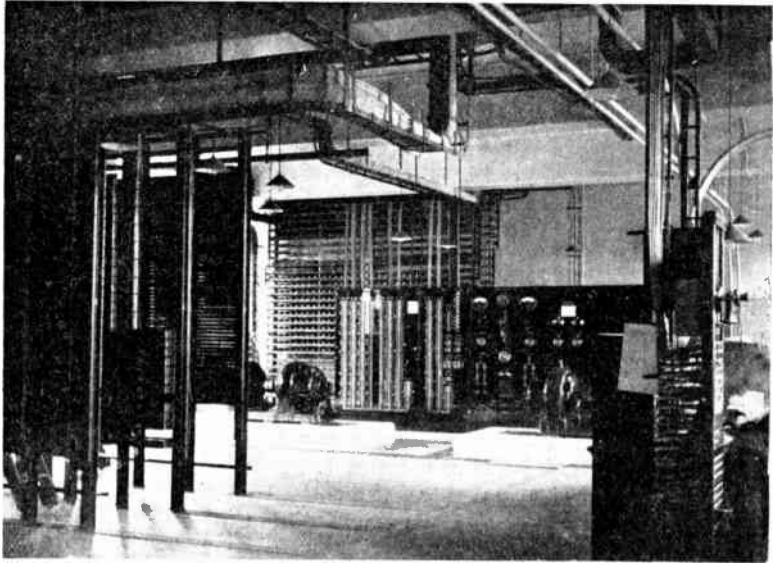


Fig. 14A.—APPARATUS ROOM OF A SMALL C.B. EXCHANGE.

receives a demand for a particular number on exchange R. The relay LA is operated by the current round the loop to the calling subscriber, thus shunting and darkening the answering side supervisory lamp. The calling plug is then inserted in the jack of a disengaged junction to exchange R, with the result that current flows over the B wire and operates the answering supervisory lamp at R. The Q operator then asks R for the required number and the junction plug is inserted in the called subscriber's jack, when the conditions shown result. Immediately the called subscriber answers the ring and thus joins the A and B wires by his speaking apparatus, the relay LC is

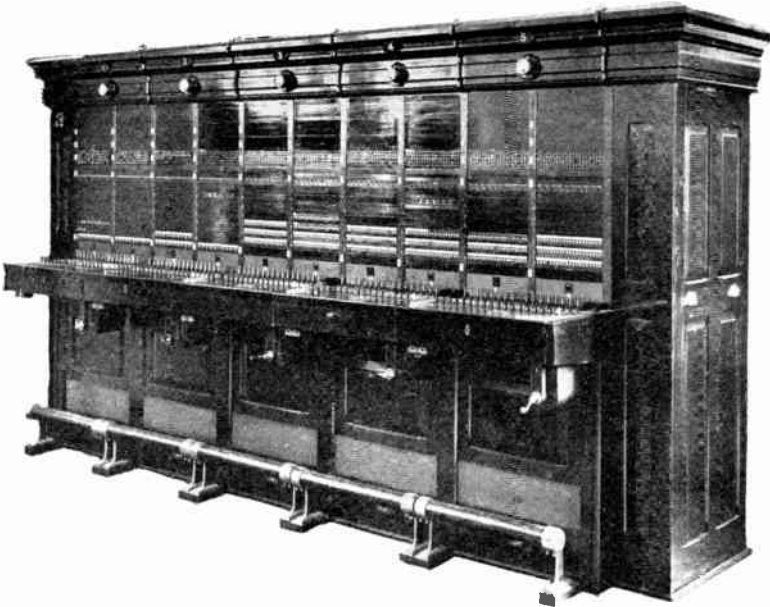


Fig. 15.—CENTRAL BATTERY SIGNALLING SWITCHBOARD.

TRUNK EXCHANGES.

In large cities, trunk lines are connected to a separate trunk exchange having junction circuits to all the local exchanges in the area. These long and costly circuits are operated in a special way so as to obtain the maximum use out of them and thus to reduce the charge to the user—incidentally, the charges in this country are much less than those levied in the United States.

energised and earthed battery is applied to the A wire, thus operating LC at Q and darkening the calling supervisory lamp. Hence the calling and answering supervisory lamps at Q are controlled by the calling and called subscribers respectively. When both light, the calling plug at Q is withdrawn and the armature of the relay LA at R falls back and removes the shunt from the answering supervisory, which forms the instruction to the R operator to take down the connection.

gives particulars of the call required, and then replaces his receiver. The details are entered on a ticket which is passed by hand or by pneumatic tube to the particular section of the trunk switchboard, and when his turn arrives the trunk operator rings him via a junction circuit and completes the connection over the trunk line with the required correspondent. Many short trunk lines are placed on the switchboard at local exchanges and immediate connection is made on request.

