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PART 13

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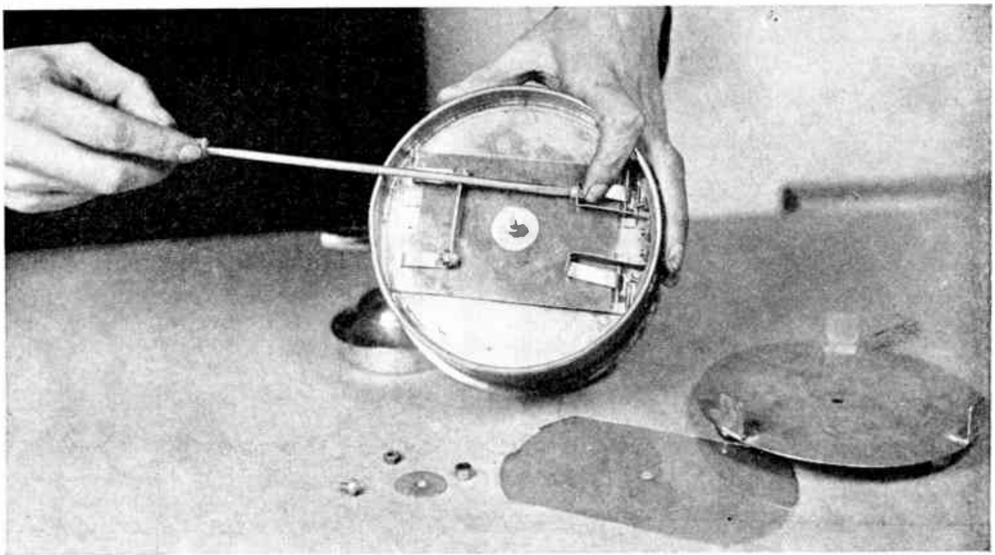


Fig. 2.—ASSEMBLING THE COMPONENTS OF THE ELECTRIC KETTLE.
This shows the thick brass cover plate and the first sheet of mica in position and screwed down by the centre nut. The heating element contacts are then screwed on to the brass strips with 2 B.A. bolts.

How to Make the Flange.

Take a strip of copper 1½ inches wide and ½ inch longer than the circumference of the kettle and scribe a line ⅛ inch from the edge. Bend over the edge as shown in A, Fig. 3, by tapping it with a mallet while the strip is held against a metal straight-edge or block.

Now take a length of the tinned iron wire and lay it in position so that it projects slightly beyond the ends of the copper strip, see B, Fig. 3. Commencing at one end, gently hammer the edge over so that it surrounds the wire.

Cut out a circular piece of wood the same diameter as the kettle; this forms a template upon which to shape the flange. Pull the wire out slightly at one end of the copper strip so that the round edge is free of the wire core for 1 inch from the end. Cut off the surplus wire, leaving ½ inch projecting and trim away ½ inch of the hollow edging to allow for the over-lap where the soldered joint is made.

The flange can now be shaped round the template, engaging the projecting wire in the hollow end, and held securely in place with a twisted cord and stick as shown in Fig. 4. The lapped joint can then be soldered. It now remains to cut the slot in the back of the flange, see

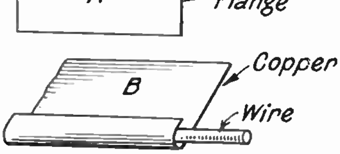


Fig. 3.—HOW TO MAKE THE FLANGE.

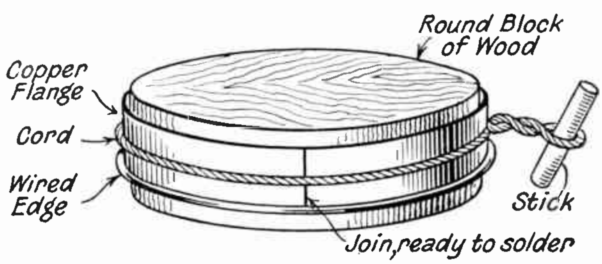


Fig. 4.—USING A PIECE OF WOOD AS A TEMPLATE ON WHICH TO SHAPE THE FLANGE.

A

Fig. 5, behind which is bolted the insulating strip of fibre.

Fixing the Flange.

Having tinned the inner edge of the flange, fit in position with about $\frac{1}{4}$ inch overlapping the sides of the kettle and $\frac{7}{8}$ inch projecting beyond the base. Make sure the ring is square and fix temporarily with a couple of blobs of solder. Now wind a length of insulating tape round the body of the kettle immediately above the edge of the flange; this will prevent any solder running up the side of the kettle

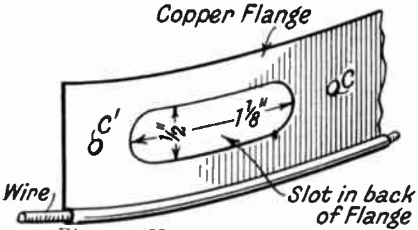


Fig. 5.—How to Cut the Slot in the Back of the Flange.

and spoiling the appearance of the work.

The kettle should now be inverted and a neat soldered joint made between the base and the inner surface of the flange.

Another useful hint to prevent unwanted solder taking to the sides of the kettle above the joint is to run a wide line of Brunswick black immediately above the union; this is easily cleaned away afterwards with a little turpentine.

How to Fix the Central Bolt.

Bore a hole $\frac{3}{16}$ inch in diameter in

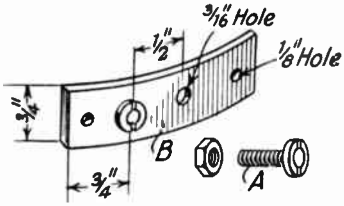


Fig. 6.—Dimensions of the Fibre Insulating Strip.

the centre of the base of the kettle and well tin the surface surrounding it. In like manner, tin the head of the bolt, insert in the hole with the head inside, and hold firmly in place by stuffing some clean rag inside the kettle. Pressing on the head with the left hand securely solder the bolt in position from the underside.

The Fibre Insulating Strip.

Take a piece of fibre the size shown in Fig. 6 and file up the edges, finishing with fine emery cloth; burnish the surface to prevent the fibre absorbing moisture which may spoil its insulating properties.

Set out the holes as shown in Fig. 6; the two outside ones should be $\frac{1}{8}$ inch diameter, and the inner ones $\frac{3}{16}$ inch diameter. The two sockets A in Fig. 6 can then be screwed into the larger holes, B. Place the fibre in position on the inside of the flange, making sure that the sockets lie centrally within the slot in the

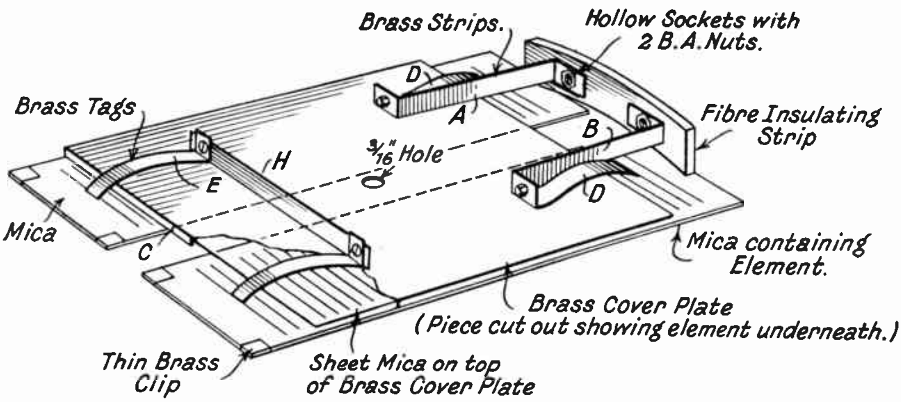


Fig. 7.—The Layout of the Elements and Cover Plate.

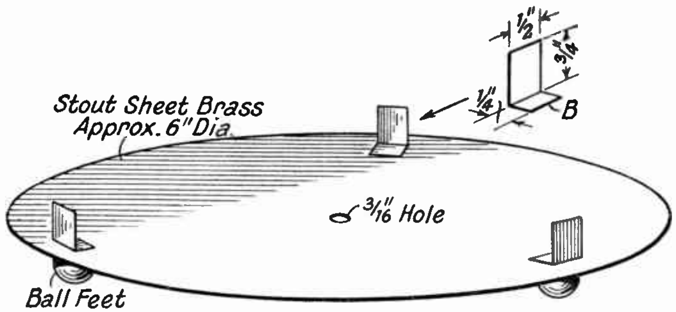


Fig. 8.—THE CIRCULAR BASE.
Showing ball feet and right-angled brackets.

flange, then punch mark the two holes C and C[1], Fig. 5. Drill these holes and fasten the insulating strip in place with 4 B.A. bolts.

Making the Cover Plate.

The brass cover plate, see C, Fig. 7, holds the elements tightly against the base of the kettle ; its size is 3 inches by 4½ inches by ⅛ inch, but as kettles of the same capacity vary in diameter it is best to lay the elements in position and make sure that the plate clears the contact strips D and E in Fig. 7 by ¼ inch.

Having squared up the brass (iron will do at a pinch) plate, scribe the diagonals and bore a 3/16-inch hole in the centre. Now support the plate at its corners and give the centre a sharp blow with a hammer, so that it becomes *slightly* concave. This ensures a tight grip on the outer edges of the element strips.

The Connecting Bars.

The pieces marked A, B and H in Fig. 7 are made out of stiff springy gauge 22 brass. They are 5/16 inch wide, and their exact length must be found by experiment, as the size of kettles varies. The holes at the ends are 3/16 inch to take 2 B.A. bolts and sockets. When bending the two strips A and B it is necessary to heat and soften the ends, otherwise they may crack in the operation.

Making the Base.

This consists of a circular piece of brass or other available metal cut to exactly fit into the base of the kettle, a hole being drilled in the middle permitting the central bolt to pass through. On the underside three small brass balls are soldered, acting as feet to lift the kettle. Above these small feet right-angled brackets are soldered as shown in Fig. 8. The

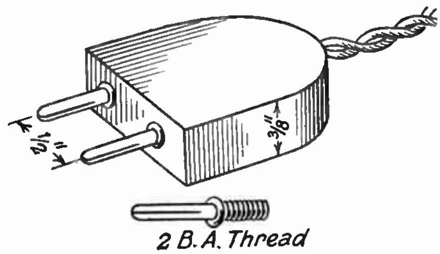


Fig. 9.—THE EBONITE ADAPTOR.
The pins fit into the sockets, which are mounted on the fibre.

length of these must be so adjusted that they come in contact with the true base of the kettle when the false base or cover plate is screwed down in position ;

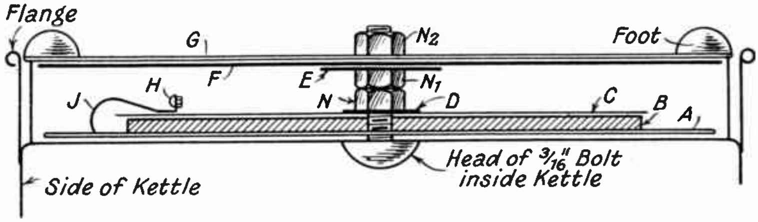


Fig. 10.—SECTION THROUGH THE BASE OF THE KETTLE WHEN HELD IN AN INVERTED POSITION.

A, element strip ; B, brass cover plate ; C, sheet of mica ; D, brass washer ; E, second brass washer ; F, second sheet of mica ; G, base or false bottom of the kettle ; H, connecting link ; J, one of the brass connecting strips ; N_1, first nut ; N_2, second nut.

Fig. 11.—Assembling the Components of the Electric Kettle.
Showing how the base plate is fitted in position.

this relieves much of the strain on the central bolt.

When shaping this base plate to fit the bottom of the flange arrange that one foot comes directly to the front of the kettle.

The Ebonite Adaptor.

Fig. 9 shows the details of this: it is simply a block of ebonite with two $\frac{3}{16}$-inch holes tapped out 2 B.A. into which the contact pins are screwed. These two holes communicate with the larger $\frac{1}{4}$-inch hole at the back of the adaptor through which the flex is introduced.

How to Assemble the Parts.

Invert the kettle and then lay the "Creda" elements in position so that they are approximately $\frac{3}{8}$ inch from the central bolt. Now place the thick brass cover plate in position with the concave side against the elements, and see that it is square with the mica strips. The next thing is to place the sheet of mica, C, see Fig. 10, on the top of this cover plate; note that it has a central hole and overlaps the brass $\frac{1}{8}$ inch at the ends. A 1-inch washer, D, is now placed on the mica, and the first nut, N, is screwed down firmly in position.

The connecting tags, E and D in Fig. 10, should now be bent to lie snugly on the top of the mica sheet C; the ends must be bent up at right angles so that the link H (Fig. 10) can be attached.

The tags D must now be fastened with 2 B.A. bolts to the strips A and B, which, in turn, are clamped down to the sockets attached to the fibre insulating strip. It is a good plan to secure the nuts on

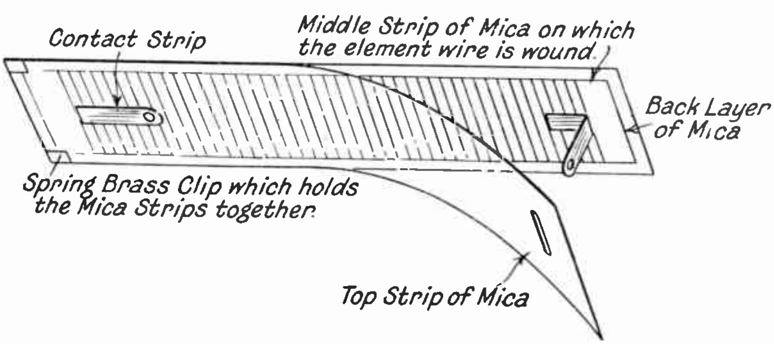


Fig 12.—How the Element is Wound on a Mica Former.

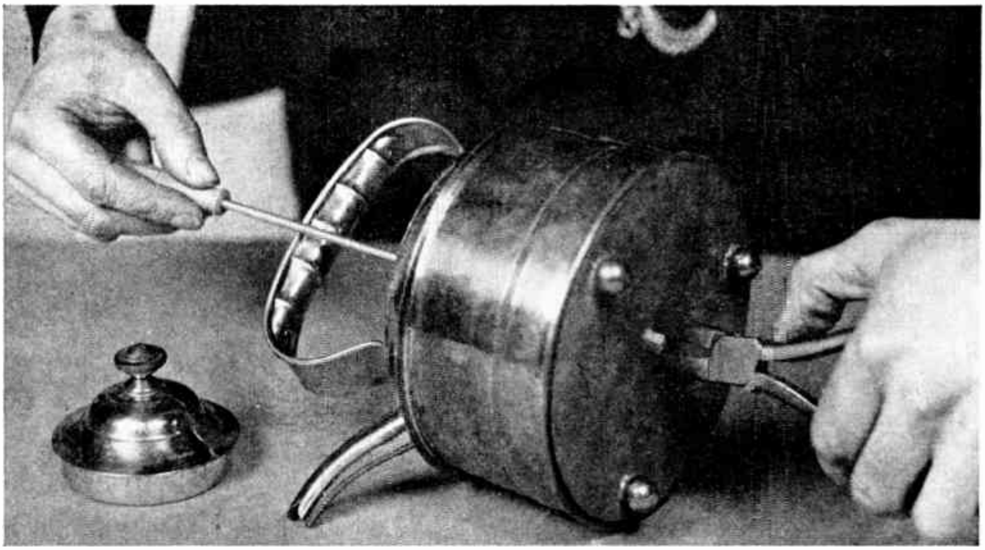


Fig. 13.—Assembling the Components of the Electric Kettle.
The base plate is fixed firmly in position by means of centre nut.

the sockets with small spring washers, as the heat tends to shrink the fibre, and it is fatal for either of the strips A or B to work loose.

The nut N^1, in Fig. 10, should now be screwed down and on top of this rests a $1\frac{1}{4}$-inch brass washer, which supports the mica sheet F. This sheet is 4 inches wide and reaches right across the base of the kettle to prevent the connecting tags from coming into electrical contact with the base. The ends of the mica strip must be rounded to fit snugly against the edge of the copper flange, a little slot being cut in the front to admit the bracket attached to the base plate immediately above the ball foot. The other two brackets will then fall to the rear and miss the mica strip.

Finally, fit in the base plate and bolt down firmly with the nut N^2, Fig. 10. The kettle is now ready for the flex and its first test.

Testing Out.

It is an excellent plan to fit a lamp holder with two short lengths of flex, then put one short end in the plug attached to the kettle flex and twist up the free end of the kettle lead with the second short end. Thus the lamp is in *series* with the elements in the kettle. Switch on and the lamp should light feebly owing to the resistance of the elements; if it glows brilliantly a short may be expected.

For the final test, three parts fill the kettle with water, stand it on the hearth, when in 7 to 8 minutes it should boil.

Switch off when boiling, as the thick cover plate becomes very hot, and will maintain the water at boiling point for several minutes.

Do not drain the kettle absolutely dry immediately after boiling; allow the cover plate time to lose its heat.

Final Hints.

"Creda" elements have been used in making this kettle, each rated at 325 watts 110 volts, making a single element of 650 watts for a 220-volt circuit; similar elements can be bought for other voltages and of greater capacity for larger kettles.

Some readers may like to wind their own elements. Fig. 12 shows how the element is wound on a mica former and sandwiched between two outer strips of the same material. Element wire can be purchased from the "Creda" company, in lengths which consume one unit.

MORE RADIO RECEIVING CIRCUITS

TWO- AND THREE-VALVE A.C.; D.C. SUPERHETERODYNE; AND THREE-VALVE D.C. RECEIVERS.

By A. E. WATKINS.

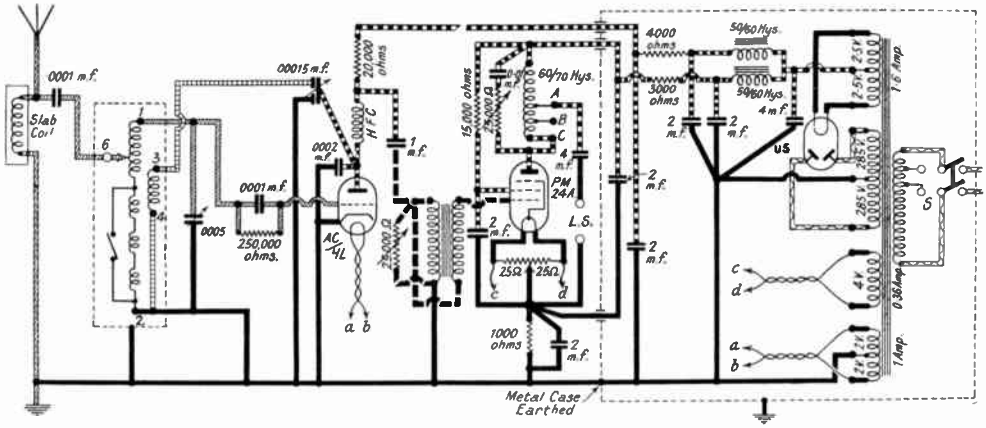


Fig. 1.—CIRCUIT FOR A TWO-VALVE RECEIVER OPERATED FROM A.C. MAINS.
This is a powerful short-range set with power-grid detector, followed by a pentode output.
The explanation of the symbols used in this or the following illustrations will be found on pages 374 and 375.)

TWO-VALVE A.C. RECEIVER.

THERE are a number of listeners who are satified with the local stations and have no desire for programmes from afar. Therefore, the opportunity has been taken of designing a powerful short-range set with power-grid detector, followed by a pentode output (see Fig. 1).

The Power-Grid Detector.

With the conventional grid-leak detector, there is considerable high note loss, due to the fact that the necessary value of grid leak and condenser, to produce good sensibility, shunts away the higher fiequency. Moreover, with 60 volts H.T. the signal which is rectified on the grid is applied to a very curved anode characteristic, and, therefore, if the signal could be applied after rectification on the grid of the 150-anode curve, the output would be nearly proportional to the input, and curvature distortions in the anode circuit would be absent.

High Anode Voltage.

Thus one of the first considerations with a power-grid detector is a high anode voltage. A valve used under these conditions at approximately near a zero-grid voltage passes a very heavy anode current and it is as well to ascertain from the manufacturers whether the valve is suitable for use under such conditions, and that the life of the valve will not be shortened. The valve used in this receiver is an A.C./H.L., with a 4-watt dissipation limit, so that with 8 milliamperes and 140 volts H.T. there is a safe wattage of just over 1 watt. Other valves which are suitable are the Marconi, and Osram M.H.L.4 and Mullard 354V.

