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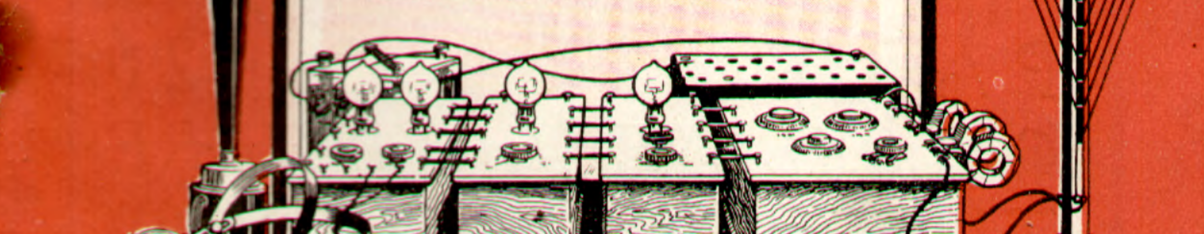
THIS PART CONTAINS

219 New Photos and Diagrams with 105 'How-to-Make' & Other Articles

REINARZ CIRCUIT
REJECTOR CIRCUIT
RELAYING BROADCAST
REMOTE CONTROL
RESISTANCE-COUPLED AMPLIFIER
RHEOSTAT : ROTARY SWITCH

SPECIAL PHOTOGRAVURE PLATE:
THREE-VALVE REGENERATIVE RECEIVING SET

J. LAURENCE PRITCHARD, F.R.Ae.S., Technical Editor, with expert editorial and contributing staff



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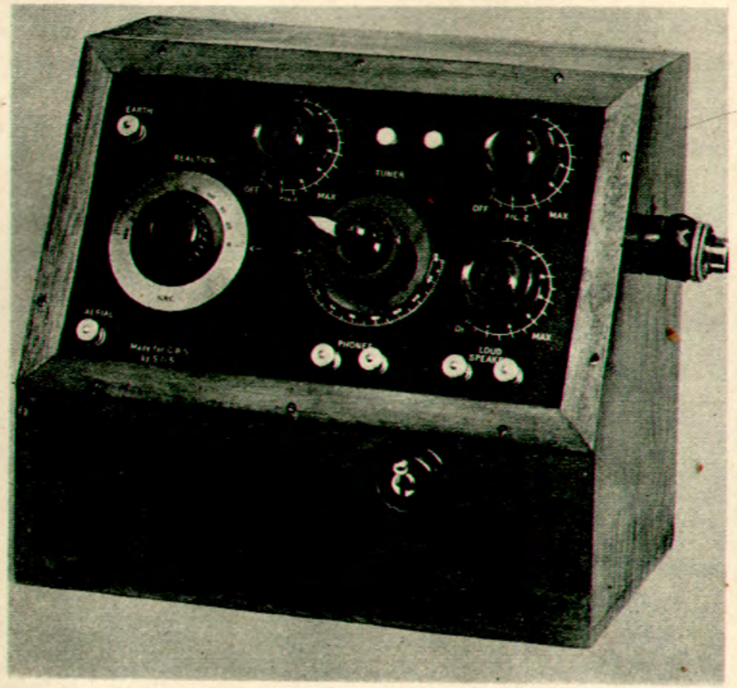


Fig. 22. Complete set in case with battery leads plugged in. An adapted valve-holder is used as plug. Note the opaline valve peep-holes