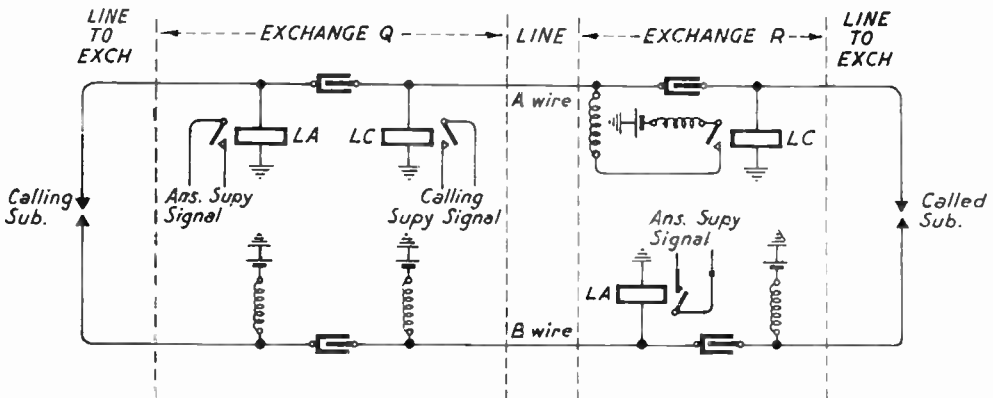


Fig. 16.—DIAGRAM SHOWING PRINCIPLE OF JUNCTION SIGNALLING.

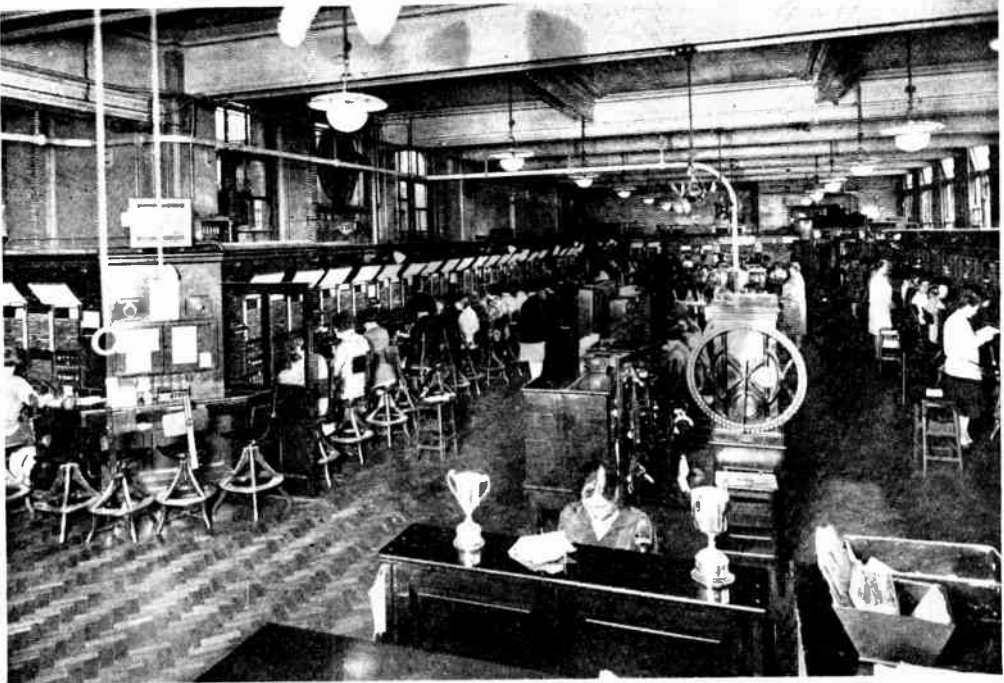


Fig. 17.—A PORTION OF THE LONDON TRUNK EXCHANGE.

“Record and Demand” Working.