All these valves have the same dissipation limit and can be used as power-grid detectors with 150 volts actually on the plate.

With A.C. valves, grid current flows when the grid and the cathode are joined together. No positive bias is thus required.

The Inter-Valve L.F. Coupling.

Having given the detector a good signal there should be in the anode circuit a rectified output worthy of a good inter-valve coupling. It was therefore decided to use in this receiver a resistance filter feed with auto-choke coupling. This has the advantage of transformer coupling with the step-up amplification of an ordinary transformer, and for this type of choke an ordinary transformer can be used, such as the Ferranti A.F.6. The G and H.T. are connected together, the P being connected to the bias and the G.B. connected to the grid.

Fig. 4 shows the correct connections. This method of connecting with inter-valve coupling is, in the writer's opinion, one of the most satisfactory forms of inter-valve L.F. coupling, as it gives a practically straight-line output.

The Output Pentode.

The valve used in the output stage of this receiver is a P.M.24A. and when properly used, the pentode will give satisfactory reproduction. It is quite certain that no valve will give as many milliwatts output per volt input, but it is necessary when using a pentode to use a filter feed to the loud speaker as a pentode must always have a constant load upon the plate. Further, a tone control is necessary. This tone control is a very simple contrivance, it being a 50,000-ohm wire-wound potentiometer or variable resistance in series with a fixed condenser. This condenser should be of the mica type. The resistance and condenser are connected directly across the filter choke, as shown in the circuit, and by varying the resistance, an excellent tone control results. To obtain a large undistorted output from a pentode with loud speakers designed for triode valves, it is necessary that the impedance does not rise above 10,000 ohms at any frequency, and to fulfil these conditions it is necessary that the input choke is tapped at various points so that the speaker may be adjusted to give the best results. This is easily done by trial, that is to say, by connecting the output condensers of the speaker to various tappings on the input choke. There is one other variation in this receiver not noticed in many designs, and that is in the aerial tuning. It will be noticed that there is a slab coil and that the top end of the winding of the tuning inductance is connected by a small condenser. This slab coil is serving two purposes. First, it increases the selectivity and secondly it improves the reception on the long waves.

THREE-VALVE A.C. MAINS-OPERATED RECEIVER, CONTAINING BAND-PASS TUNING, POWER-GRID DETECTOR AND PENTODE OUTPUT.

This circuit, which has screened-grid H.F. amplification, will be found to be free from trouble and easy to maintain. Hum, the principal trouble in mains sets, is not likely to be encountered. The circuit is simple and straightforward. It will be found very easy to wire, and the pentode valve gives generous output and is quite suitable for operating a moving-coil speaker with sufficient volume to fill a large-sized room (see Fig. 2).

Controlling Input to the Grid of the Screened-Grid Valve.

It will be noticed in the circuit that the band-pass tuner is fed from the aerial by the choke feed. This system has the advantage that various-sized aerials do not affect the ganging of the band-pass tuner. The circuit is highly selective and meets all modern broadcasting conditions, and as the band-pass tuner and the H.F. tuner can be ganged together, single-dial tuning may be used. That is to say, all three condensers may be ganged together providing that the coils are correctly matched. With all screened-grid receivers it is necessary to have some means of controlling the input to the grid of the screened-grid valve, as, otherwise, when working on powerful local stations, the valve will be over-loaded and this will cause not only distortion but poor selectivity.

Using a 50,000-ohm Potentiometer.

It will be noticed that in this circuit a 50,000-ohm potentiometer is placed across the second band-pass tuner and

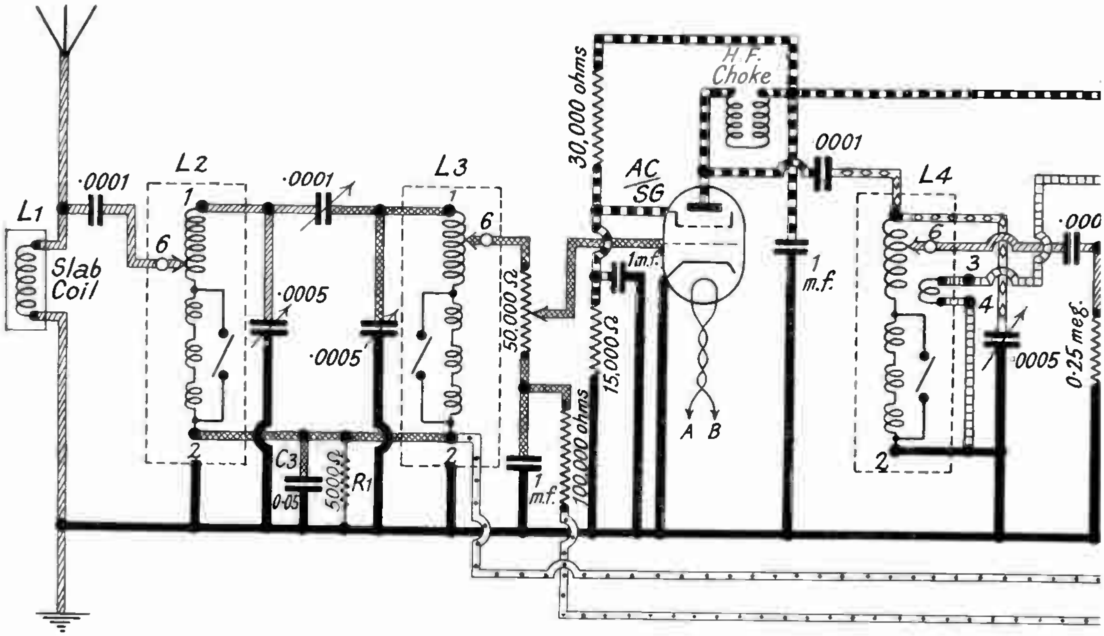


Fig. 2.—CIRCUIT FOR THREE-VALV
This is a receiver containing band-pass tuning

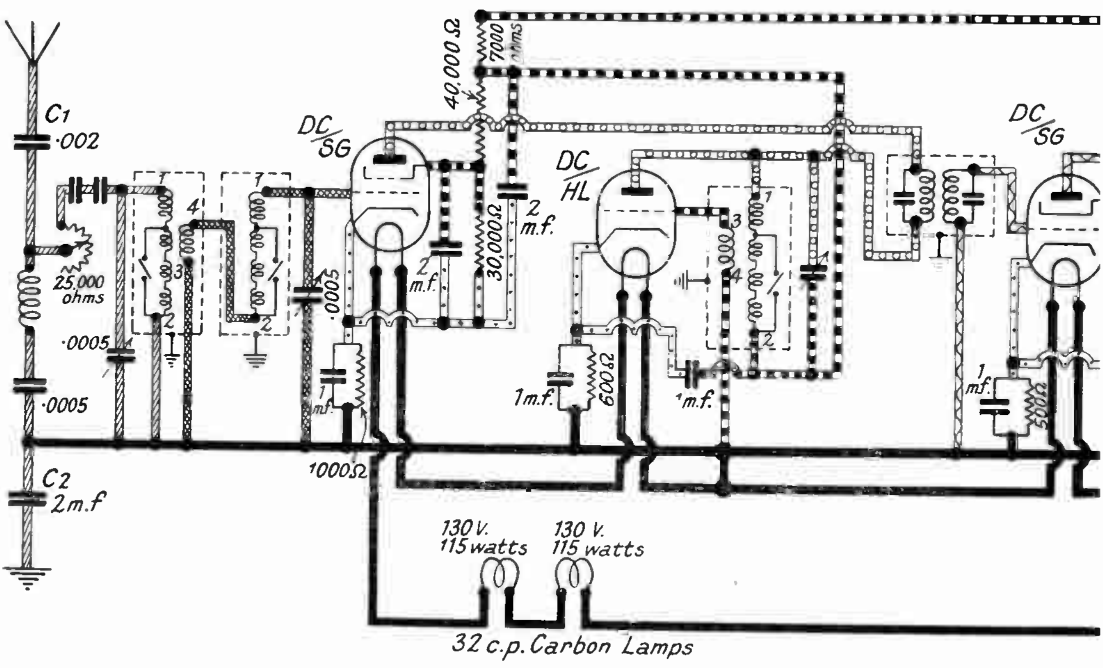
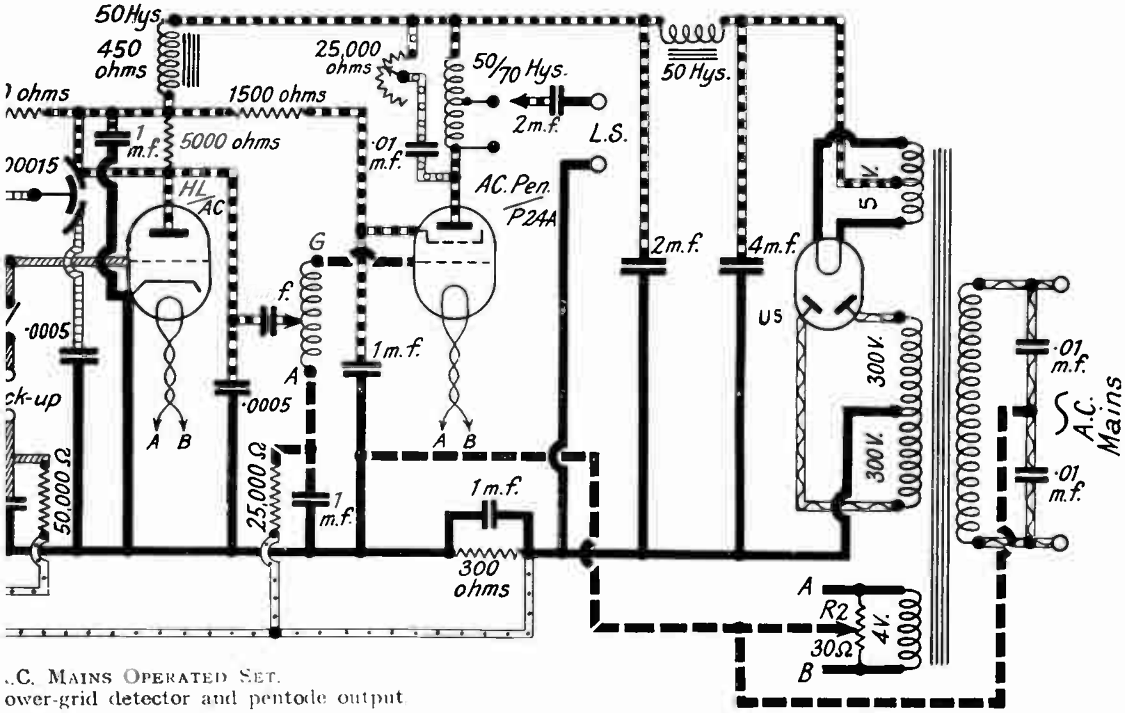
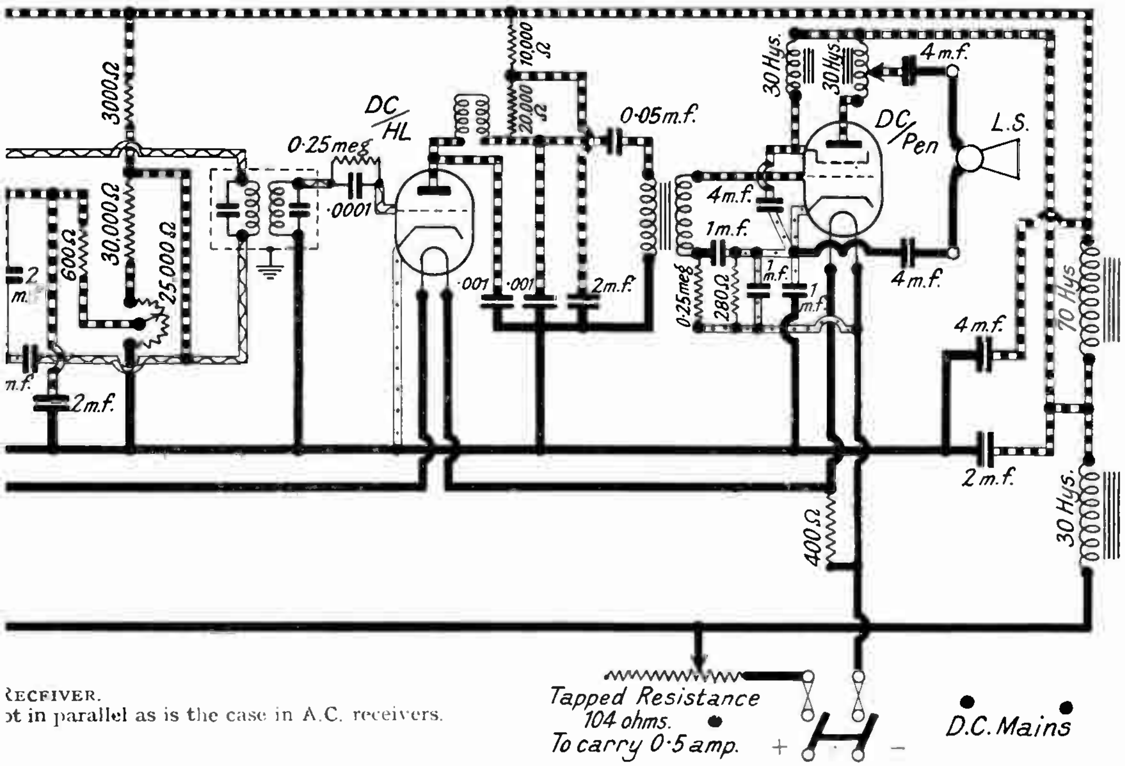


Fig. 3.—CIRCUIT FOR D.C. MAINS SUPERHETERODYNE
This is a five-valve set, and it will be seen that the filaments are connected in series, and



.C. Mains Operated Set.
ower-grid detector and pentode output



Receiver.
ot in parallel as is the case in A.C. receivers.

the rotor contact is taken to the grid of the screened valve. Now this system has several points to commend it, particularly as a steady increase in negative voltage is developed across the control of the potentiometer as its earth end is approached. By this method a steady increase of grid bias is introduced as the volume control is turned down for the reception of strong local stations. It is particularly important that if a metal front panel is used on this receiver, the spindle of the potentiometer must be very efficiently insulated from the panel, also that the screw for holding the knob to the spindle of the potentiometer is sunk to prevent any contact with the hand during operations, for it will be noticed that the spindle is connected direct to the grid of the valve.

How Reaction is Applied.

Reaction is applied to the H.F. tuner in the usual manner by means of a differential condenser. The connections are also shown for gramophone pick-up, but these may be omitted if they are not required.

The detector valve is coupled to the pentode by the auto-choke coupling, as it is always desired in a mains receiver to obtain the highest quality possible.

Connecting Up the Transformer.

A standard three-to-one transformer will serve this purpose and it is only necessary to connect the primary and secondary windings together, using the connected terminal as the tap for the feed of the 1 mfd. condenser. It is important that the correct direction of winding be maintained, and as some transformer manufacturers mark their transformers differently, alternative methods of connection must be tried. That is to say, if G.B. and the plate have been connected together and are not satisfactory, the G.B. and the H.T. should be connected together. Either of these two connections will be the correct one which will give the best results.

The Tone Control.

Across the pentode choke is connected a 25,000-ohm variable resistance in series with a .01 mica condenser. This is the tone control and is a very necessary requirement to a receiver of this description.

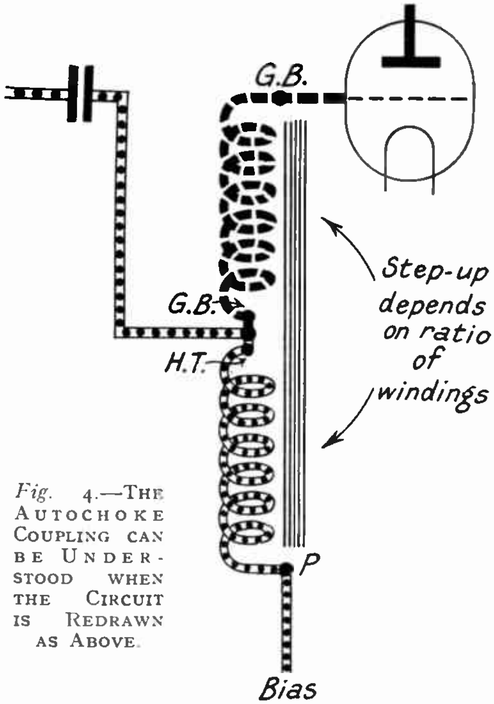


Fig. 4.—THE AUTOCHOKE COUPLING CAN BE UNDERSTOOD WHEN THE CIRCUIT IS REDRAWN AS ABOVE.

The rectifying unit and the smoothing circuit are quite conventional and clearly shown in the diagram. They need no explanation, other than that the components must be good.

The Resistances.

The various resistances should be wire-wound and the necessary filter condensers of a high test value.

The 300-ohm resistance in the main negative lead of the H.T. must be capable of carrying at least 50 milliamps., otherwise it will over-heat.

The 5,000-ohm resistance in the detector plate circuit must be capable of carrying 10/12 milliamps. This circuit has been designed for the use of screened coils of modern design. That is to say, coils designed similarly to those employed in the superheterodyne receivers described in a previous article, but, for the benefit of those who may wish to construct their coils, full details of the winding are given in the accompanying sketch and coils

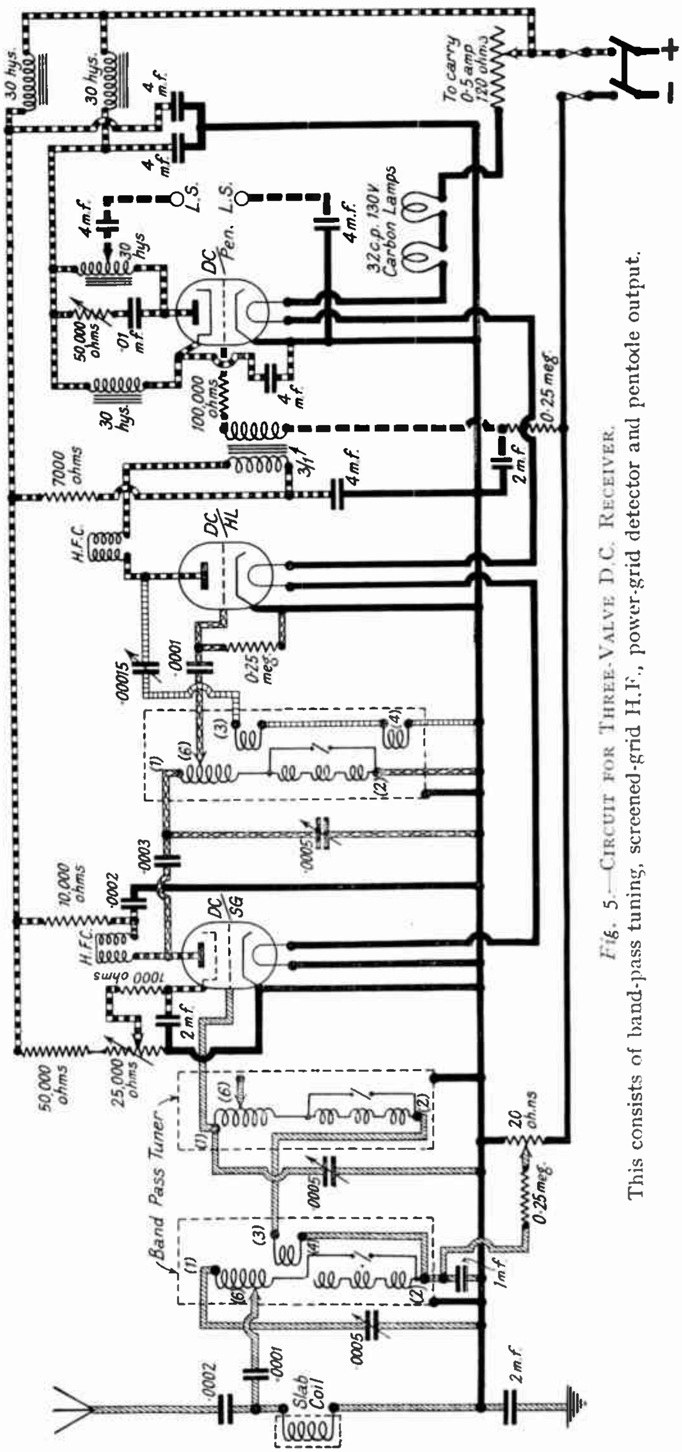


Fig. 5.—CIRCUIT FOR THREE-VALVE D.C. RECEIVER.