Considerations of space render it impossible to discuss the technical details of the circuit arrangements, more especially so since the trunk telephone system of the kingdom is at present in process of conversion to what is termed “Record and Demand Working.” When the A operator receives a request for “Trunks,” the subscriber will be connected to a trunk operator at the originating exchange, who will record the particulars of the call and immediately make the required connection.

A general view of a trunk switchboard is given in Fig. 17.

Voice Frequency Key Sending.

When the trunk line terminates at an automatic local exchange, the trunk operator at the originating exchange will obtain the distant subscriber by means of a key sender, which will transmit combinations of four voice-frequency currents over the trunk line.

AUTOMATIC EXCHANGES.

The idea of replacing the telephone

operator by a machine acting in obedience to signals from a subscriber's telephone is a very old one, but it is only within very recent years that systems have been devised which are capable of dealing with very large cities.

The advantages gained by the substitution of machinery for the human element lie first in lower operating costs and secondly in the more efficient utilisation of line plant. There is, too, the fact that where a city comprises a large number of exchanges, the complications resulting from the building up of circuits via the various exchanges increase, and a chain of operators is often involved in calls from outlying exchanges across the city. Indeed, it would be true to say that radical changes in operating methods would have been required had the automatic system not been developed.

Economy in Line Plant.

The point as regards the economy in line plant arises from the fact that large groups of junction circuits connecting two exchanges can be more efficiently

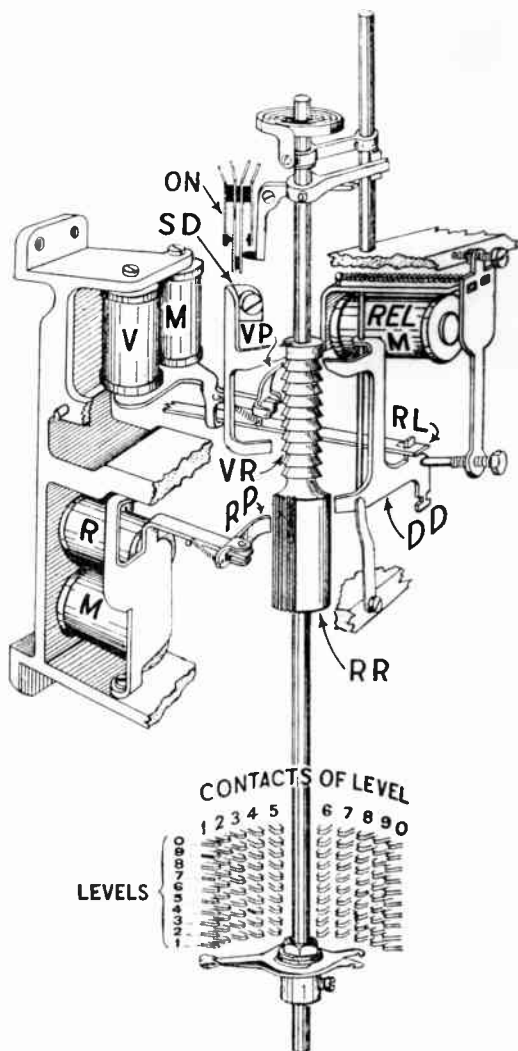


Fig. 18.—GENERAL ARRANGEMENT OF A FINAL SELECTOR.

utilised when they are selected and operated by a machine. The larger the group, the greater is the number of telephone conversations per circuit which can be carried. On the completion of the conversation the connection is almost instantaneously broken down and the junction is available for other conversations.

The principles and methods adopted in automatic telephone switching have an exceedingly wide application. Even where

an exchange is operated on the manual system there is an increasing tendency to attain greater efficiency by arranging for the automatic selection of junction circuits and in many other ways. Outside telephony, the totalisator is an example of the application of automatic telephone principles, and a large amount of switching at unattended electric light power substations is effected by similar methods.

Advantages of Machine Switching.

A notable advantage of machine switching lies in the fact that the replacement of the receiver brings about the instantaneous disconnection of the circuit, with the result that a large number of calls can be made consecutively without having to wait for an operator to take down the connection. Then again, in the case of exceedingly small rural communities where an operator cannot be continuously employed, a small exchange is established in a little single-storey building and the rural subscriber consequently obtains all the advantages which the subscriber connected to a large exchange enjoys. These small exchanges are virtually unattended, and continuous day and night service is provided without additional cost.

Fundamental Ideas of Machine Switching.

Before considering any of the details of machine switching, it is necessary to explain in general terms the fundamental ideas involved. The switching plant at the exchange to which the subscribers are connected must, first of all, be regarded as a machine operated by remote control. This involves the addition to the ordinary subscriber's telephone of a signalling device for operating the switching machine in conformity with the signals. The signalling device consists of a dial (see Fig. 1). In order to signal a given number the finger is inserted successively in the holes opposite the numerals, the dial is rotated to the finger stop and then released. On the return journey of the dial to its normal position of rest the circuit is interrupted a number of times equal to the figure signalled, that is to say, if the figures signalled were 1357, on the return of the dial after No. 1 one interruption would occur, after No. 3 three interruptions.

No. 5 five interruptions and No. 7 seven interruptions. In other words, the number would be represented by one, three, five and seven interruptions separated by a period of time between the various trains. These trains of disconnections can be made to operate switches in such a way as to establish connection with the subscriber whose number has been dialled on that exchange.

The Selector.

In the instance cited, a four figure number is employed, and the method of selecting a required subscriber consists, first of all, in selecting the correct thousand group. The second figure selects the correct hundred group, and the final selector picks out the particular subscriber in a group of one hundred by selecting first the ten level and then the actual unit. The general arrangement of a final selector is shown in Fig. 18. A hundred pairs of contacts are arranged in semicircular formation, one above the other. The contact arm, which makes connection with these contacts, is carried on a rod which is capable of both vertical and rotary motions. The magnet V.M., when operated, raises the vertical spindle to a level corresponding with the number of impulses passed through it. The rotary magnet R.M. then, by means of the ratchet pawl, twists the contact arm in accordance with the impulses passed through it. The spindle is held in its normal position by the double dog D.D. When the release magnet Rel.M. is operated, the dog is withdrawn and by the action of the spiral spring to be seen at the top of the spindle, the contact arm first twists round and then falls to its normal position.

How the Magnets are Operated.

It remains now to explain the means by

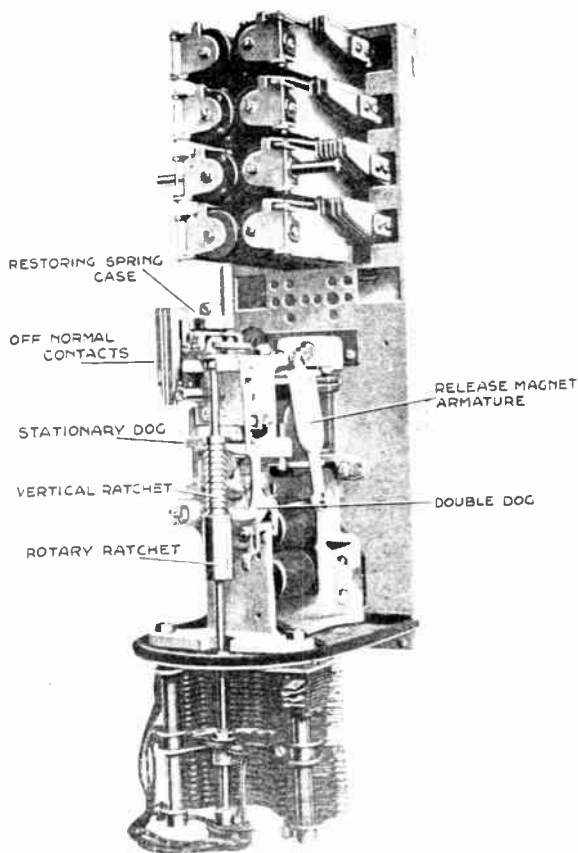


Fig. 19.—VIEW OF SELECTOR WITH RELAYS, ETC.

which these magnets are operated.

The apparatus at the subscriber's station is of the ordinary C.B. type, with the addition of the dial. When the receiver is on its rest the lines are disconnected for direct current by the condenser in series with the magneto bell. When the receiver is raised the lines are joined together through the speaking apparatus. The dial is so connected that after being rotated to the stop it makes a series of disconnections in rotating back to its normal position of rest in accordance with the figure dialled. The first train of disconnections is arranged to raise the shaft of the selector to the appropriate level, and the second series of disconnections to rotate it round the bank of contacts at