This consists of band-pass tuning, screened-grid H.F., power-grid detector and pentode output.

identical to these specifications are manufactured by the Watmel Wireless Company, Ltd.

The result of any receiver depends, to a great extent, upon the tuning inductances being carefully constructed, particularly in view of the necessity for very high selectivity in present-day broadcasting.

D.C. SUPERHETERODYNE RECEIVER.

The problems of D.C. mains operation are more difficult than those of A.C. mains largely because little attention has been devoted to many of the difficulties. These have disappeared recently, however, owing to the introduction of special indirectly heated D.C. mains valves, the characteristics of which are almost identical to those of the A.C. mains type.

The chief difference of the D.C. valve is that the current of ½ amp. at 6 volts is taken for the valve filament and 8 volts for the pentode filament.

Filaments Connected in Series.

On reference to the circuit diagram it will be seen that there are five valves, and that the filaments are connected in series. This, of course, is quite different to A.C. mains or battery-operated receivers in which all filaments are in parallel. In the filament circuit also will be noticed two carbon filament lamps; *on no account* must metal filament lamps be used for this purpose. These carbon lamps have a further property of possessing a higher resistance when cold than when hot, and this is a protection to the valve when the current is switched on.

Why Fuses are Fitted.

The set is intended to work on the normal voltages from 200 mains, and, in order to accommodate higher voltages, a tapped resistance is included. As the lamp resistance is not exactly correct to give ½ amp. through the heaters, a small portion of this resistance must be included even on 200 volts. Fuses are fitted in each mains lead to guard against a short-circuit, while a double-pole switch is also necessary.

Earth Connections and Their Importance.

Another very important point in D.C. mains sets is that they must not be connected directly to earth. Therefore, the condenser C2 is inserted in the earth lead. Also, the condenser C1 is inserted in the aerial lead. This is also important for D.C. sets because it must be remembered that one side of the main is always earthed, and in a D.C. operated set there is no isolation transformer; that is to say, the mains are connected directly to the receiver's various circuits. Therefore, any accidental shortage of the aerial to earth would cause serious damage, and the only way to isolate the receiver from such short-circuits is by means of the condensers C1 and C2. Care should be taken that no parts of the receiver come into contact with any metal substances or anything which would cause a direct connection to earth. The whole receiver should be contained in a non-metallic case so as to guard all the component parts. There should be no open terminals or any part of the circuit which could be touched. Never attempt any adjustments while the mains are switched on.

On no account should these precautions be disregarded.

The aerial circuit, band-pass filter and intermediate frequency transformers are exactly the same as those in the set described in the previous article (page 388), and the only difference in the D.C. receiver is the value of the various resistances and condensers. Each of these is clearly marked in Fig. 3.

The Grid Bias.

The bias for the valves in this receiver is obtained in exactly the same manner as in an A.C. set. That is, by the use of a resistance in each cathode lead, and tests have shown that this is extremely satisfactory. The circuit is very simple and is clearly shown in Fig. 3.

This superheterodyne receiver and those described in the previous article (page 384) can be thoroughly recommended when high amplification and high quality are required, to say nothing of their simple and easy construction, and they offer the most satisfactory approach to the deal receiver yet obtained.

THREE-VALVE D.C. RECEIVER.

This receiver is not an ambitious one, as it consists of three valves and an arrangement of band-pass tuning, screened grid, H.F. power-grid detector and pentode output. The circuit is shown in Fig. 5.

Coupling the Detector and Power Valves.

Transformer coupling is employed between the detector and the power valve. This transformer should not have a larger ratio than 1 to 2 as the pentode necessarily imposes a limitation upon the permissible stage gain. By choosing a transformer capable of carrying the detector anode current it is possible to simplify the coupling arrangements, and also in view of the fact that the voltage is limited this allows for a higher voltage on the detector valve. It must be remembered that we cannot obtain a higher voltage than the mains, and as the H.T. is smoothed, a certain amount of voltage must be lost in the smoothing. It should be mentioned here, however, that it is useless to think of operating a D.C. mains receiver on anything under a 200 volts circuit, and in districts where the voltage is only 110 we must, if we wish for a mains-operated receiver, use a motor generator. In these instances it will be better to use a motor generator which gives an A.C. output and to use then an ordinary A.C.-operated receiver.

Using a Motor Generator.

When a motor generator is used it is advisable that it should be of the two-machine type, that is to say, one motor driving an independent generator. The two machines should be housed in a heavy metal case and the case securely earthed, as otherwise trouble will be experienced from the commutation of the motor. Also, it would be a wise precaution to connect inductances and condensers across the input lead from the main. This will be dealt with more fully in a later article on "Preventing Interference from Electrical Appliances, such as Small Motors, etc."

The Circuit Diagram.

On reference to the circuit diagram, it will be noted that the usual form of band-pass aerial tuning is used. This is particularly necessary in the case of a mains-operated grid receiver, as without band-pass tuning the selectivity would be useless under the present-day broadcasting conditions. A condenser is inserted between the aerial and also between the earth to prevent any chance of short-circuit, due to one side of the mains being earthed, as pointed out with the superheterodyne D.C. receiver dealt with previously.

Why Aerial and Earth Must be Isolated.

In every D.C. main one pole is earthed; it may be the positive or it may be the negative. It is, therefore, essential that the aerial and the earth are isolated. The only means of doing this is by means of a condenser in the aerial lead and the earth. There is one other method, and that is to use a separate aerial coupling. This, however, adds a complication and is unnecessary.

Values of Resistances.

The various values of the resistances are stated on the diagram, and all the values hold good for receivers constructed to operate between 200 and 250 volts.

Smoothing Chokes and Condensers.

In the smoothing circuit, it will be noticed that there are three smoothing chokes and also a pentode choke, and that the smoothing condensers are of a larger size than are usually employed in A.C. sets. This is because D.C. mains require more smoothing than A.C. mains. The smoothing chokes should be wound to a low resistance of approximately 200 ohms. The wire used must be of a heavier gauge to obtain the necessary number of turns for a given inductance. The lower the resistance of these chokes and the higher the inductance the better will be the results, as otherwise the voltage dropped across the choke will reduce the voltage on the plate of the valve. This, of course, is particularly so in the case of the choke preceding the pentode. The usual system of tone control is connected across the pentode choke and consists of a wire-wound potentiometer and mica condenser.

The valve filaments are connected in series and the voltage dropped by means of two 130 volts 32 c.p. carbon filament lamps in series with a tapped resistance to regulate the various voltages, as it is not possible to obtain a correct regulation of the lamps alone.

What to Do when Fitting Up the Receiver.

When fitting up the receiver, or before putting it on test, it is advisable to connect a small ampere meter in series with the filaments so that the current can be adjusted to ½ amp. When once the correct tapping is found on the adjustable resistance no further adjustment is necessary and the ampere meter can then be taken off the circuit.

A double-pole switch and fuses must be added to a mains receiver. The fuses should be rated to carry 1 to 1½ amps. Never use a metal panel for this type of receiver. Always use one which can be insulated. Any screws used for fixing the components to the panel should be well countersunk and covered with wax.

Screening Coils and Condensers.

Each coil and condenser should be separately screened, and all the screens connected to the filament of the cathode circuit.

Never, however, connect any screens or other components to the series connecting wire between the valve filaments, otherwise the filaments will not be in series and will be short-circuited.

Keep Terminals Inside the Cabinet.

All terminals should be inside the cabinet so that when the cabinet is closed all metal parts are protected, for a shock from a D.C. mains receiver may be serious, and even result in a casualty, because with a D.C. receiver there is no isolating transformer between the parts of the receiver and the mains, whereas in the A.C. mains receiver the transformer secondary is insulated from the primary, therefore the parts of the receiver are not directly connected to the mains.

Ventilation.

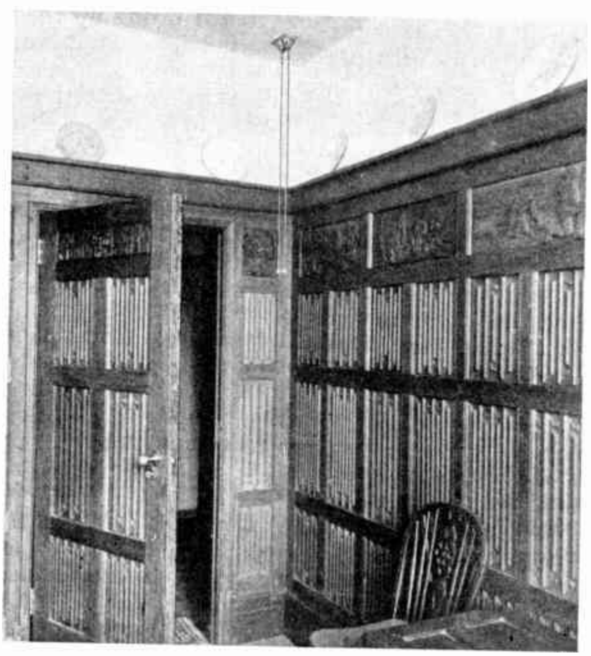
One other important point is the question of ventilation : because we have, in the cabinet, two carbon lamps which generate a considerable amount of heat, also the valves themselves generate heat, therefore it is wise that the back of the receiver should be a frame covered with perforated metal, and the resistance lamps placed at the back of the receiver so as to give free radiation to the heat. The receiver should not be placed directly against the back of a wall, but should have an air space between. If possible, the cabinet should be lined with metal, or, failing this, asbestos, for it must be remembered that where a wire is passed through the metal it must be bushed to insulate the lead wires. In any case, all the connecting wires should be covered with good quality insulation, for the ordinary connecting wire used for battery receivers is not sufficiently insulated.

The actual lay-out and design of the cabinet is left to the reader's imagination, but if the lay-out is kept in accordance with the diagram, no trouble will be experienced.

AN IDEA FOR THE WIRING CONTRACTOR

Cases occasionally arise where for some reason or other it is not desirable to fix electrical switches on the walls. It may be that the owner will not have the valuable panelling interfered with, or it may be that he considers switches are unsightly projections which spoil the appearance of a room.

The use of sunk switches necessitates cutting a recess in the surface of the wall, and there are cases where anything of this kind would be considered sacrilegious.



A Ceiling Switch for Panelled Rooms.

The method illustrated in the picture herewith provides a very convenient solution to this problem. It will be seen that the switch is mounted above the ceiling, and two actuating cords or light chains are provided for turning the switch on or off as required.

SAFETY RULES FOR ELECTRICAL ENGINEERS

By PROFESSOR W. M. THORNTON, O.B.E., D.Sc., D.ENG., M.I.E.E.

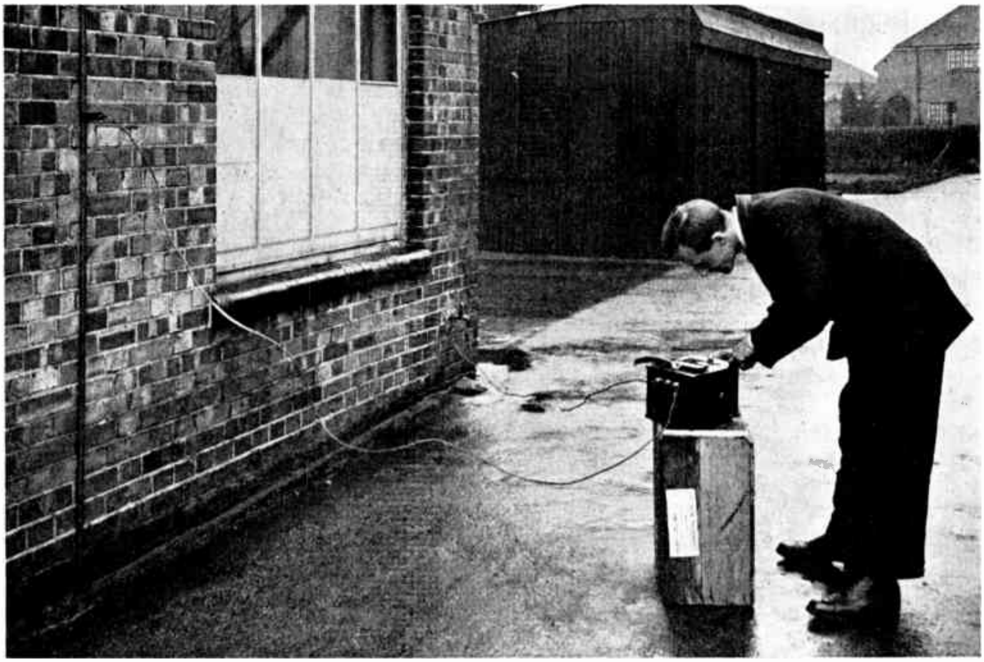


Fig. 1.—MEASURING THE RESISTANCE OF A LIGHTNING CONDUCTOR EARTH PLATE.

Unless the resistance of an earth plate is low, it is quite useless as a protection. In dry ground, the resistance tends to increase and periodical testing is essential. A test is being made above with a "Metrohm" Earth Plate Tester, one terminal being connected to the lightning conductor and the other to a water main. On turning the handle, the resistance of the earth plate is read off direct. If it proves to be too high for effective protection, dig a small hole in the ground over the earth plate and pour salt water into it. This will render the soil more conducting.

ELECTRICITY is used for power supply and lighting because it is so conveniently led to the point where the supply is required, and is so readily switched on and off and controlled. Its one disadvantage, by no means negligible, is that it gives no warning of whether a conductor is alive or not. In the early days of electric lighting at voltages about 50, for which lamps were then available, the danger of shock was remote except in electric power-stations and substations where high tension conductors were in those days exposed. Fifty volts is, under normal conditions, scarcely to be felt by contact with the hands.

A Point of Law.

Lamp makers gradually succeeded in raising the voltage at which lamps could be continuously run and there came a time when it was necessary to limit this voltage to prevent danger from shock. After a long series of accidents and some direct experiment it was made law that the highest voltages of incandescent filament lamps for general use was 250. The three-wire system of distributing current had, therefore, a voltage of 500 between the power conductors.

The Danger of Running Lamps in Series on a High Voltage Circuit.

It is highly undesirable to have several lamps in series across 480-volt mains, for if one lamp breaks, the whole voltage is across the broken lamp, and in renewals there is grave risk of shock.

Permitted Voltages.

The wiring rules of the Institution of Electrical Engineers make clear what is permissible and are in fact safety rules so far as they go. These permitted voltages depend on the laws of probability. A certain risk is acknowledged to be present, for it is impossible to obtain perfect immunity from accident by any human device, and even at voltages as low as 80 fatal shocks have occurred. When the current is taken between, say, a moist hand or foot and the more sensitive skin of the mouth or eye, or a cut or abrasion, 25 volts alternating have been fatal, to animals if not to man. The question is then what safety rules are reasonable having regard to the vast ramification of electrical leads and apparatus.

Effects of Current and Voltage.

The answer is in two parts, the voltages that man can stand under a given condition and the probability of exposure to them in the daily use of the house or works. The sensation of shock depends not in itself on voltage but on the current passing. A third of an ampere is invariably fatal taken through the body, 10 milliamperes causes sharp muscular contraction and a little more than that an electric wound, the skin disintegrating and sloughing.

250 volts is about the highest that a man with normally dry hands can grasp fully and let go of. One cannot let go of 350 volts alternating or 480 volts direct, the muscles of the hands and arms are paralysed and in most cases one cannot speak or cry out. Under these circumstances death is only a matter of time of contact.

Two Methods of Rescue.

One leading rule of safety is never to attempt to remove anyone so held in contact with live terminals by trying to unlock the hands. The best way is to charge him as in football without touching him with the hands; one may receive a capacity shock in the process, but it is only momentary, and if one leaps at him there is little risk of that. This has been done many times. An alternative is to put a non-conducting band around him such as a dry jacket held by the sleeves and endeavour to jerk him away.

If the switch controlling the live circuit is near the right thing is, of course, to open it; the muscles then relax and artificial respiration can be applied as to a half-drowned man.

Golden Rules.

There are a few golden rules to ensure safety. The first is *never to touch exposed conductors if one does not know the voltage upon them*, the next to *touch only one at a time* with one hand held behind the back. In the old test room days, before safety enclosures were enforced, one hand used to be tied behind one's back to prevent any chance of shock between the hands.

Low Voltage and High Voltage Shocks.

Low voltage shocks taken from hand to hand paralyse the breathing muscles of the chest and artificial respiration restores this function. High voltage penetrates deeper and paralyses the muscles of the heart.

One hears constantly that very high voltage shocks are not so dangerous as low voltage shocks. The reasons for this belief are not satisfactory. In approaching too near a live conductor at say 30,000 volts, a pilot spark may jump across and be followed by a power arc causing serious burns, without having fatal effects, but it must not be said that one has received and survived a 30,000-volt shock. Shocks can be had even when one is standing on a rubber mat, due then to the body acting as a condenser to earth. Such sparks, though rarely fatal, may be very uncomfortable.

Some Figures Relating to Electrical Accidents.

The reports of the Senior Electrical Inspector under the Factory and Workshop Acts are valuable reading. They deal only with accidents in such places, not with shocks in dwelling houses as such. In the Report for the year 1929 there is a record of 420 electrical accidents of which 35 were fatal. These are classified under the head of high tension accidents (over 650 volts), and medium low pressure accidents. Twice as many fatalities occurred on voltages at or below 400 as on systems from 1,000 to 33,000 volts. All the cases but one were on A.C. systems, and in all but a few the accident occurred by carelessness or was preventable.

Better Sure than Sorry.

The conclusion to be drawn from this and other reports and from the record of accidents which do not come under the Factory Acts may be summarised as follows. No electrican having a regard for his own or his comrades' life must merely *think*, he must KNOW. If he is not sure that the line is dead or that anyone is working on it he cannot afford to take risks, he must sacrifice time and find out, the penalty may be death, lifelong disability or regret.

It is not correct to say that one must never take risks oneself. Risk is a very debatable word. In a power station risk is in many places where there is running machinery. It is *undue* risk or carelessness that may become criminal. When life

Fig. 2.—TESTING THE RESISTANCE OF JOINTS IN A RUN OF CONDUIT.

It is essential on grounds of safety for the conductivity of the conduit, armouring, or other cable enclosure, to be high. The Mining Regulations, for example, lay down that the ohmic resistance of a length, including any joints (in the length under test there are seen to be two joints),shall not be more than twice that of the same length of the cable inside it. The Earth Conductivity Tester shown in use enables the resistance to be read off direct in ohms, upon pressing the two hand spikes firmly into contact with the sheathing.

is concerned no electrician can afford to rely on someone else doing the right thing if it is in his power to check it.

When Working on a Low Voltage Installation.

When working on a low voltage existing installation the simplest rule is to draw the fuses. It is not sufficient to open the switches alone. If the fuse on one side only is drawn or blown there may be risk if that is the earthed side.

A Note on the Three-Wire System.

The earthing link in the neutral of a three-wire system must never be broken until the supply to the outer conductors has been cut off, for if the system is out of balance a dangerous pressure may be thrown on to the less loaded side.

Ironclad Switch Gear.

The use of ironclad switch gear, introduced by Messrs. Reyrolle & Co. for mining purposes many years ago and now universal, had so beneficial an effect in reducing risk of shock, and by the use of mechanical interlocks of preventing mistakes in operation, that in places where it is desirable to enclose live parts safety as complete as human ingenuity can devise is now available.

The Grid Supply System.