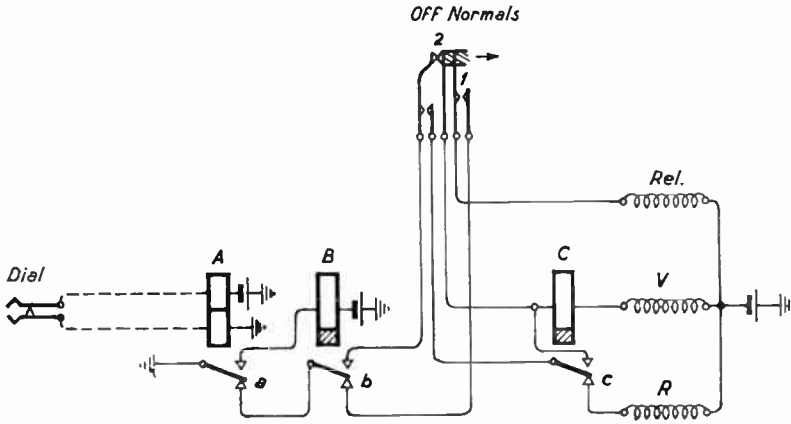


Fig. 20.—PRINCIPLE OF AUTOMATIC SWITCHING.
(Post Office Technical Pamphlets.)

C, there is a set of springs which are operated immediately the switch shaft rises and takes its weight off the lever. These springs are termed the "off-normal springs" and their function is to prepare the circuit for the receipt of the second train of dial impulses. Relay C is of the slow-

that level. The principle of the arrangement by which this is effected is shown in Fig. 20. The exchange battery is applied through the windings of relay A. Immediately the subscriber lifts his receiver relay A attracts its armature *a* thus making the circuit of relay B. Armature *b* then makes and all is in readiness for dialling.

"Slow-to-Release" Relay.

Here attention should be drawn to the character of relay B. It has a heavy copper cylinder known as a slug fixed on the core, with the result that momentary interruptions in the current flowing through this relay do not release the armature. It is known as a "slow-to-release" relay and the first train of disconnections sent out by the dial does not bring about the release of its armature. The slug placed on the end of the core forms a very low resistance closed secondary circuit for currents induced in it, and consequently the breakage of the main circuit induces a heavy current around the copper cylinder which tends to maintain the magnetism of the core, and it is only after about one-third to half of one second of interruption that the magnetism of the core falls to such a value as to release the armature.

to-release type. Immediately the first train of disconnections arrives, the armature of relay A makes and breaks in accordance with the train, but relay B retains its armature, whilst C operates with the first disconnection and retains for the remainder of the train. In this way impulses are sent via the armature of relay A and the off-normal springs 2, through relay C, which is of the same type as relay B and is therefore unaffected by the disconnections through the vertical magnet marked V.M. This raises the switch shaft to the required level. The pause between the first set of impulses and the second set during which the dial is being pulled round for the new number, and the travel of the dial to the stop point, forms an interval which is sufficiently long to permit relay C to release its armature. The next train of disconnections thus pass to the Rotary Magnet via *a b*, off normal 2 and *c*. Hence the wiper will now have been stepped to the required vertical and around to the required contacts.

When the conversation has concluded

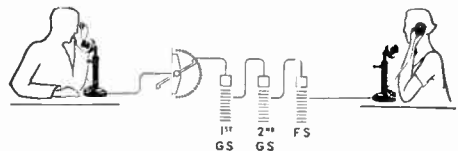


Fig. 21.—DIAGRAMMATIC REPRESENTATION OF SWITCHING ON A FOUR-DIGIT SYSTEM.
(Post Office Technical Pamphlets.)

"Off-normal Springs."

In addition to the three relays A, B and

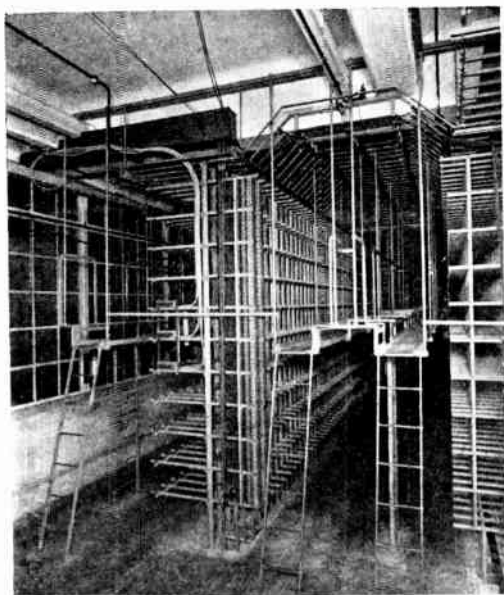


Fig. 22.—MAIN DISTRIBUTING FRAME UNDER CONSTRUCTION.

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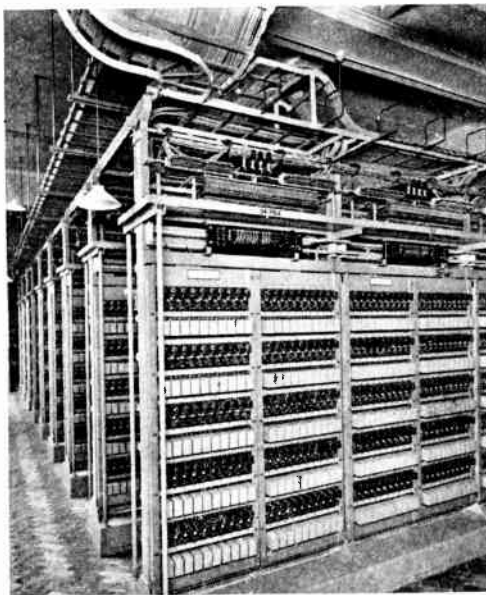


Fig. 23.—LINE SWITCH UNITS.

the subscriber restores his receiver, with the result that the armatures of relays A and B fall back and the release magnet is operated. The switch shaft revolves to zero under the influence of the spring and then falls to its normal position, at the same time operating the off-normal springs in readiness for a further call.

The arrangements which have been described contain many of the basic principles of automatic switching. It will be appreciated that in this way any one of a hundred subscribers may be selected in obedience to two operations of the dial.

Extending an Exchange.

In order to extend the exchange to one thousand lines, a final selector for the numbers up to 100, 200, 300 and so on would be required, and selection would have to be made by a further switch to each 100 group. In this case three trains of impulses would be necessary. The first number dialled would select the correct hundred, and the further two trains of impulses the correct ten level and then the correct unit around the level. To increase the exchange capacity to ten

thousand, selection would first have to be made to the thousand groups, that is to say, the arrangements previously described would have to be multiplied by ten and an additional switch introduced to select the correct thousand. This would be effected by a four figure number, the first impulse selecting the correct thousand and the other three impulses as described. This is diagrammatically illustrated in Fig. 21. By multiplying the arrangement by ten again and using five sets of impulses the capacity can be raised to one hundred thousand. This condition meets fairly large cities such as Sheffield or Leeds, but is not large enough for the great cities of the Empire such as London, Manchester, Liverpool or Glasgow. The method of dealing with this problem will be dealt with later.

Traffic Problems.

The arrangements described show how a particular number can be reached, but the provision of the apparatus described for each subscriber is, of course, economically impossible. A technique has grown up which deals with the amount of traffic

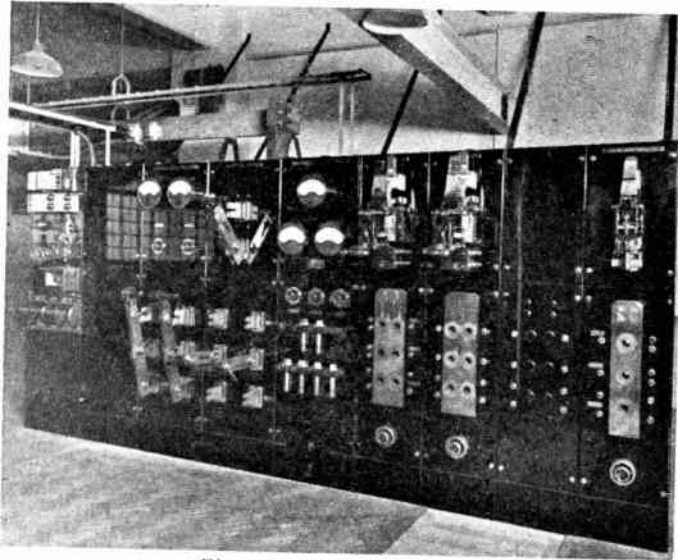


Fig. 24.—A POWER BOARD.

related to the quantity of connecting mechanisms to be provided. This forms the theme of the article by Col. Sir Thomas F. Purves on "Traffic Problems of Telephone Engineering," on page 466, Vol. I.