In the approaching era of "grid" supply there is, however, the necessity for using bare conductors at high tension in places

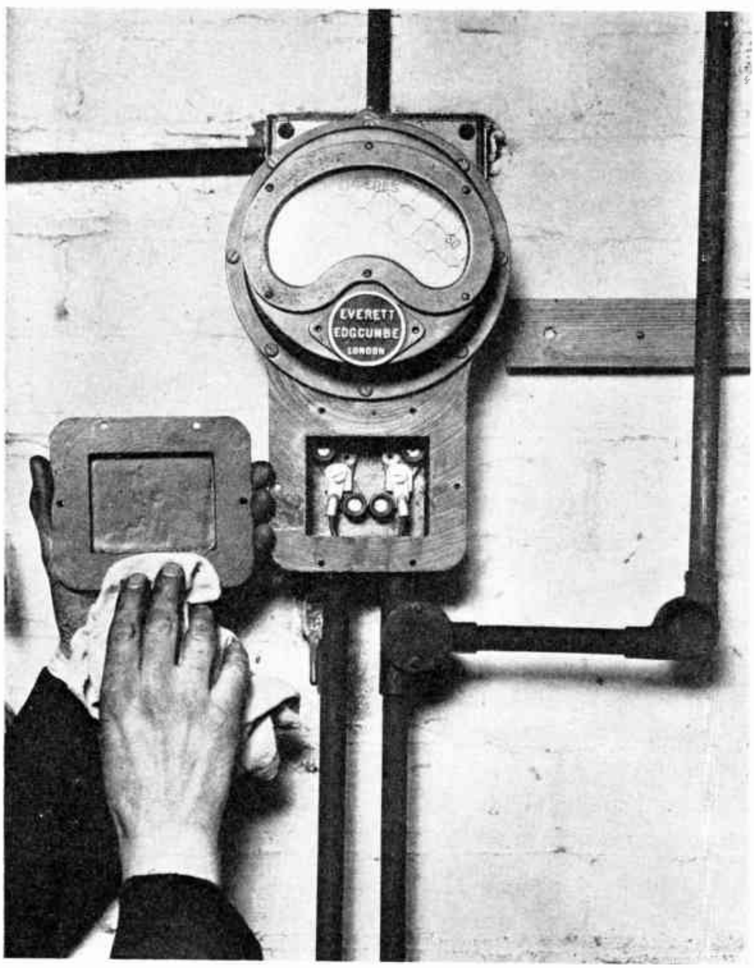


Fig. 3.—A "FLAMEPROOF" AMMETER FOR USE IN FIERY MINES.

Note the wide, roughly machined joint. Should an explosion occur inside the enclosure, the flame and hot gases in passing out through the narrow gap so formed are cooled down to such an extent that no external ignition can take place, even if the surrounding air is charged with fire-damp. The erector is carefully wiping any dirt from the flange before screwing down. If this precaution is omitted, too wide a space may be left. It is important to replace *all* the screws, but the design must be such that if one is accidentally left out, the open hole does not pass into the interior of the enclosure.

which can be reached by ladder. There are two courses to pursue in such a case. The responsible person must ensure by examination that the lines are made dead before operations are carried out of cleaning or alterations, or the workman must be provided with an infallible means of ascertaining from a safe distance whether the voltage is on or off.

A Useful Instrument.

When there is current flowing this is possible now by the use of a telephone and search coil which when placed in an alternating magnetic field indicate by the characteristic hum that a current is flowing in neighbouring conductors.

A Chance for the Inventor.

But in the case, for example, of armoured and lead sheathed three-core cables, there is no external magnetic field for that is all stopped by the iron wire armouring and no external electric field for that cannot pass the lead sheath. There is need for a device which will indicate whether such a cable is carrying voltage or is dead. At present there seems to be no remedy but to drive a conducting spike into the cable in the same way that workers on a third-rail electric railway are enjoined to see that a crowbar is placed across the live and running rails, but this is an operation not to be carried out except after doing all that is possible to ensure that the pressure is cut off. Numerous fatalities have occurred from the omission of this precaution.

A merely negative indicator is rarely sufficient—for safety one must have an apparatus which can be tested without the need of an electric field to see whether it is in perfect working condition, before testing whether there is a field present. At the moment there is no device in common use for this test, but experiments are being made to this end.

The Importance of Efficient Earthing.

There would be few accidents from shock if the rule that the metallic enclosures of machines or cables must be efficiently connected to earth were rigidly carried out. The subject of earthing is itself extensive, but it might be taken that all large metal parts such as piping laid in earth, not like tropical sand dry most of the time, provides an earth within the meaning of the Act. Earthing an electric system on to a gas pipe is of course not advisable if any other place is possible, but where there is any doubt or difficulty a special earthing plate must be installed in such a way that its contact with the ground cannot be broken.

Every care must be taken to make perfect contact between the earthing wire and the apparatus at one end and the earthed metal at the other; merely twisting a wire around a pipe is not sufficient for voltage of 250 or over. The contact should be fixed by a screw or band contact or soldering. In carrying out an installation the metal conduits carrying the insulated wires must be earthed efficiently in the above manner and enamel removed. It is not sufficient to place an enamelled tube through a hole in a junction box and trust to it making satisfactory connection; a thin layer of insulation or paint may support a voltage sufficient to give a dangerous shock.

The great safety rules are:—

(1) Earth all metallic parts of machines, switches, plugs, lampholders and the like which may come in contact with live conductors or by acting as a condenser surface acquire voltage above earth potential.

(2) Never attempt to work on or near a supply system, however safely one may seem to be placed, if there is the least chance of a contact with parts which may be live unless you are satisfied by seeing the parts short-circuited to earth that there is no danger of shock.

Electric Cranes.

Crane trolley wires are a frequent source of danger. The above rule (2) holds in their case perhaps more urgently than in any other for it is sometimes necessary to work near crane wires which should be run in places inaccessible to any workman under ordinary conditions. If it is impossible so to run the leads, a reduction of voltage to 250 greatly reduces the risk.

The Importance of Good Jointing.

A constant cause of fatal accidents is

the careless making of joints in wires or cables. All sharp ends or edges of conductors should be smoothed down before applying the rubber tape. This is usually an excellent insulator but when drawn tight and thin over a sharp edge its electric strength may be weakened "a hundredfold or more, making it quite unreliable and the taped joint quite unsafe to touch."

Maintenance.

In all electrical work, in mining practice in particular, lack of maintenance of machinery and switch gear in good condition is the chief source of danger. A screw omitted, dirt not removed from "flame proof" flanges, a trailing cable not properly inspected, may have fatal consequences. Incessant alertness and attention to details should be the electrician's leading characteristic. To make a bad connection is his worst offence.

The publishers are indebted to Messrs. Everett Edgcumbe for assistance in staging the photographs which illustrate this section.

QUESTIONS AND ANSWERS

What is the law regarding the highest voltages permissible for incandescent lamps?

The pressure across the lamp terminals must not exceed 250 volts. With the 3-wire D.C. system the pressure must not exceed 500 volts between the outers.

Why is it dangerous to run several lamps in series across a high-voltage circuit?

Because if one lamp fails the whole voltage is across the lamp terminals. This introduces a grave risk of shock when the lamp current is being renewed.

What current is fatal to the human body?

One-third of an ampere.

If this is so, why can low voltage conductors carrying much larger currents be handled with safety?

Because the resistance of the body is high, so that a fairly high voltage is required to pass a current of one-third of an ampere through it.

What would you consider to be dangerous voltages?

Anything above 250 volts. An alternating voltage is more dangerous than a direct voltage.

What is a leading rule of safety in rescuing a person from live terminals?

Never attempt to unlock the person's hands. The best way is to charge him as in football.

What must be borne in mind when working on a 3-wire system?

The earthing link in the neutral must never be broken until the supply has been cut off from the outer conductors.

What is the worst offence against safety rules when installing electrical equipment in mines and what maintenance work is essential?

The worst offence is to make a bad or faulty connection. All flameproof flange joints should be made with particular care. Machinery switchgear and trailing cables should be inspected at frequent intervals, and any incipient faults immediately remedied.

ELECTRIC HEAT TREATMENT FURNACES

By E. P. BARFIELD, A.M.I.E.E.

ELECTRIC furnaces used for heat-treatment purposes in works and engineering shops vary widely both in size, shape and design, due to the numerous purposes for which these appliances are installed. Briefly, heat-treating equipments may be classified as follows :—Tempering ovens or furnaces working up to about 600° C. ; hardening furnaces for carbon and alloy steel up to 1050° C., and electric furnaces for hardening high speed steels up to a temperature of 1400° C. In addition, there are, of course, other kinds of furnaces, such as continuous or conveyer types, rotary hearth, and numerous others designed specially to suit the requirements of different industries, and like all types of electric furnaces, depending in size mainly upon the output desired by the user.

When approaching the question of installing electric furnaces in works, it is most important that the fullest details of the user's requirements should be conveyed to the furnace maker. Fig. 2 shows what details should be supplied.

How to Install the Furnace.

The furnace maker will in due course submit his estimated cost of furnace, together with an outline blue-print of the

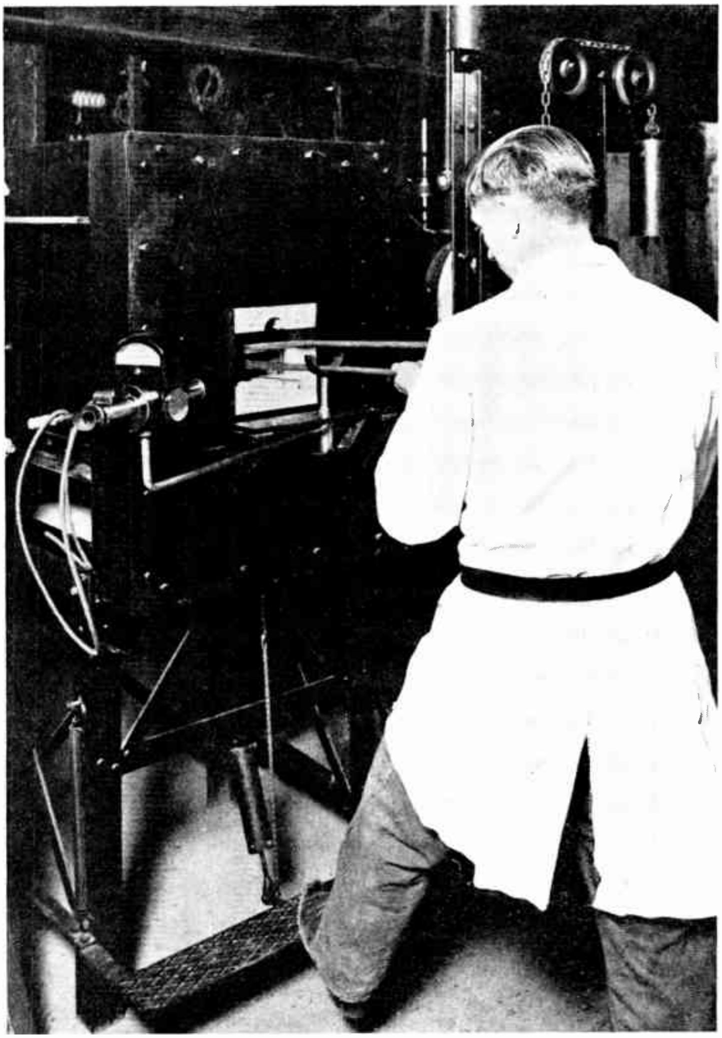


Fig. 1.—ELECTRIC HIGH-SPEED STEEL HARDENING AND TEMPERING FURNACE.

proposed furnace, and in addition, a schedule of operating costs. Should the furnace be of such a size that it has to be built on site, the supplier will in all probability desire to see the actual site on which it is to be erected.

Foundations and any excavations necessary are usually carried out by the user to plans supplied by the maker.

Smaller types of electric furnaces which can be built in the maker's own works and transported may require an angle iron stand or brick piers only. In the latter case, it is customary for the firm building the furnace to supply the user with a plan a few days after acceptance of the order, so that the purchaser may proceed with the erection of the piers ready to receive the furnace when delivered by the maker.

Should the furnace be of such small size that it will stand on a bench—for example, in the tool-room—the maker will, upon request, send details of the space occupied, or any other information required to enable the user to install same in a convenient position.

ENQUIRY FORM

We should appreciate the following particulars to enable us to put forward plant suitable for your requirements :—

MATERIAL.

Nature of Material to be Heat-Treated..........................

Dimensions of Largest Article—Length....Width....Height....

Weight in lbs. of—Largest piece......Average......Smallest......

Total weight of Material required to be handled per hour............

OPERATION.

Nature of Heat-Treatment required.

Maximum temperature required..............................

If charge requires soaking—period in hours.....................

Cooling of Material—? In Furnace—in Air—Quench...........

Complete Cycle of operation (preferably for a period of one week), giving number of hours worked.

ELECTRIC POWER AVAILABLE.

Volts. D.C. or A.C. Periodicity. Phase.

Name ....

Address ....

Date................................

Fig. 2.—How to Specify Requirements for a Furnace.

Connecting the Furnace to your Electric Supply.

Furnaces, tempering ovens and other industrial appliances heated electrically are invariably provided with the necessary terminals or sockets to which connections have to be made to the main electric supply. Between the main switch (which will be specially installed to control the furnace) and the furnace itself is the temperature controller. This controller may be, in the case of small furnaces, just a simple regulating rheostat, but in the case of furnaces over about 10 kw. consumption, automatic temperature control is most usually adopted. In any case, blue-prints of the electrical control and connections are invariably sent to the user, and from the electrical point of view the connections to furnace rheostat and mains become quite an ordinary matter.

Two Ways of Controlling the Temperature.

There are various types of automatic temperature control suitable for use in connection with furnaces and tempering baths or ovens. Two distinctive types may be described. The first, which is of the expansion type for temperatures up to about 400° C., is used for tempering ovens and other low temperature operations. The second type is the thermo-electric controller, which is suitable for temperatures up to 1200° C. Expansion controllers usually consist of a tube of heat-resisting metal containing two strips or rods of dissimilar materials, such as silica and nickel chrome, in order that they may have different coefficients of expansion when heated. Means are provided to regulate contacts which operate at different temperatures and provision is made by means of a relay and, if necessary, an electro-magnetic switch, to make and break the heating current in order to obtain temperature control.

For Higher Temperatures.

Above 400° C., a thermo-electric temperature regulator is necessary. The one described here has been chosen on account of its rugged construction, simplicity of operation and freedom from trouble, three factors which make it eminently suitable for continual service in heat-treatment shops.

The actual controller is a standard thermo-electric indicating pyrometer of the millivolt meter pattern, with certain additional parts. The instrument has a moving coil mounted in the patent "Resilia" suspension, which renders it immune from trouble due to vibration. The moving coil has a pointer attached to it, which is deflected when the thermo-couple in the furnace is heated, the magnitude of the deflection depending upon the temperature of the furnace.

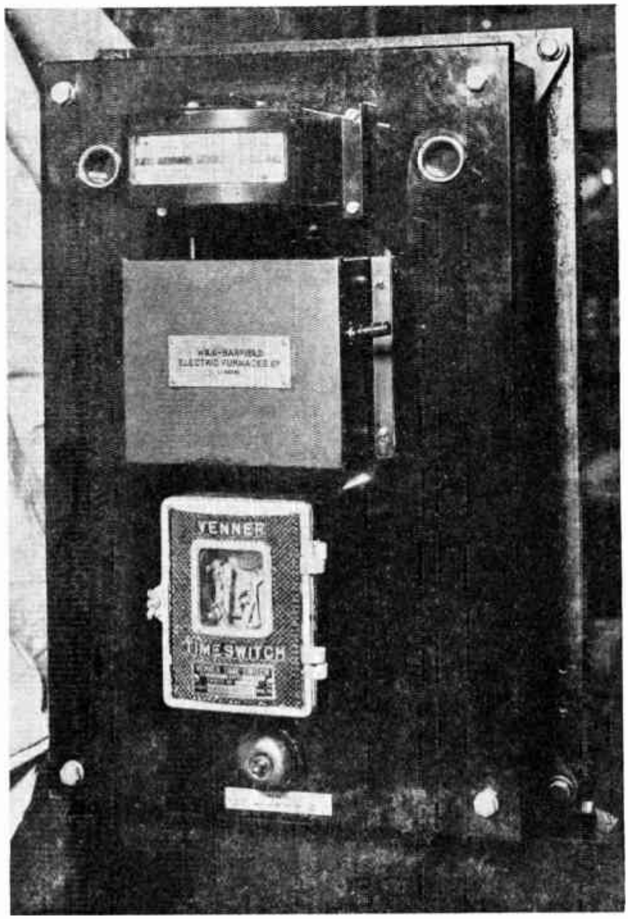


Fig. 3.—A Typical Control Panel for an Electric Furnace.

This shows the apparatus closed and ready for use. (See Fig. 4 for the inside connections.)

How the Automatic Control Works.

An additional pointer is fitted, which can be set at any point on the scale according to the temperature at which the furnace is required to be maintained. The arm to which this pointer is fixed carries a contact piece above the scale, whilst an additional contact is fitted on the instrument frame below the zero on the scale. A "chopper bar" extends across the top of the scale from one end to the other, the indicating pointer swinging between the bar and the scale. This chopper bar is pivoted at the rear of the instrument, and is held up by a spring loaded lever. A periodic release of the lever and consequent depression of the bar is made by a push rod projecting down the side of the instrument, and running on a cam, the cam being driven through suitable reduction gearing by a fractional horse-power motor.

"On" and "Off" Contacts.

As long as the indicating pointer is below the control pointer, the chopper bar falls on the contacts below zero, known as the "on" contact. As soon, however, as the indicating pointer reaches the required point, the chopper bar, instead of falling on the "on" contact, traps the pointer arm on to the other, or "off," contact.

The Connections Explained.

Both these contacts are connected to a relay of the mercury switch type, fitted with two energising coils. Reference to the circuits shown in the wiring diagram (Fig. 4A) will assist in explaining the operation. The "on" contact A is connected to the "on" coil B of the relay R, whilst the "off" contact C is connected to the "off" coil D. These relay coils are fed through the contacts from a small double wound transformer T, which has an output at 20 volts. It will be readily seen that when the "on" contact is depressed, the mercury switch is pulled into the "on" position, whilst making the "off" contact brings the mercury switch into the "off" position.

The Main Contactor.

So far, all the instruments described are mounted on the control panel, and Figs. 3 and 4 show, respectively, closed as in use, and opened as when being connected up. The relay, however, operates a main contactor or electro-magnetic switch, which is used for breaking the main supply to the furnace, and which, owing to its size, cannot conveniently be mounted on the panel. Leads are connected to this from the terminal strip seen in the view of the panel open. Reference to the external wiring diagram (Fig. 9) will make these circuits clear, when taken in conjunction with the internal diagram previously mentioned. It will be seen that the mercury switch is connected to the coil of the contactor switch, so that breaking circuit in the mercury switch causes the contactor to open, and vice-versa. In practice, the door switch and thermal fuse, which are described elsewhere, are placed in this same coil circuit so that the supply is cut off when the door is opened or when the furnace is accidentally overheated. These items are shown in the diagram, but only passing reference need be made here.

Installation is Easy.

Installation of the controller in this form is simple enough to enable the actual user to carry it through without difficulty. All the instruments on the panel are fully wired up and connected to the terminal strip above mentioned. Connections have to be made between these terminals and the contactor switch, door switch and thermal fuse. Main supply connections are made to the contactor, and leads from the contactor are fed to the furnace terminals. The equipment is then ready for operation.

How Faults are Caused.

Faults on this type of controller are few and far between, and are usually due to such simple things as the panel not being level, or bad connections to the thermocouple. A panel which is leaning backwards or forwards to any great extent will tend to make the mercury switch sticky in operation, sometimes causing it to remain in the "on" position when it should be "off," and vice-versa. Detection of this fault is easy if the relay cover is removed, for it will be noted that the relay gives a "kick" but does not move over. Levelling the instrument will cure this trouble immediately. The contacts inside the instrument should be cleaned if the relay shows no sign of movement when one or other of the contacts should be made. A loose connection of the leads to the thermo-couple or a burnt thermocouple will cause an unsteady movement of the pointer, whilst a broken couple will fail to give a reading on the pointer at all. Both these faults are easily traced and equally easily remedied by the user, at little or no expense, whilst for years the controller will operate without any expense.

Take the Usual Precautions.

Usual precautions should be taken with these equipments as would be taken with any other electrical apparatus. The contactor contacts should be examined three or four times a year, and cleaned when necessary. The thermo-couple should be examined at the same time, and if badly burnt, should be replaced by a new one. The whole equipment should be kept dry and as clean as possible. If these precautions are taken, the controller will give perfect and reliable service free from trouble for years.

In cases where automatic temperature control apparatus is installed, the actual controller as pointed out is in the form of a pyrometer so that the temperature of the furnace or oven can be ascertained at any time desired. In the case of units that have the temperature controlled by hand, an ordinary indicating pyrometer is invariably installed.