Taking the case of the four-figure number, the first selector is of the general form already described, but the first train of impulses raises the switch shaft to the correct level, and then the wipers move along the banks to find a disengaged link to the second selector. The second train of impulses raises the second selector switch shaft to the appropriate level and then the wipers move over the contact banks to find a disengaged final selector containing the number required in the last hundred. Since many final selectors are required in an exchange, it is essential to prevent the possibility of a second subscriber obtaining connection with a subscriber who is already speaking. This is accomplished by adding a bank of contacts, known as the "test bank," below the level of the line circuit banks. An additional wiper is added to the

switch shaft and this arrangement is used to prevent the connection of a second subscriber.

Other Functions of the Switches.

There are, of course, many functions which have to be performed by the switches. The mere connection of the circuits has already been described but additional relays contained in some more complicated circuits are required to provide first of all the speaking current, secondly to test the subscriber's circuit to see if it is engaged, and, if so, to give an indication to the subscriber that the line wanted is engaged. If the line is disengaged, then to apply a ringing current to call the wanted subscriber.

The "Uniselect" Switch.

The apparatus already described is designed so as to provide for the peak load on the exchange. The apparatus is necessarily costly and in order to secure the close relation between the traffic and the apparatus provided, a switch is added to each subscriber's circuit at the exchange to search for and find a disengaged con-



Fig. 25.—MOTOR GENERATORS FOR BATTERY CHARGING.

necting mechanism, actually, of course, to find a disengaged first selector. This switch, technically termed a "uniselector," consists of a bank of contacts with a magnet and ratchet wheel, and a circuit is formed so that the wipers rotate round these contacts until they establish connection with a disengaged link to a first selector. This is the switch mechanism shown in Fig. 21 immediately connected to the subscriber's line.

How Economy in Apparatus is Effected.

Here it may be interesting to remark that some economy in apparatus can be effected by arranging that instead of the subscriber having a uniselector to search for a disengaged connecting mechanism, the connecting mechanism itself can be arranged to search for calling subscribers. Indeed, this principle is actually employed in exchanges of the rural automatic type and on private automatic branch exchanges. The new system will also in future be applied to large exchanges.

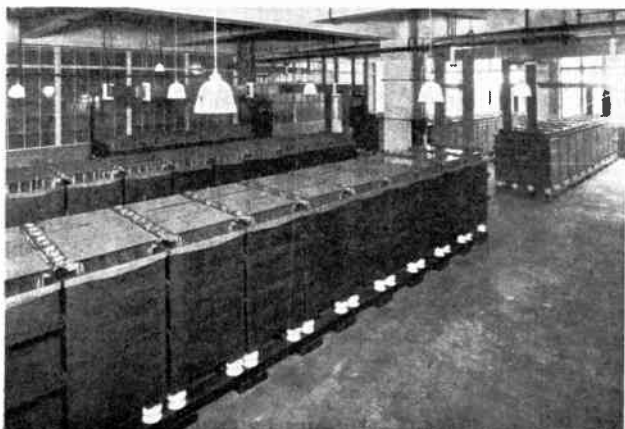


Fig. 27.—BATTERY ROOM.

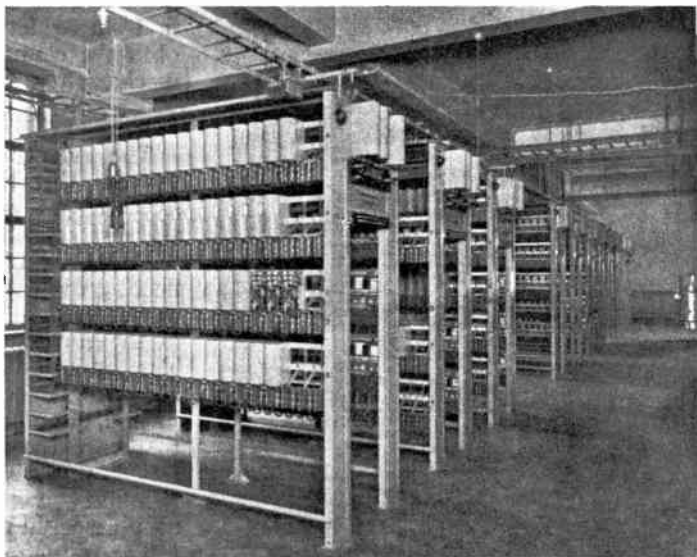


Fig. 26.—SELECTOR RACKS.