As the outer cases of both controllers and pyrometers are sealed by the maker,

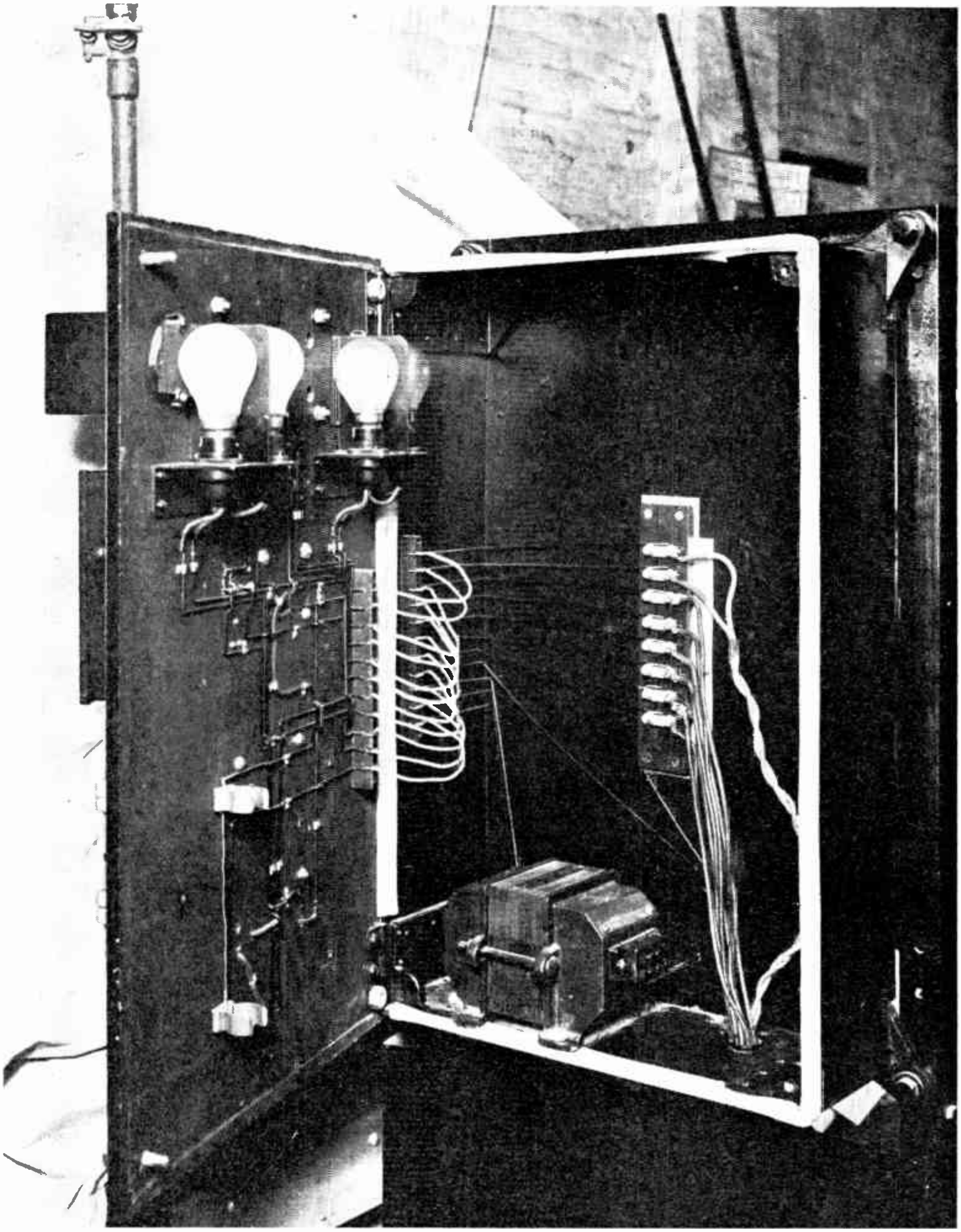


Fig. 4.—INSIDE CONNECTIONS OF A TYPICAL CONTROL PANEL FOR AN ELECTRIC FURNACE.
The mercury switch is connected to the coil of the contactor switch so that breaking circuit in the mercury switch causes the contactor to open, and vice-versa. (See Fig. 4A for wiring circuit.)

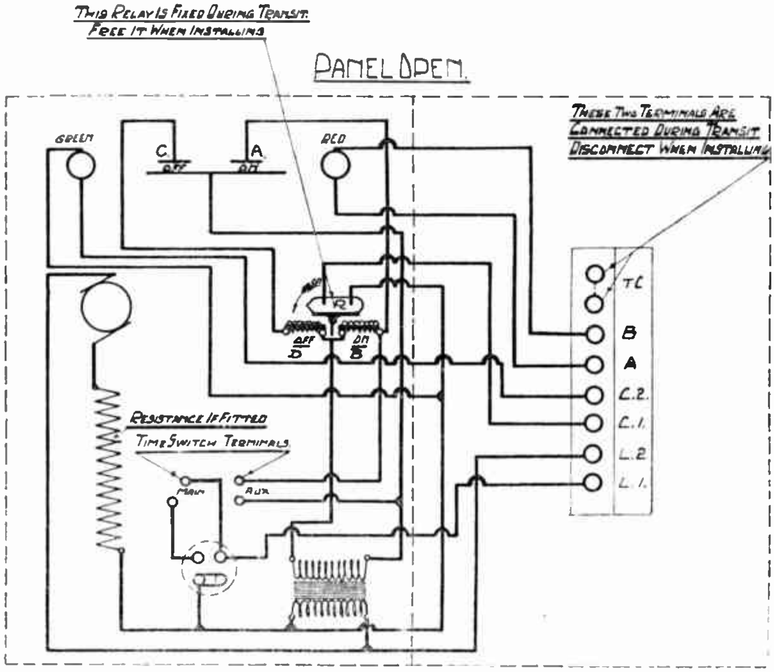


Fig. 4A.—Wiring Diagram for Auto-Control with Time Switch
The "on" contact A is connected to the "on" coil B of the relay R, whilst the "off" contact C is connected to the "off" coil D. The panel is hinged on the left-hand side. Remove bolts to open.

any repairs must be carried out by the instrument manufacturers.

How Pyrometers are Constructed.

The principle on which thermo-electric pyrometers are constructed is as follows :—

If two wires of dissimilar metals are joined at their ends to form an electric circuit, and one junction is heated, an electro-motive force is set up which gives rise to an electric current in the circuit. The magnitude of the electro-motive force depends on the difference in the temperatures of the hot and cold junctions. If a galvanometer is included in the circuit, it is possible to determine the temperature of the hot junction, provided the cold junction temperature and the relation between temperature and electro-motive force for the two metals used are known. In practice the two dissimilar wires, suitably insulated and protected, are joined at one end to form a thermo-couple which is exposed to the temperature to be measured, the ends of the wires being connected to a millivolt-meter graduated to read directly in degrees of temperature.

External Wiring.

In the case of automatic control, the invariable custom is to supply the equipment with a time switch, mounted and ready wired on a panel, so that it is only necessary to run and connect mains from furnace to panel and from the panel to the main switch. It is generally left to the user or his electrical contractor to run all external wiring required for furnaces, but where it is necessary, the maker will usually contract for this work if required.

Starting up the Equipment.

After completing the erection of large installations, it is customary for the furnace maker to send an erector to inspect and start up the equipment and to give any instructions or advice to the user that may be required to assist him in the working and maintenance of the furnaces. In a well-constructed electric furnace, designed to withstand reasonable wear and tear, the upkeep offers no difficulties and little expense. The greatest care and consideration should be shown before purchase to ascertain that the heating elements are designed and fitted in such a manner that the work of replacement can be easily and safely carried out by the user's electricians. The most suitable form, from the user's point of view, both in regard to life and ease of replacement, is one in which a furnace element can be

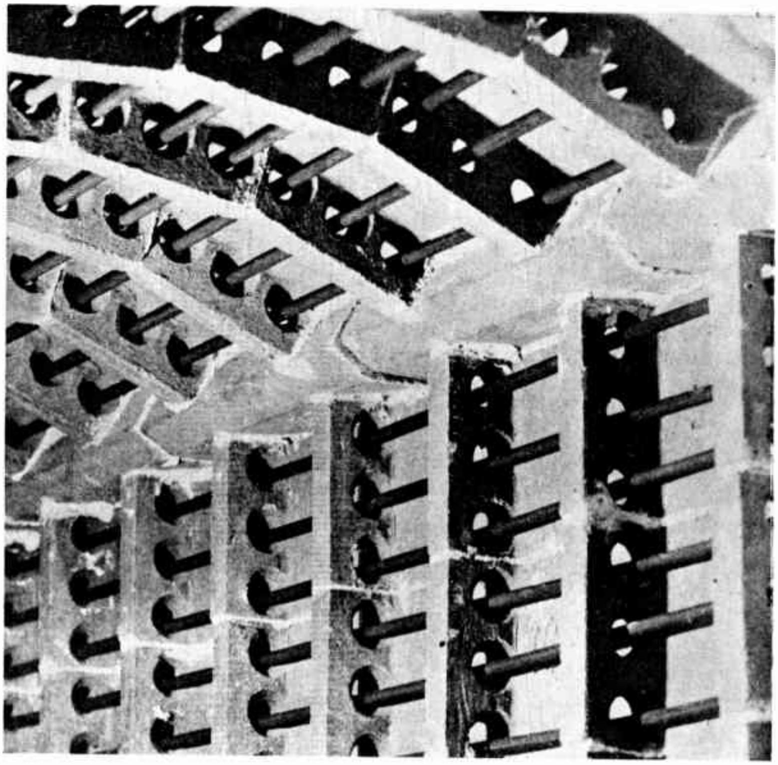


Fig. 6.—A SIMPLE METHOD OF FURNACE HEATING.
The hairpin rods are pulled through from the front after unbolting on back bus bars, and a new hairpin pushed back in its place.

withdrawn whilst the furnace is still hot and a new element inserted at once. It will be obvious what a very great saving in time this effects.

Two Simple Methods of Heating.

Two simple methods of furnace heating are shown in the accompanying illustration. The hairpin rods in Fig. 6 are pulled through from the front after unbolting on back bus bars and a new hairpin pushed back in its place. In the case of Fig. 7, the heating element is a continuous helix of nickel chrome wire, which can be withdrawn and replaced in much the same way as the hairpin rod.

It will be observed that the two methods of fixing described entail no cutting or actual fixing to the refractory bricks in the furnace lining. Such work could not be easily or safely carried out by the user.

Rewinding a Muffle Chamber.

In dealing with muffle furnaces, i.e., bench furnaces, maintenance is such a simple matter that no suggestions are necessary. As in the case of larger furnaces, tempering ovens, and all industrial units, a few spares should be carried, particulars of which will be found on another page. The repairing of a muffle or bench type furnace when the time comes for rewinding is much simplified if the original chamber is deeply and continuously grooved. Fig. 8 shows such a chamber being wound. Such provision permits comparatively easy winding and correct spacing of the wire or wires, for at times several nickel chromium wires are used in parallel.

It is unnecessary in this article to make reference to the method of making off or anchoring the ends of the wire to the corresponding ends of the muffle chamber, or how to assemble and replace lagging. This information can always be obtained by the user from the maker, who invariably has printed instructions and prints to assist customers who wish to carry out their own repairs.

The nickel chrome rod or wire used for the elements should always be obtained from the original manufacturer of the furnace to ensure the correct quality and gauge being supplied.

The Safety Fuse.

Practically all electric furnaces are fitted with some form of protection against thermal overload, usually in the form of a safety fuse which blows at a temperature well below that likely to endanger the windings.

How to Replace a Fuse.

A standard fuse consists of a loop of silver (or gold) wire in series with the main heating circuit, in the case of small furnaces, or in circuit with the coils of the contactor switch in the case of larger furnaces. The fuse often consists of pure silver wire which fuses at a temperature of 960° C. and automatically cuts off the power supply from the furnace windings. The insertion and replacement of these fuses is a perfectly simple matter, it being only necessary to disconnect the burnt-out fuse from the terminals of the fuse plug, which projects at a convenient point on the casing of the furnace, and to fit a new length of the requisite gauge of silver wire to be obtained from the manufacturers. It is important to note, however, that old fuses should never be used a second time by twisting the ends together or otherwise, as the depth of insertion in the furnace chamber is fixed by the design of the furnace.

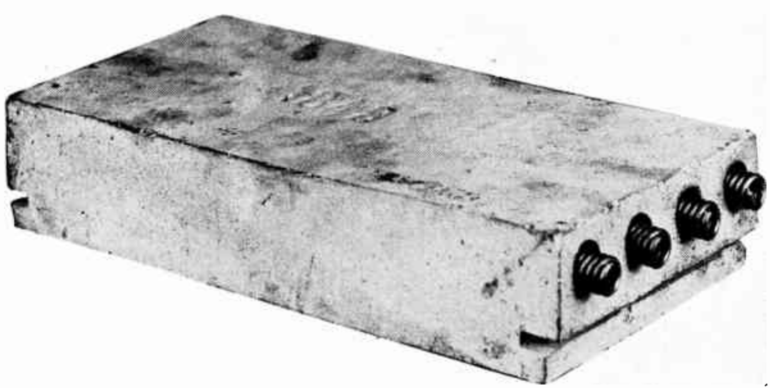


Fig. 7.—Another Method of Furnace Heating.

The heating element is a continuous helix of nickel chrome wire which can be withdrawn and replaced in much the same way as the hairpin rod in Fig. 6.

Another Safety Device.

A further protective device, consisting of a switch fitted to the door, is usually employed in the case of larger furnaces. Such a switch automatically cuts off the power supply from the heating elements when the door is opened for charging or discharging, thus obviating any possible risk of electric shock due to the charge or rakes, etc., in the hands of the operator coming into contact with the heating elements. Some forms of door switch are of the single pole variety, but in order to ensure absolute protection it is necessary that the switch should be of the double pole type, otherwise it may be found that portions of the chamber, i.e., the silver thermal fuse, may still be in circuit when the door is open.

A New Alloy for High Temperatures.

The furnaces, etc., so far described are invariably heated by rods or wire of nickel chrome and suitable for temperatures up to about 1050° C. As a result, however, of researches extending over several years, a new alloy has been produced suitable for temperatures up to 1200° C., and already continuous electric pottery kilns are utilising the new alloy as the heating elements. Generally speaking, however, and particularly in the case of smaller furnaces where temperatures in excess of 1050° C. are required, the heating elements consist of recrystallised carborundum, which is suitable for temperatures up to 1400° C. and are consequently largely made for hardening high speed steel.

Resistor Troubles.

All resistor bars of carborundum have the drawback that at temperatures in the neighbourhood of 1300° C., the carborundum partially dissociates and oxidises, causing the bars continuously to increase in resistance with age. Actually their resistance increases about fourfold during their life before rupture occurs.

Overcoming Increased Resistance.

To overcome this effect of increasing resistance, some means have to be adopted to reduce the power input to the furnace when the bars are new, lest the rate of heating be so great as to cause damage, and where carborundum bars are old, the rate of heating becomes so diminished that they must be discarded before they are really worn out, unless some equalising device is employed.

When to use an Auto-transformer.

In order to obtain constant time in heating the furnace from cold to working temperature, the power supply must be uniform throughout the life of the elements. This involves increasing the applied voltage in several steps until it finally is twice that which it was at the start. This is effected by employing an auto-transformer with a plurality of secondary tappings.

So that the operator may be informed as to when it is necessary to add a step to the secondary voltage, an ammeter is connected in the primary circuit. When the current has fallen by, say, 20 per cent., the power applied to the furnace has fallen 20 per cent. An increase of 10 per cent. to the secondary voltage, effected by changing to the next higher tapping, brings the power up again to its original value.

The Danger of Too High a Voltage.

Without some further safeguard it would be possible for the operator to apply too high a voltage to the furnace and too much power, resulting in burning out the heating elements and very likely destroying the furnace lining also.

This is prevented by the inclusion in the primary circuit of an excess current circuit breaker. This is sealed so that the operator cannot alter its adjustment. He can, however, reset it after it has interrupted the circuit if he first puts back the secondary tapping switch to the amount required reducing the power to the safe limit.

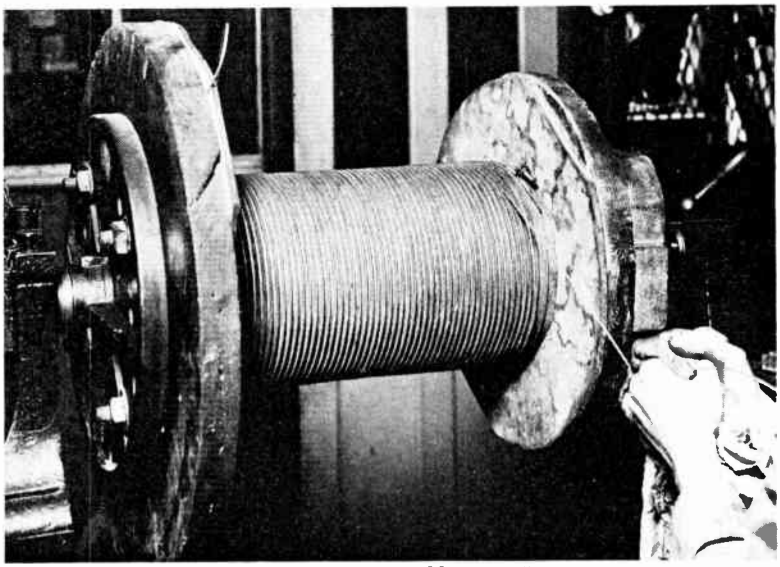


Fig. 8.—REWINDING A MUFFLE CHAMBER.
The nickel-chrome wire for winding should be obtained from the furnace-maker.

As a transformer, especially when loaded, is liable to create a surge on being switched on, the circuit breaker is further furnished with a delayed action device which prevents it from operating until the excess current has been established for a few seconds.

Points to Remember.

To sum up :—

The tapped transformer compensates for ageing of the elements.

The ammeter instructs the operator how to change the tappings of the transformer.

The circuit breaker safeguards the

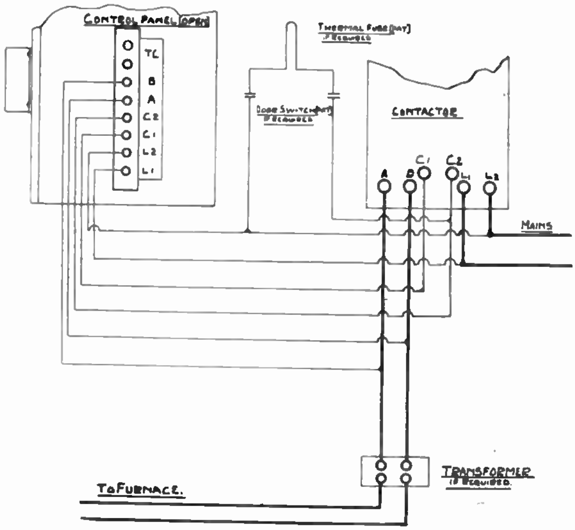


Fig. 9.—EXTERNAL WIRING DIAGRAM OF CONTROL, CONTACTOR, FURNACE, ETC.

The mercury switch is connected to the coil of the contactor switch, so that breaking circuit in the mercury switch causes the contactor to open and *vice-versa*.

furnace should the judgment of the operator be at fault. The delayed action prevents the circuit breaker operating on momentary surges occurring on switching on. All these features are essential to successful operation of a furnace furnished with carborundum elements.

It must be pointed out that the above method of control is the subject-matter of patents, both in this country and abroad.

The secret of working high speed steel tools successfully lies mainly in correct heating.

Apply the Heat Slowly and Evenly.

As the thermal conductivity of high Tungsten steel, when cold, is considerably lower than that of ordinary steels, it is particularly important to heat it very slowly and evenly over the lower temperature ranges. A preliminary warming of the tools near the furnace, followed by "pre-heating" in a furnace chamber to about 800° C., gives the best results provided that the preheating chamber is uniformly heated and the temperature is properly and closely controlled. The final heating from about 800° C. to the hardening point (say, 1250°–1400° C.), must be carried out as rapidly as possible; but here again uniformity of heating and accuracy of temperature control, together with regulation of chamber atmosphere, are vitally important.

The subsequent tempering, or secondary hardening, is carried out at about 600° C., in a muffle heated by a resistance winding often fitted with automatic temperature control.

Fig. 1 shows a complete electric high-speed steel hardening and tempering equipment, with the operator inserting the steel in the high temperature (hardening) chamber.

Don't Forget the Equipment Number.

All electric furnaces and industrial heating apparatus manufactured by firms of repute bear an equipment number on the name plate and when corresponding with makers regarding spares, etc., this number should be given.

The Importance of Periodical Inspection.

In many works the maintenance of electric furnace is divided between the electrical and mechanical staff. It is advisable, however, that the electrical staff should closely inspect the interior of furnaces and ovens with a view to ascertaining the condition of the heating elements. Care should be taken to watch for any accumulation of scale which may fall from boxes or work and become a source of danger to the elements, or, in the case of a pit type furnace, possibly shield the thermal fuse or thermo-couple. Periodic inspection of industrial heating equipments are advisable and such inspections should be recorded.

Keep Some Spares in Stock.

Spares for various equipments should be carried in stock. These may consist of a few heating elements, one or two thermal fuses and some thermo-couples.

Repairs Should Be Easy.

Repairs to furnaces are usually a simple matter, but, as already pointed out in this article, it is a matter of importance to prospective users that they ascertain before purchase what repairs to elements necessitate, and quite apart from any guarantee of life, simplicity and ease of replacement will save users considerable expense in the future.

Assuming that the maker has supplied instructions for replacing heating units and provided the design of furnace used does not embody elements permanently fixed to metal supports in the refractories, repair to heating elements is a perfectly simple matter. Repairs to pyrometers, automatic temperature controls, time switches, and other form of instruments installed are best left to the maker should trouble occur. It may be said that modern instruments and switches of the type adopted for furnaces, if properly and intelligently installed, are most reliable, and no anxiety need be felt as to their upkeep.

Little more remains to be considered in regard to repair and maintenance of electric furnaces. Motors used for fans in ovens and for the heat-treatment of non-ferrous metals should have periodic inspection, oiling and cleaning. Contacts of electromagnetic switches, where used for temperature control and similarly selector switches on tapped transformers, will all receive a reasonable inspection from time to time.

The Advantages of an Electric Furnace.

Provided the various points mentioned are observed, it will be found that electric furnaces and their associated equipments used in all engineering works for heat-treatment, will give long and faithful service, and will amply repay their users both in regard to economy and the better results obtained by reason of the uniformity of heating and the simplicity and certainty of correct temperature control.

STARTING D.C. MOTORS

When a shunt-wound motor is running, the mains are directly connected across the armature of the motor. The resistance of the armature, or even the armature and field of a series-wound motor, is only a fraction of an ohm in a machine of several h.p. output. Consider an actual example. A 40 h.p. shunt motor has an armature resistance of one tenth of an ohm, and the mains pressure is 500 volts. By applying Ohm's Law $(c = \frac{E}{r})$ it is evident that if the armature of this motor were connected to the mains without any resistance in series with it, a current of 5,000 amperes would flow, if there were no fuse or circuit breaker in the supply system. This large current not only puts a sudden strain on the mains of the supply company, for many factories would be starting their motors simultaneously, but would give rise to very heavy sparking at the commutator with consequent damage.

The actual current which is permitted to flow when starting a motor is from one to one and a quarter times full-load current. In the above example the maximum current would be 80 amperes. A motor starter having a maximum resistance of not less than 6¼ ohms is used.

As the motor speeds up the armature generates an E.M.F. which opposes the supply and so the resistance is gradually reduced step by step until the machine attains full speed, when on no-load the motor passed a current sufficient only to overcome the electrical and mechanical losses. It is not necessary to use a starter with motors of ½ h.p. and under.

Other functions of a motor starter are to switch on the field winding before the armature, to disconnect the motor from the mains should the supply fail, and to switch off the motor when it is overloaded.

X-RAY APPARATUS

By E. M. Sutton

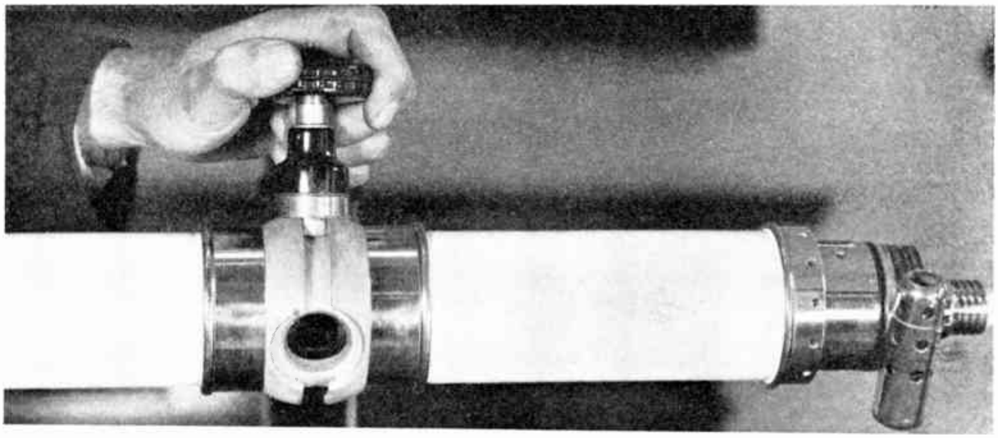


Fig. 1.—Method of Attaching X-ray Tube to Holder.

X-RAY apparatus has evolved through many phases during its comparatively short life, and for this reason there are still quite a number of different types of apparatus in use. It will, therefore, be necessary to review very briefly some of the earlier types before we discuss in greater detail the more up-to-date apparatus.

General Principles.

X-rays are of an extremely short wave length and occur in that band of the spectrum which comes between the ultra-violet and gamma rays of radium. They are generated by the bombardment of a solid by a stream of fast-moving electrons.

In actual practice, this is brought about by applying a high voltage current to two electrodes situated opposite to each other in a vacuum tube. One electrode, the anode, serves as the target and the negative electrode, or cathode, with its hot filament, liberates the stream of electrons, which then impinges against the target.

The X-ray Tube.

The modern X-ray tube consists of a glass bulb evacuated of air and hermetically sealed. Inside this are the anode and the cathode. The cathode takes the form of a copper rod terminating in an inclined plane on the surface of which is a tungsten button. This piece of tungsten has to withstand the bombardment of the electronic stream. A considerable amount of heat is generated at this spot. This heat is dissipated by a system of cooling, which takes different forms, depending upon the type of work for which the X-ray tube is designed. Generally, the copper stem of the anode is hollow, so that it can be used to hold water, which is fed to it from a reservoir situated on the X-ray tube itself.

The cathode consists of a cup-shaped electrode inside which is a spiral filament. Sometimes this filament is elongated, and is then mounted in a trough-shaped electrode. In the newer types of tubes, two filaments are fitted side by side. Either one or the other of these filaments may be switched into circuit as required.

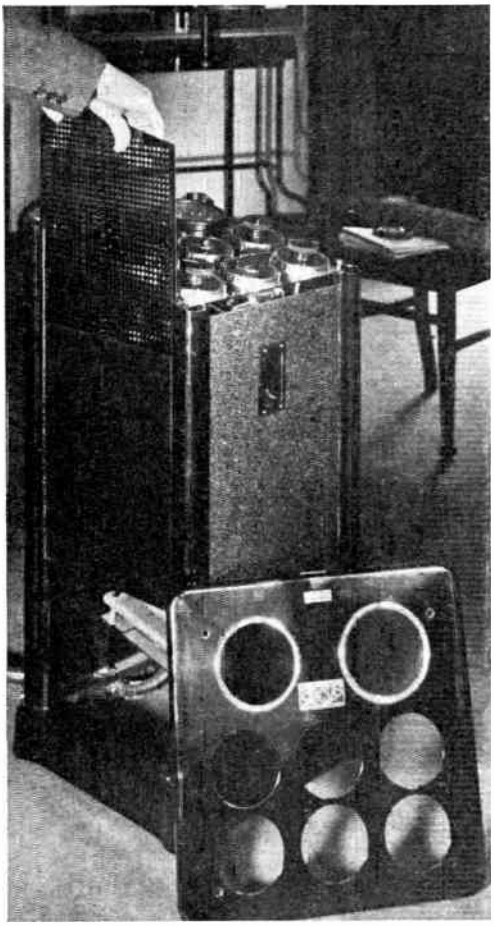


Fig. 2.—Showing Method of Obtaining Access to Connections Inside Simple Type Switchtable.

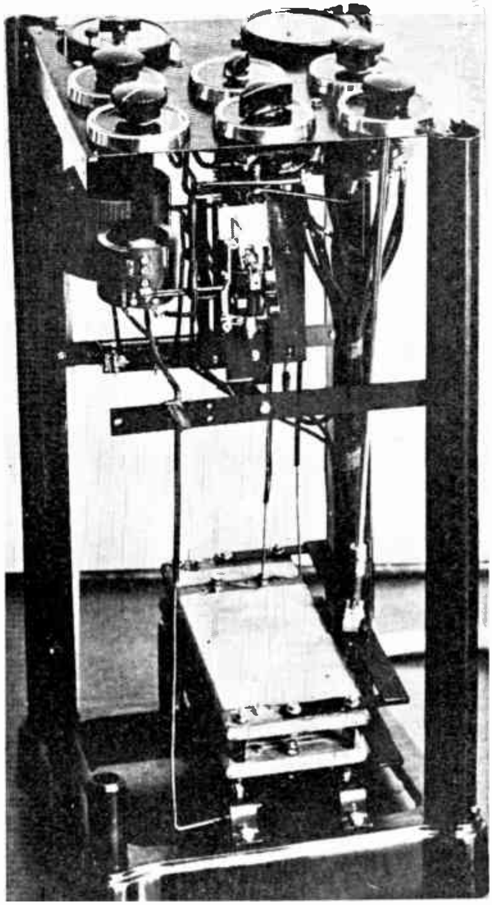


Fig. 3.—Interior of Simple Type Switchtable.

The switch for this is on the end of the tube (see Fig. 8). By means of this arrangement either a broad or fine focus can be used as desired.

Protection Against Unwanted X-radiation and High Voltage.

Most X-ray tubes are now designed with a protective lead band round the centre of the tube. This is provided with an aperture to allow for the emission of the normal beam of X-rays. Additional protection can be afforded along the insulating sleeves on either side of this central portion. The latest advance in the design of X-ray tubes consists of employing means to insulate the tubes against high voltage—thus rendering them shock-proof. This will be referred to later.

Control of the Rays.

The penetration of the rays depends on the voltage applied to the terminals of the X-ray tube. The quantity of radiation is determined by the state of incandescence of the filament, i.e., the hotter the filament, the more current will pass, the greater the quantity of X-rays and *vice versa*. From this it will be seen that two circuits are required for the proper functioning of an X-ray tube. One is the high tension circuit up to

100,000 volts for radiography and anything up to 450,000 volts for treatment work. The other is the filament-heating circuit of about 12 to 15 volts. The different methods employed for carrying out these adjustments will be explained when discussing the high tension units.

HIGH TENSION GENERATORS.

X-ray tubes have to be fed with high tension uni-directional current. At one time the usual method of generating such a current was by means of the induction coil and interrupter working from direct current mains. Such an arrangement had many drawbacks. The interrupter, in which the current was made and broken many times per second, was the chief source of trouble. Experiments were then made, chiefly in America and Germany, to rectify the high tension current given by a transformer working from a source of alternating current.

How High Tension Rectifiers Developed.

The high tension rectifiers first consisted of rotating contacts which revolved inside corresponding stationary contacts. The former contacts were rotated in synchronism with the periodicity of the supply. This method has now been discarded in favour of valve rectification. This form of rectification has great advantages over the mechanical rectifier, the chief of which are that it is noiseless and it does not generate nitrous fumes or high frequency surges in the high tension system.

Valve tubes also allow heavier currents to be passed through the rectifying system.

Types of High Tension Transformers.

There are many different types of high tension transformers in use. These can be classified as under .—

1. Half-wave transformers.
2. Fully rectified transformers.
3. Three-phase transformers.
4. Condenser units.

No. 1 can be sub-divided into unrectified transformers and transformers in which one valve tube only is used. No. 4 can be sub-divided into diagnostic sets and therapy sets.

What the Radiologist Requires.

Before we discuss these sets in detail it will be necessary to explain briefly the requirements of the radiologist. It is usually necessary for the doctor to see the shadow of the bones, or internal organism of the patient, on a fluorescent

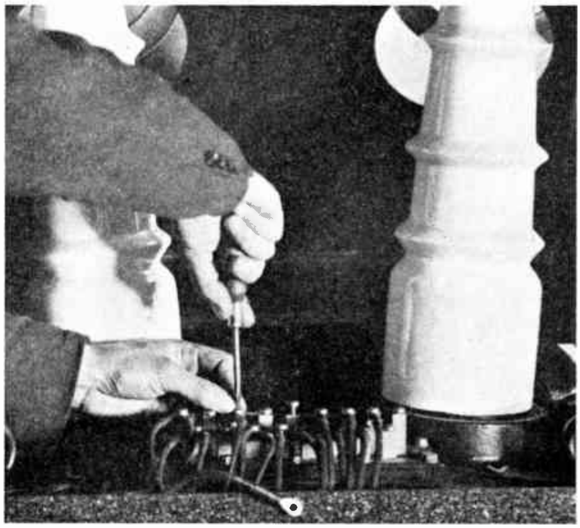


Fig. 4.—METHOD OF CONNECTING PRIMARY LEADS TO HIGH TENSION TRANSFORMER.

screen. For this purpose a small current of about 4 milliamperes is required. The screen examinations will last from about 3 to 4 minutes. A film is then exposed in order to obtain a permanent record and also to enable the radiologist to report in detail upon the radiograph. For this it is necessary to use a comparatively heavy current, say, 200 or 300 milliamperes for a fraction of a second. In some cases it is also necessary to vary the kilovoltage. In most cases it is very important that no time should be lost in resetting the controls between the screen examination and the exposure.

If one keeps these requirements in mind one will be able to grasp the arrangement of the controls better as they are explained below.

HALF-WAVE APPARATUS.

The first class consists of transformer sets in which one-half of the phase is suppressed by the X-ray tube or by the valve tube. In this case the current is able to pass along the electronic stream liberated by the hot cathode, but is unable to pass in the reverse direction. Where a valve tube is not used, the X-ray tube itself offers the necessary resistance to the inverse current. Care must be taken to ensure that the X-ray tube is not overloaded, as this might cause the focal spot on the anode to attain a state of incandescence, in which case electrons would be given off from both electrodes, and inverse current would pass. With a valve tube in series with an X-ray tube this is guarded against. This type of transformer gives a pulsating uni-directional current. The pause between each pulsation equals the time taken by the pulsation.

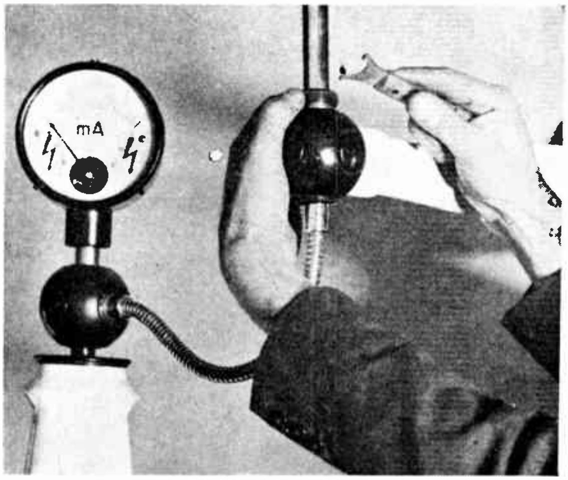


Fig. 5.—SECURING THE HIGH TENSION LEADS.

Construction of Half-wave Apparatus.

Half-wave apparatus is usually of the closed iron core type, the whole being immersed in oil in a welded steel tank. Enclosed in the same tank is a step-down transformer which provides the current necessary for the heating of the filament of the X-ray tube. It must be remembered that the secondary winding of this transformer is in contact with one pole of the high tension transformer, thus the primary has to be well insulated from the secondary. The high tension current is led through the metal top of the tank by means of heavy porcelain insulators. One of these leads also includes the two filament connections. The controls are mounted on a separate trolley switch-table and generally include a coarse and a fine control for the filament of the X-ray tube, an automatic time clock which controls the exposures from one-tenth of a second up to ten seconds, a dual control switch, a voltmeter and an automatic cut-out.

Method of Control.

The kilovoltage regulating crank moves over contact studs which are connected to various tappings on the primary of the high tension transformer. Some times this regulation is carried out by means of an auto-transformer. This method, however, has the disadvantage that it increases the internal voltage drop of the apparatus. The fine voltage control consists either of a regulating resistance or an inductive regulator.

Filament Control.

The filament controls are generally resistances with sliding contacts. The dual control switch enables the operator to switch on either a small current suitable for screening, or a heavy current suitable for radiography. The switch is of the rotary type with five positions. In one position all the current is switched off. If the switch is then turned to the left the filament heating circuit is closed, which only allows sufficient current to pass for a screen examination. The next position also switches on the high tension current. If the switch is brought back to the zero position and then turned to the right, some resistance in the filament heating circuit is cut out, with the result that when the switch is again moved in the same direction the radiographic high voltage current is switched on. At the same time the automatic time clock is brought into action. This should have been set beforehand to the desired time for the exposure. At the end of this period two contacts open and the main switch falls out. The dual control switch must then be brought back to zero. It will be seen that the dual control switch is in the nature of a remote control. That is to say, it closes the solenoid circuit of the main switch. The latter switch can be clearly seen in Fig. 2. The voltmeter serves to show the primary voltage and thus the actual kilovoltage can be ascertained. The overload release switch is connected in the screening circuit, and protects the X-ray tube against accidental overloads. Such an apparatus is shown in Figs. 1, 2 and 3.

THE FULLY RECTIFIED TRANSFORMER TYPE.

In the second class are those transformers which employ four valve tubes, which have the effect of rectifying both half phases of the high tension current. Each of the high tension terminals is connected to the negative terminal of one valve tube and the positive terminal of another, the opposite ends of each pair of valves being connected to each side of the X-ray tube. This type of transformer also gives a pulsating uni-directional current, but in this case the pulsations follow after one another without any appreciable pause.

Both this and the half-wave types are fed with single-phase alternating current.

Construction of Fully Rectified Apparatus.

In fully rectified apparatus the general design of the high tension transformer is the same as for the half-wave apparatus, except that the electrical balance is better, and so, for the same output, the dimensions can be kept smaller.

Controls for Four-valve Transformer.

The controls for a four-valve transformer are generally rather more elaborate than for a half-wave apparatus. The radiographic filament control and the screening filament control are entirely separated in the better-class sets. The kilovoltage controls are also separate. The mechanism of the time clock is also generally more accurate. We must again pause here while we consider the special functions of medium-powered four-valve apparatus. First, the output of the apparatus in milliamperes is roughly double that of the half-wave apparatus. This calls for a more efficient form of milliamperage control. It also calls for a more efficient method of timing the exposures, as an error of one-tenth of a second, when using a heavy current, may mean a failure, so far as the resultant radiograph is concerned. It is also necessary to guard against undue voltage drop in the apparatus, and especially against voltage drop in the filament circuits of the valve tube and X-ray tube.

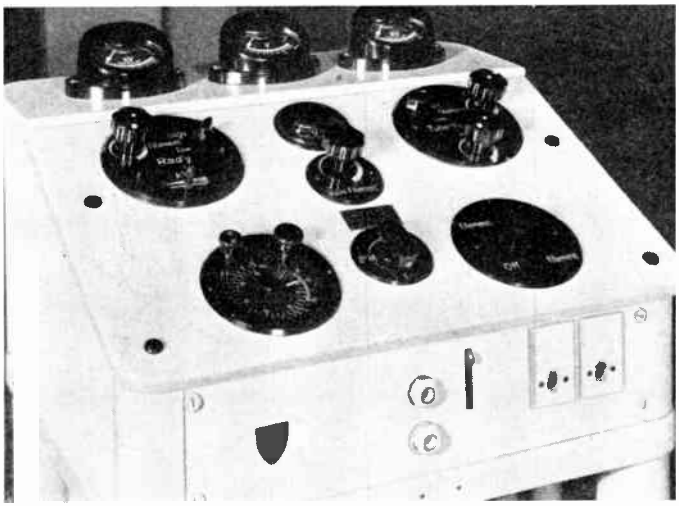


Fig. 6.—Controls on Switchtable of Three-phase High Tension Transformer.