Connection with an Exchange.

What has been said explains in general terms the method by which subscribers on a particular exchange can get into connection with each other by the operation of their dials. When connection with an exchange is wanted, a number may be assigned by which the calling subscriber obtains the services of an operator, who sets up the connection required in the ordinary way by plugs and cords. This applies also to such services as trunks and telegrams. In the case of a fairly large area using a five-figure number, the first figure dialled may be used to obtain connection with a particular exchange. The disadvantage of this system is that the numbering system is inflexible and once fixed would involve wholesale alteration of all the numbers if a particular exchange outgrew the level assigned to it.

Dialling Tone and Ringing Current.

It is unfortunately quite impossible to describe the details of the multiplicity of circuits used in automatic

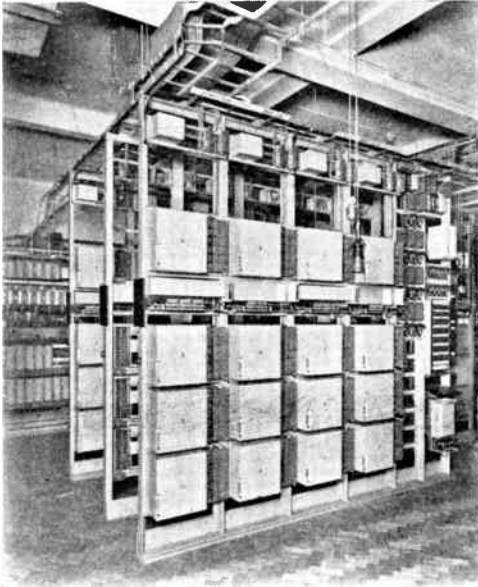


Fig. 28.—DIRECTOR RACKS.

telephony owing to their complexity and it must suffice to say that the dialling tone is applied when a connecting mechanism is available for the use of the calling subscriber, and that ringing current, number engaged or number unobtainable, is sent out by the operation of relays.

The "Routiner."

Perhaps the most remarkable device in the whole range of telephony is the "Routiner," a scheme for which Post Office engineers are responsible. This machine automatically picks up the various switches one after the other and subjects them to a series of rigorous tests. Immediately failure occurs, the machine stops and a lamp lights indicating the location of the defect.

DIRECTOR SYSTEM.

The problem of huge telephone systems has been solved by the introduction of what is known as the "Director System." Actually, this consists of a seven-figure system, but the first three figures are represented by letters. The first three letters of the name of the required exchange are spelt out and then the four figures constituting the subscriber's num-

ber on that exchange are dialled. The first three letters by suitable switches obtain connection with connecting mechanism at the required exchange.

How the System Works.

The seven trains of impulses are received by the director, which consists of an arrangement of a two-motion switch of the same general form as a final selector, uniselectors, relays and a series of connecting tags, which last enable rearrangements in the routing of calls to be made as the growth of the system may require. The impulses are stored by positioning the various switches and then retransmitted, often in a somewhat different form, to secure the required connection. This latter possibility gives the system a flexibility which a plain seven-figure number could not.

The director does not wait until the dialling of the letters and figures is complete, but commences immediately to select while dialling is in progress. Having performed its function, it immediately cuts itself away from the circuit and awaits the next call for its services.

The circuit arrangements are exceedingly complex, but the whole of the apparatus used is of a simple and robust type, consequently the system works with uncanny speed and efficiency.

It remains to explain that in a director area which is being gradually converted to automatic, calls from an automatic to a manual exchange can be dialled. When the director reaches the manual exchange,

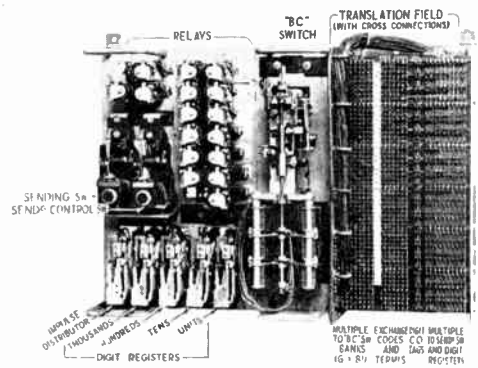


Fig. 28A.—DETAILS OF ONE OF THE DIRECTOR RACKS.

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