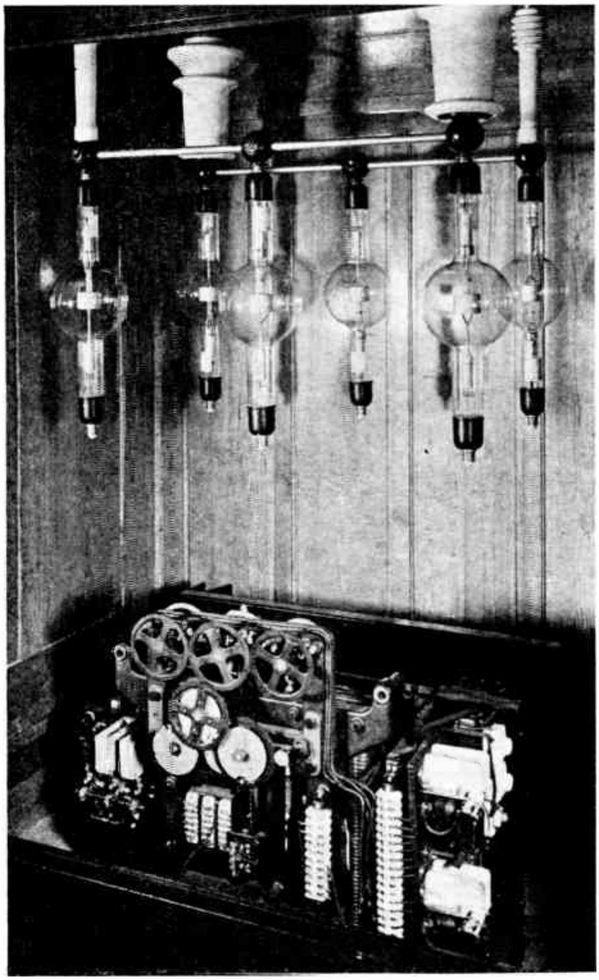


Fig. 7.—VALVE RECTIFIER AND CONTROL GEAR OF THREE-PHASE HIGH TENSION TRANSFORMER (TRANSFORMER NOT SHOWN.)

Auto-transformer Control.

It is possible to use an auto-transformer to provide the necessary kilovoltage control, but this would entail a certain amount of voltage drop when using heavy currents. A better method is to arrange various tappings on the primary winding of the high tension transformer, these being connected to a crank regulator situated on the switchboard. This provides kilovoltage control for radiography. The kilovoltage for screening is provided for by means of a small auto-transformer. Voltage drop need not be taken into consideration here, as only small currents are used for screening. This method of control has the additional advantage that it provides the radiologist with two entirely separate controls for screening and radiography.

How the Filament Currents are Kept Constant.

To protect the valve filaments against voltage drop when the main circuit is closed it is necessary to provide a small compensating transformer. This generally takes the form of an open core transformer, the primary winding of which is in series with the primary winding of the high tension transformer. A secondary winding is in series with the primaries of the valve and X-ray tube filament transformers. It will thus be seen that the greater the current passing through the main circuit, the greater will be the compensating effect in the filament transformer circuits.

Meters on the switch-table show the operator what the output of the apparatus will be before actually switching on the high tension current. A milliamperemeter in the high tension circuit serves as an additional check on the milliamperage.

How the Controls are Arranged.

It is obviously an easy matter to arrange separate controls for the filament of the X-ray tube. These are so connected to the dual control switch that one set is cut out of circuit when the other set is switched in. The clockwork mechanism of the time clock is replaced by a synchronous motor. Incidentally, this clock can be made to reset itself immediately the exposure is made. This is useful when taking a series of radiographs.

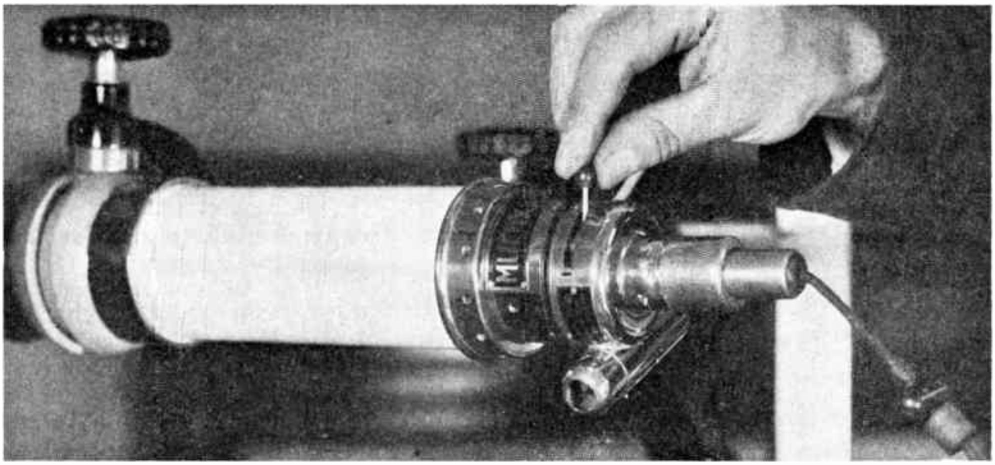


Fig. 8.—SWITCHING OVER FROM NO. 1 FILAMENT TO NO. 2 FILAMENT.

THE THREE-PHASE TRANSFORMER TYPE.

Three-phase transformers utilise all three phases of the main supply. For this purpose six valves have to be employed. As in the four-valve unit, these valves have the effect of suppressing the inverse potential, but allowing it to pass in the right direction only.

If one imagines an oscillogram of a three-phase alternating current, it would appear as three separate sine curves overlapping one another. Half of these curves would be above the zero line and half would be below.

Current Curves After Rectification.

After the current has been rectified by the valve tubes, the oscillogram would show that all the curves on one side of the zero line had been transferred to the other side of the line. In other words, the voltage curves would all appear on the same side of the line and all overlapping each other. The resultant effective voltage would be represented by a series of "peaks." In effect, this gives a continuous potential which has a slight "ripple."

Construction of Three-phase Apparatus.

Transformers utilising three phases of the main supply are usually fitted with much the same form of control as the single-phase apparatus. Additional windings and controls are, of course, needed for the two extra phases. Voltage drop is further eliminated by doing away with the voltage control leads between the transformer and the switch-table. The three crank regulators are, in this case, mounted on the side of the transformer tank, the different primary tappings being connected to the respective studs with which the crank arm makes contact. These crank regulators are actuated by an electric motor working through a train of gear wheels. This motor is

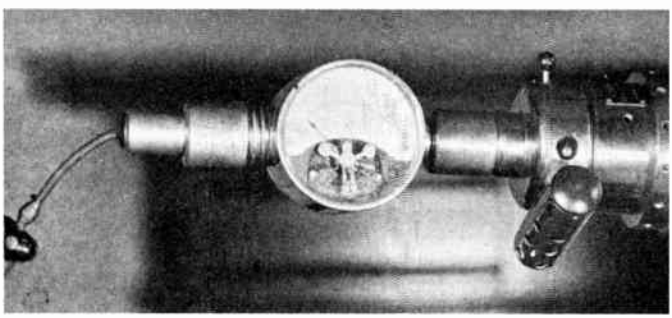


Fig. 9.—TESTING FILAMENT CURRENT ON DOUBLE FOCUS PROTECTED X-RAY TUBE.

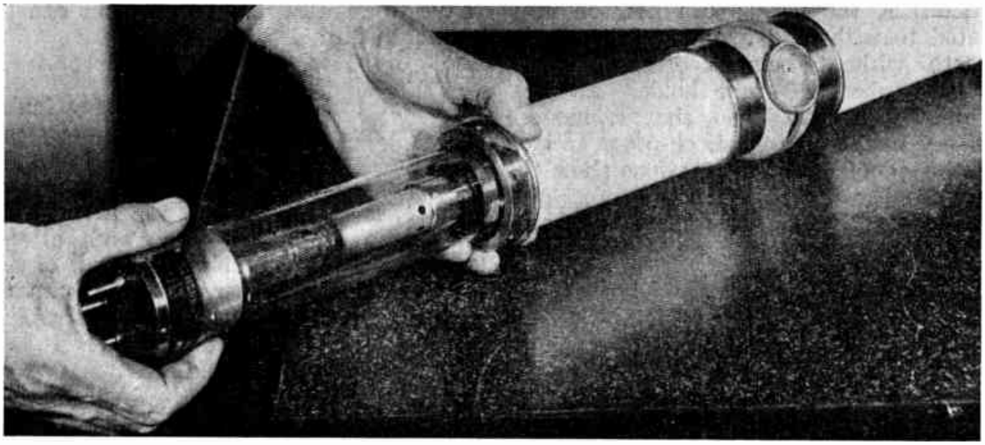


Fig. 10.—Withdrawing Siemens Multix X-Ray Tube from Its Protective Covering.

controlled from the switch-table and can be made to rotate either one way or the other, depending upon whether the kilo-voltage is to be raised or lowered. A sliding contact on a small transformer is electrically imposed between each pair of studs so as to provide continuous voltage regulation.

CONDENSER APPARATUS.

The condenser diagnostic unit consists of a high tension transformer, which is used to charge two condensers through two valve tubes. When a sufficient charge has been accumulated the charging current is switched off and the X-ray tube put into circuit. The latter operation only consists of switching on the filament current of the X-ray tube. When it is necessary to excite the X-ray tube continuously (during screen examinations), both the filament of the X-ray tube and the high tension transformer are connected to the main supply for the necessary period. In this case the connections are the same as for the condenser therapy apparatus of the Stabilivolt type.

The latter type of apparatus gives a constant continuous current, which is used to excite the tube for treatment purposes. The usual voltage of such an apparatus would be 230 kilovolts, but apparatus of this nature are available to give up to 880 kilovolts.

Construction of Condenser Apparatus.

Condenser diagnostic apparatus are particularly useful when the current supply is limited, as in some country places where the hospital has its own generating plant.

Condenser apparatus for deep therapy work has been used with great success for a number of years. The high tension transformer charges two condensers *via* two valve tubes so that one condenser receives the full potential of one-half phase and the other is charged by the half-phase of opposite sign. Thus across the inner layers of these condensers we have double the potential delivered by the transformer. This charge is led away to the X-ray tube. The rate of discharge being limited by the internal resistance of the tube and hence by the state of the filament.

The controls for this type of apparatus follow the lines already described, but no provision is made for taking radiographs. The dual control switch is replaced by a simple "off" and "on" switch.

HIGH TENSION LEADS.

Up to the present the high tension current has been fed to the X-ray tube from the transformer by means of tubing, about ¾ inch in diameter, held by insulators fixed to the ceiling. As the result of extensive research work on insulating materials, these leads can now be insulated to withstand over 100 kilovolts to earth without being too cumbersome. X-ray tubes and tube holders are also similarly insulated, so that a modern X-ray installation is shock-proof as well as ray-proof. The illustrations show the "coronaless" type of high tension gear as this is, at present, most commonly met with, but it will not be long before this is superseded by the shock-proof high tension system mentioned above.

DOUBLE FOCUS X-RAY TUBES.

One of the ray-proof X-ray tubes is illustrated. This is fitted with two filaments. One of these is arranged to focus the cathodal stream on to a small spot on the target and the other filament gives a broader focus. The fine focus gives radiographs showing fine detail, but the current carrying capacity of the tube is limited. Where heavy currents have to be used, the broad focus can be switched into circuit.

Testing for Faults.

When testing an apparatus for faults the various circuits must be taken separately, and by a process of elimination the fault can be discovered. For instance, if the filament of the X-ray tube fails to light, it may be a fault in the tube itself, in the secondary circuit of the step-down transformer, or in the primary connections of same. Another test which should be made is an insulation test between the primary and secondary windings and also between the high tension gear and earth.

A modern X-ray apparatus, however, has now reached the stage where it can be relied upon to do its work almost unfailingly. Any trouble can generally be traced to a faulty contact as might be met with in any commercial electrical apparatus.

QUESTIONS AND ANSWERS

What are X-rays?

X-rays are radiations of extremely short wave length. The wave length is rather shorter than that of ultra-violet light.

How are X-rays produced?

By bombarding a tungsten plate with a stream of electrons.

What is the special characteristic of X-rays?

These rays have great penetrating power. They will pass through many materials which are opaque to light; thus wood, flesh, and, to a lesser extent, bone, are all capable of being penetrated by X-rays. It is this property which makes the rays so useful for taking X-ray photographs. It has been found that X-rays also exert a special action on the tissues. This factor is utilised in X-ray treatment.

What substance offers the greatest resistance to the penetration of X-rays?

Lead is practically opaque to these radiations.

How can the penetrating power of the rays be controlled?

The penetration of the rays depends on the voltage applied to the terminals of the X-ray tube. The quantity of radiation is determined by the state of incandescence of the filament, i.e., the hotter the filament, the more current will pass, the greater the quantity and penetrating power of the rays.

Why is a fluorescent screen sometimes used in X-ray work?

The X-rays falling on a fluorescent screen cause it to glow. The screen is, therefore, very useful for rapid examination of a patient by X-rays. The X-rays are allowed to pass through the patient and on to the screen so that an X-ray picture is possible. For permanent records a photographic plate is substituted for the fluorescent screen.

DOMESTIC POWER APPLIANCES AND THEIR CONTROL

By H. W. Johnson

THE installation and use of domestic power appliances in the home has revolutionised the carrying out of household duties. The home is healthy, bright, and the housewife is able to manage the home with a minimum of help and to reduce the expenditure on its maintenance. The money which is paid for the installation of these appliances and the energy consumed by them, does not only represent the work done by them, but includes the expense which would be incurred by employing help to carry out certain of the work, which could not be done without the aid of these appliances.

Coal fires used for heating purposes, and old-fashioned methods of removing dust and dirt, with their disastrous effects on the decorations and furnishings of the home, is entirely done away with by the use of these appliances, and considerable saving is effected in the renewals to furnishings and decorations.

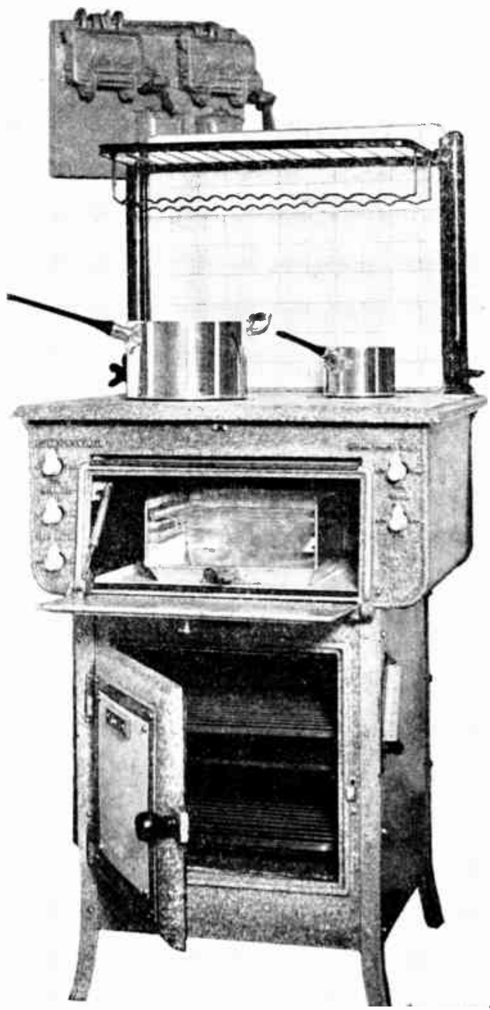


Fig. 1A.—A Typical Electric Cooker.
The oven of the stove has two elements each separately controlled with a 3-heat switch. The loading of these elements is 1.25 kilowatts each. The fuse-holders may be inspected and removed for renewal of fuses by lifting up the hob plate at the top of the stove.

Supply of Electricity to the Appliances.

The supply of electricity to the appliances is generally given through a plug and socket, with the exception of large cooking stoves. Cooking stoves are supplied on a separate circuit, controlled with a double-pole switch and fuses mounted on a suitable board which is fixed in a convenient position near the stove.

Size and Type of Plugs and Sockets.

The plugs and sockets which are installed must be designed to carry the full-rated currents taken by the particular appliances connected to them. They should be of the three-pin type so that the non-current carrying metal parts of the appliances are connected to earth. The plugs and sockets installed should all be of the same type and so arranged in the various rooms that portable appliances, radiators, vacuum cleaners, etc., may be conveniently used in any desired room.

Radiators, imitation coal fires, cylinder water heaters, wash boilers and large grillers will require a supply from a 10 to 15-ampere plug and socket.

Vacuum cleaners, washing machines, kettles, toasters, small water cistern heaters, irons and hair dryers may be safely supplied from a 5-ampere plug and socket.

The Number of Plugs and Sockets to be Connected on a Circuit.

The number of plugs and sockets allowed on a circuit fed from a distributing board is determined by the total current taken by them. The regulations of the I.E.E. allow four plug points on a circuit, the maximum current of which does not exceed 10 amperes, and two plug points, when the maximum current does not exceed 20 amperes.

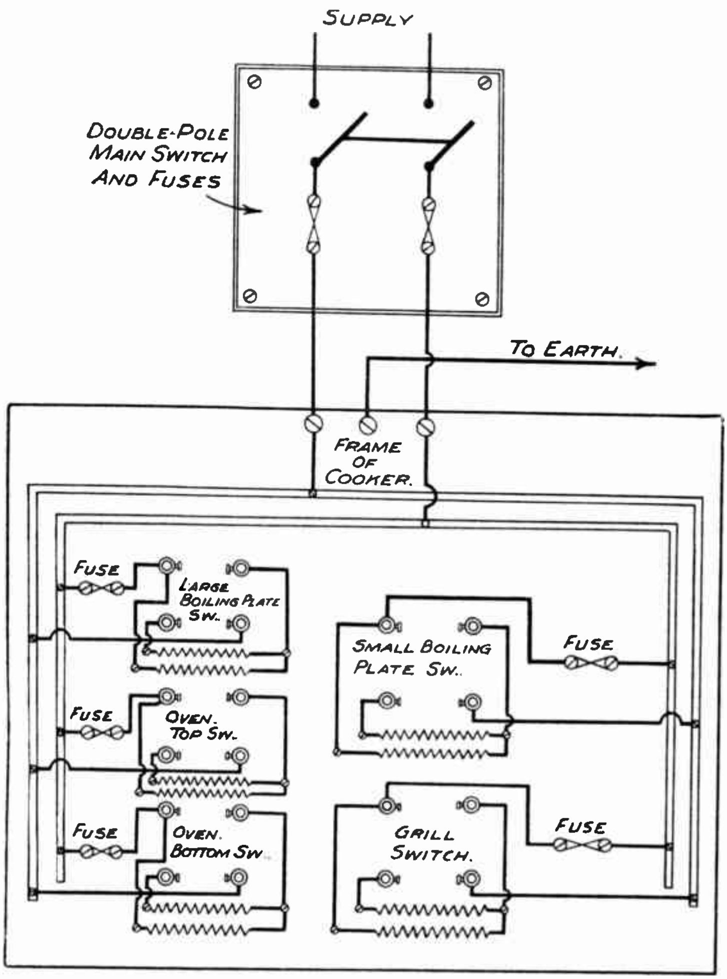


Fig. 1B.—THE WIRING DIAGRAM OF AN ELECTRIC COOKER.

Each element circuit is controlled with a three-heat rotary switch. A fuse is connected in each circuit, and a double-pole switch and fuses in each feed control the supply to the cooker.

Inadvisability of Taking a Supply from a Bayonet Cap Lampholder.

Avoid supplying a portable appliance from a lampholder through a lamp adaptor, even if the appliance takes only a very small current. The connection is not rigid and arcing may take place at the plunger contacts of the lampholder, also an efficient earth connection to the exposed metal casing of the appliance cannot easily be made.

COOKING STOVES.

Most cooking stoves have an oven, a grill, and two boiling plates. Each of these parts will have its own heating element controlled with a three-heat switch.

The Heating Elements.

The modern heating element for a cooking stove consists of a resistance spiral which is enclosed in a steel tube.

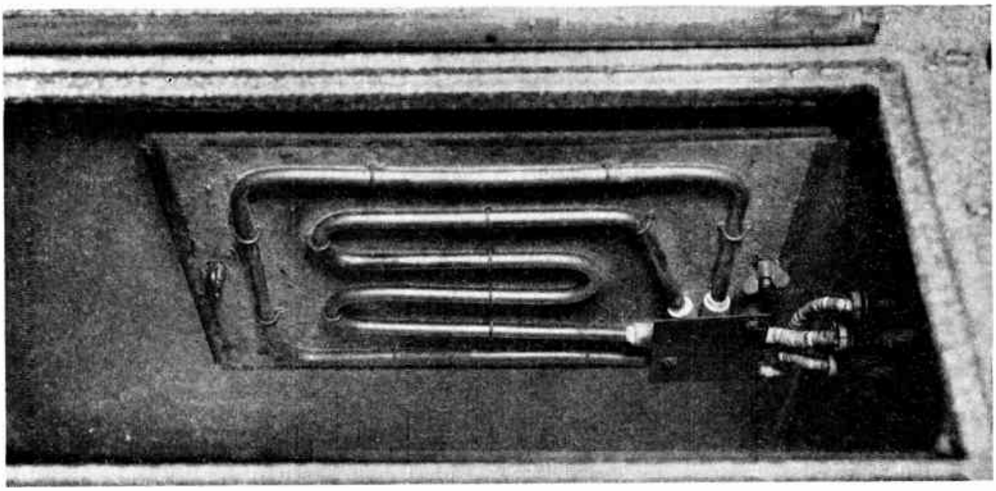


Fig. 2.—The Griller Element of an Electric Cooking Stove.
The element, which is enclosed in a steel tube, is fixed under the top plate of the stove. It is controlled with a switch which gives full, medium, and low heat. The connections to the element are insulated with porcelain beads, and shielded with an iron plate. The element may be cleaned without any detriment to the heating coil embedded inside the steel tubing. The loading of the griller element is 2 Kw. on full heat, 1 Kw. for medium heat, and 0.5 Kw. for low heat.

The spiral is insulated from the tube with a special insulating cement, which is run into the tube when the spiral is in position, and baked hard.

When the current passes through the resistance, the whole of the element is heated up, but as the tube is insulated from the resistance spiral it is shockproof, and should any water or food stuffs boil over on to the tube, the resistance heater is not affected in any way.

The Element Control from the Three-Heat Switch.

A special form of rotary switch having four positions giving full heat, medium heat, low heat, and off, is used for controlling the supply of electricity to the heating element. The heating element is in two parts and when the switch is in the " full " position the two parts of the element are connected in parallel and the element is taking its full rated current. When the switch is in the " medium " position one part only of the element is connected to the supply and the element is now taking one half of its full rated current. The " low " position of the switch connects the two parts of the element in series and the current is reduced to one quarter of its full value.

The oven is supplied with two elements, each element having its own three-heat control switch.

The Consumption of a Cooking Stove.

The total loading of an average cooker is about 7 kilowatts which means it will consume 7 units per hour.

The Fuses.

A fuse is connected in each of the element circuits. They are of the hand-grip type, and are fixed underneath the hob plate.

The Oven Thermometer.

A thermometer is fitted to the oven, the bulb of the thermometer is enclosed in a brass sheath for protection. The temperature for bread and pastry-making is about 500° Fahrenheit, and this temperature can be maintained constant by regulating the switches controlling the oven elements.

WATER HEATERS.

Immersion Heaters for Hot-Water System.

The hot-water system of a house which is normally heated with a boiler fitted at the back of a kitchen fire, can be heated electrically by using an immersion heater which is fitted in the hot-water cylinder.

The cylinder is drilled at the top and a screwed brass flange bolted and soldered in the drilled hole.

Tie up the ball tap in cold water feed tank, and turn off the cold water at the main. Drain off two or three gallons of water from the cylinder from the drain tap on the flow and return taps to the boiler.

Mark off the hole for the screwed flange and describe a circle the outside diameter of the screwed threads on the cylinder top in the correct position.

A small hole is drilled in the top of the cylinder coinciding with the centre of the screwed flange. The correct diameter of hole for the flange can now be cut by inserting a ring saw and cutting round the circumference of the marked hole.

Two slots opposite to each other are filed in the sides of the hole and the flange base pushed inside the cylinder. A joint washer is introduced between the base and the inside of the cylinder, and the flange top screwed on. The whole can be then "sweated" to the cylinder top.

Fig. 3.—An Electric Imitation Coal Fire.

The heat generated by the elements is radiated into the room with a polished copper reflector. The elements are controlled with switches fixed on the sides of the fire. Before taking out the plug it is advisable to turn off the radiator element switches. This will prevent a rush of current when the plug is replaced.

The Immersion Heater.

The heating element is a resistance spiral fitted in a watertight steel tube and insulated from it with an insulating cement. The steel tube containing the resistance spiral is fitted at the top with a screwed malethread of the same pitch and size as the screw thread in the brass flange which has been soldered in the top of the cylinder.

The Circulator Tube.

The steel tube containing the heater element is placed inside a water circulator tube which has two holes drilled in the side, one near the bottom of the tube and the other near the top. The cylinder water can circulate freely through this tube. When the current is switched on to the immersion heater, the cold water passes through the hole in the bottom of the circulator and is warmed as it rises through the tube, passing out through the hole near the top.

The Thermostatic Control of the Heater.

This consists of a metal rod which expands as the temperature of the water in the cylinder increases. The rod is connected by a system of toggle levers to a glass tube containing a quantity of mercury. The normal position of this glass tube is horizontal and the mercury contained in the tube short circuits two platinum electrodes or contacts, the ends of which are sealed inside the tube. The electrodes and the short-circuiting column

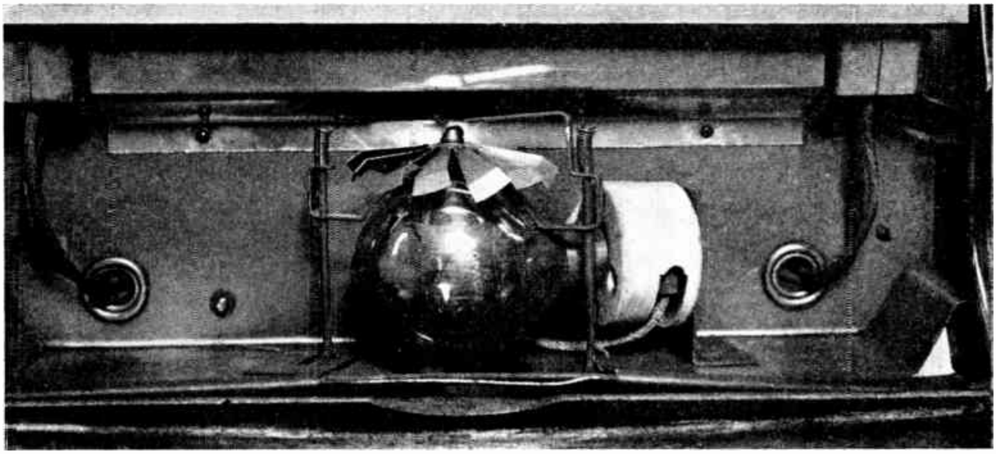


Fig. 4A.—THE INTERIOR OF AN IMITATION COAL FIRE.

The pilot lamp illuminates the imitation coal from below and the flickering flame effect is produced by the shadows of the rotary "spinner" projected on the coal.

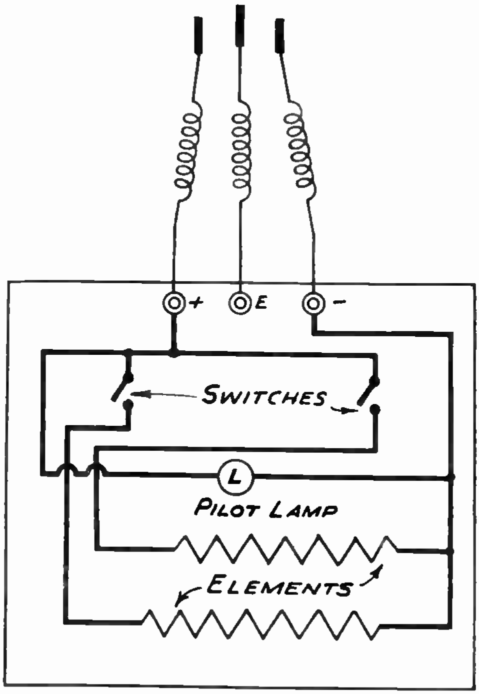


Fig. 4B.—THE ELECTRICAL CIRCUIT OF AN IMITATION COAL FIRE.

Each heater element is controlled by a switch. The coloured pilot lamp is switched on when the plug is inserted in the socket.

of mercury form part of the heater circuit. When the temperature of the cylinder water exceeds the limit, generally 160° Fahrenheit, the expansion of the metal rod causes the glass tube containing the mercury to be tilted towards the vertical. The mercury now runs to one end of the tube, and the platinum electrodes are no longer short-circuited, and the current through the heater is switched off. The temperature at which the thermostat acts may be adjusted with a setting device fixed to it. Various sizes of immersion heaters may be obtained.

Loading of the Immersion Heater.

A useful and convenient size for an ordinary domestic supply has a loading of 1 kilowatt and consumes 1 unit an hour. Hot water may be obtained in about 15 minutes after the current has been switched on.

Electrically Heated Water Cistern for Local Supply.

When a local supply of hot water to a sink or wash-bowl is required, an electrically heated water cistern may be installed directly above the sink or wash-bowl, the only water connection required being one from the cold water supply. The heating element is placed between sheets of mica which are enclosed in a watertight copper sheath. This element is fitted in the lower end of the cistern. A thermostatic control is fitted to the heater circuit, which will switch off the current when the temperature of the water exceeds 160° Fahrenheit.

Drawing Off the Hot Water.

Hot water is forced out from the outlet pipe fixed in the bottom of the cistern by turning on the cold water supply, the cold water displacing the hot water thus drawn off. By using this method, the cistern can never be run dry, also it is not subjected to the pressure of the cold water supply. A baffle plate is fixed immediately above the nozzle of the cold water inlet pipe to prevent the cold water forcing its way to the top of the water level in the cistern and mixing with the hot water.

Loading of the Element.

The heating element for a cistern having a capacity of about 4½ gallons of water takes a loading of 500 watts and consumes ½ unit an hour. This cistern will give 1 gallon of hot water per hour.

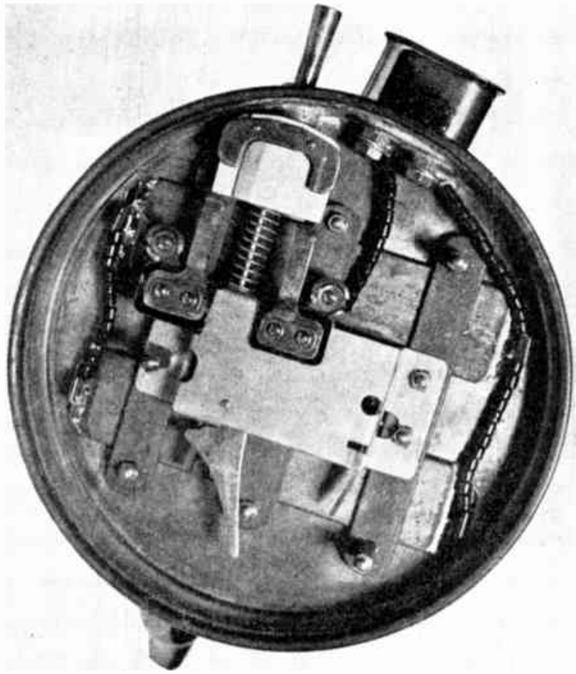


Fig. 5A.—SHOWING THE AUTOMATIC SWITCH WHICH IS FITTED TO AN ELECTRIC KETTLE.

When the kettle boils dry, the bottom is distorted and a trip lever releases the switch which is opened by the spring. The switch is reset by pushing back the plunger to its original position when the bottom of the kettle has cooled down again. The internal connections from the connector pins to the automatic switch and the element are insulated with glass beads.

The kettle consumes 0.65 unit per hour, and will boil the water in 12 minutes.

ELECTRIC KETTLES.

The heating element for an electric kettle is a long strip of resistance alloy arranged in a zig-zag fashion and fitted between two sheets of mica. The element is fitted immediately under the bottom of the kettle and covered with a metal plate which is secured to the bottom of the kettle with screwed nuts.

The Automatic Switch Control.

An automatic switch is connected in the element circuit and fitted by the side of the element. This switch is opened by a spring which is released by a trip lever when the bottom of the kettle is distorted, due to excessive heat. This will occur when the kettle is boiled dry. When the switch is opened by the pull of the spring, the current is switched off and a plunger is forced out from the side of the kettle.

Resetting the Automatic Switch.

Before the switch can be reset, the bottom of the kettle must be cooled down so that it will regain its normal shape. The plunger is then pushed back again causing the trip lever to engage with a slot cut in a bracket fixed to the bottom of the kettle, which now allows the switch blade to be replaced in the contacts.

Loading of a Kettle.

The loading of a two-pint kettle is about 650 watts, which consumes 0.65 unit per hour, and will boil the water in about 12 minutes.

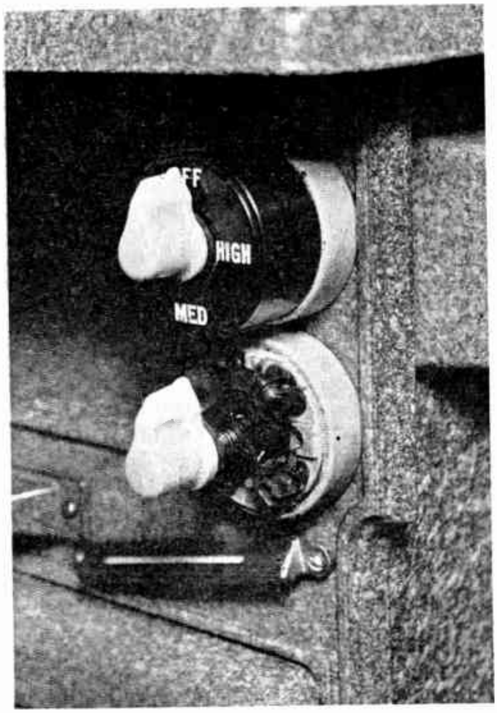


Fig. 6A.—A THREE-HEAT ROTARY SWITCH FOR CONTROLLING THE ELEMENTS OF AN ELECTRIC COOKER.

A thermometer is fitted to the oven, and the bulb fitted in a brass sheath for protection.

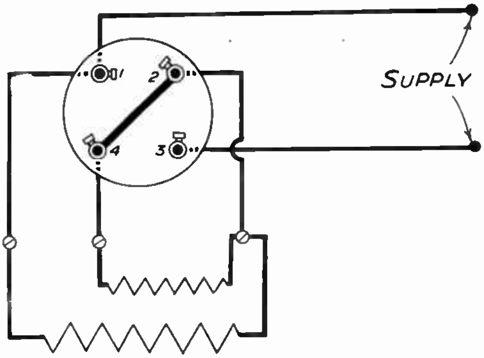


Fig. 6B.—THE THREE-HEAT ROTARY SWITCH. OFF POSITION.

The element is disconnected from the supply.

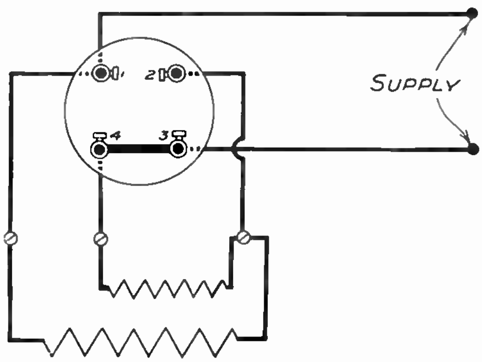


Fig. 6C.—THE THREE-HEAT ROTARY SWITCH. LOW POSITION.

The two parts of the element are connected in series.

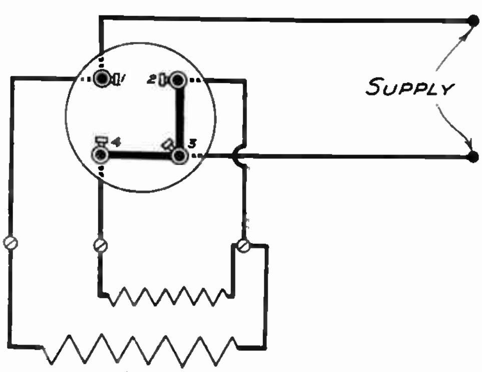


Fig. 6D.—THE THREE-HEAT ROTARY SWITCH. MEDIUM POSITION.

Only one of the elements is connected in circuit.

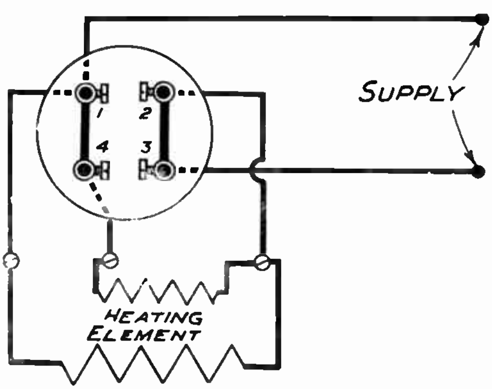


Fig. 6E.—THE THREE-HEAT ROTARY SWITCH. FULL POSITION.

The two parts of the element are connected in parallel.

The Earthing Connection.

The earthing connection to the kettle is made with spring clips, which are fitted on the outside of the connector, making connection to a metal collar, which surrounds the connector pins to the element. This collar is fixed to the side of the kettle. The spring clips are connected to the earthing conductor of the three-core flexible supplying current to the kettle.

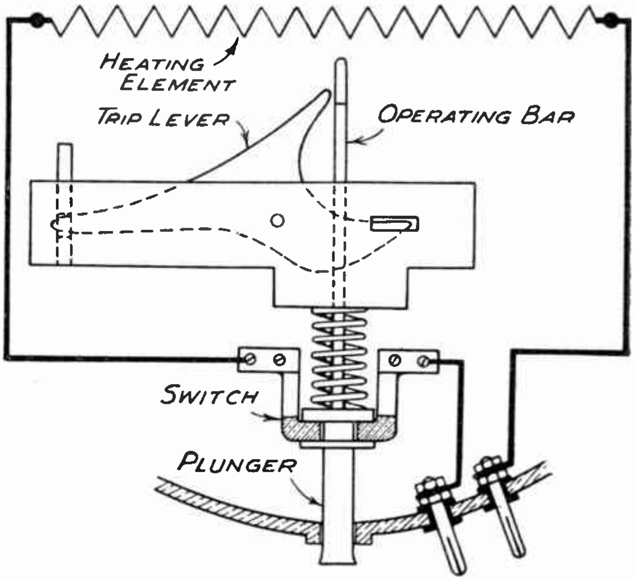


Fig. 7.—SAFETY SWITCH FITTED TO AN ELECTRIC KETTLE.

The switch is reset by pushing inwards the plunger, which causes the operating bar to engage with the trip lever. The lever is pushed over to the left and the end of the lever falls into the slot of the bracket which is fixed to the bottom of the kettle.

ELECTRIC IRONS.

How the Thermostatic Control Works.

An electric iron should be fitted with a thermostatic control which will open the element circuit when the temperature of the ironing surface becomes excessive. Much damage may be caused by leaving the current switched on to an electric iron which is not in immediate use.

The thermostat consists of a bi-metal strip which is normally in contact with another strip of metal, completing the element circuit. The thermostat is fitted inside the iron immediately above the ironing surface. When the temperature of the iron becomes excessive, the bi-metal strip is bent away from the strip with which it normally makes contact. This bending is due to the unequal expansion of the two different metals of which the bi-metal strip is made. The element circuit is opened and the current switched off. The circuit cannot be closed again until the ironing surface of the iron cools down, when the bi-metal strip regains its normal shape and the circuit is again completed.

The average electric iron takes a loading of about 500 watts and consumes ½ unit per hour.

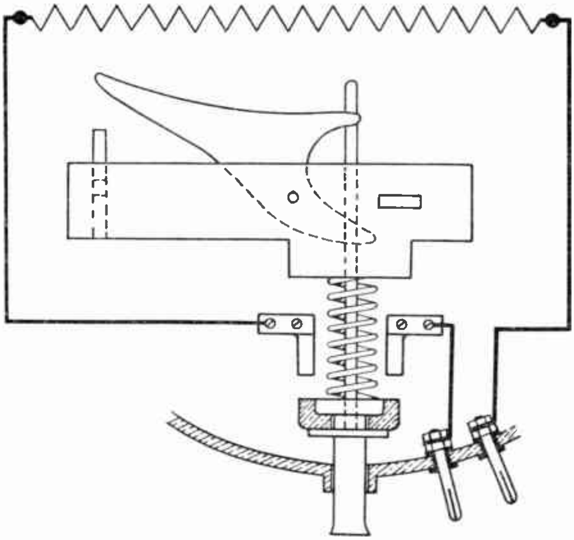


Fig. 7A.—SAFETY SWITCH FITTED TO AN ELECTRIC KETTLE.

When the kettle boils dry the trip lever is released and the spring opens the switch.

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