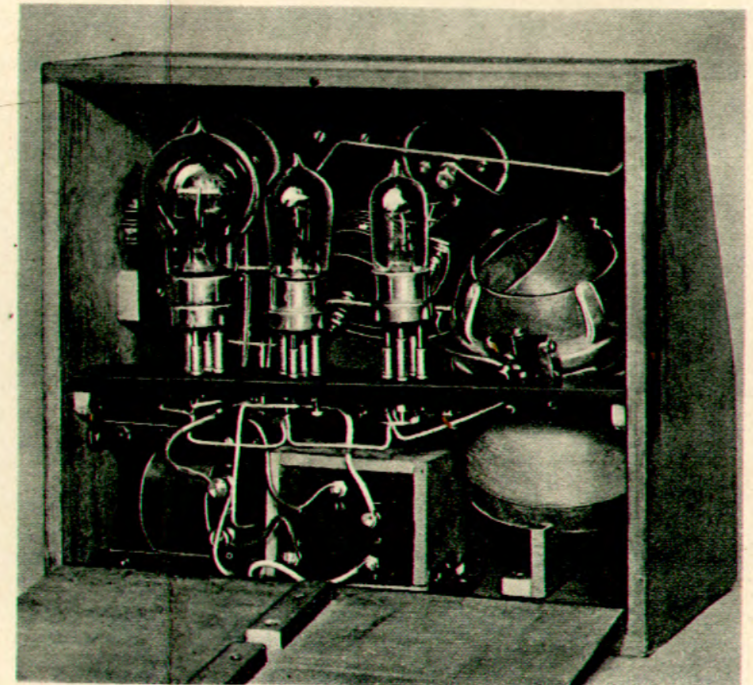


Fig. 23. Interior of cabinet showing valves in position, reaction variometer and grid biasing batteries for L.F. valves. The third valve is a small power valve

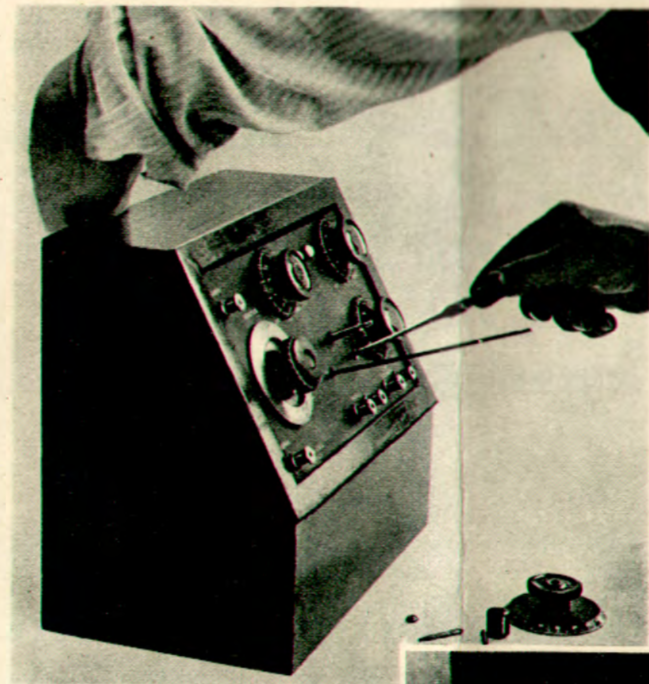


Fig. 24. A rod inserted through tapped hole in condenser and panel brings them into register

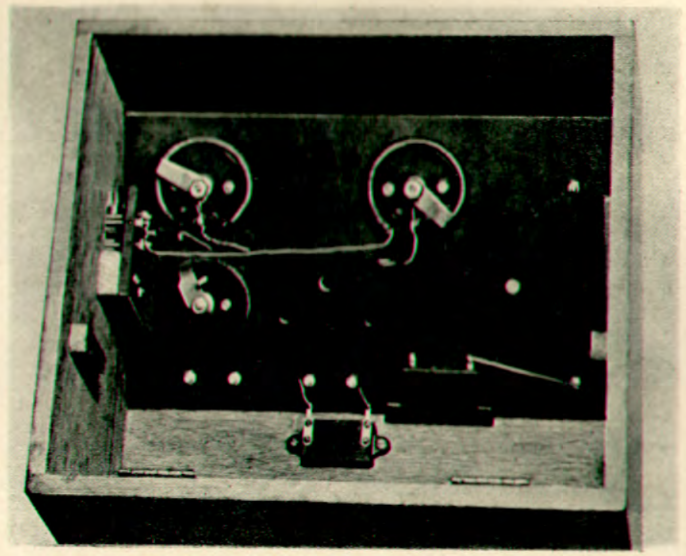


Fig. 25. Back view of panel with rheostats in place, and aerial series and telephone condensers fitted. On the left is an ebonite block with valve legs for battery plug

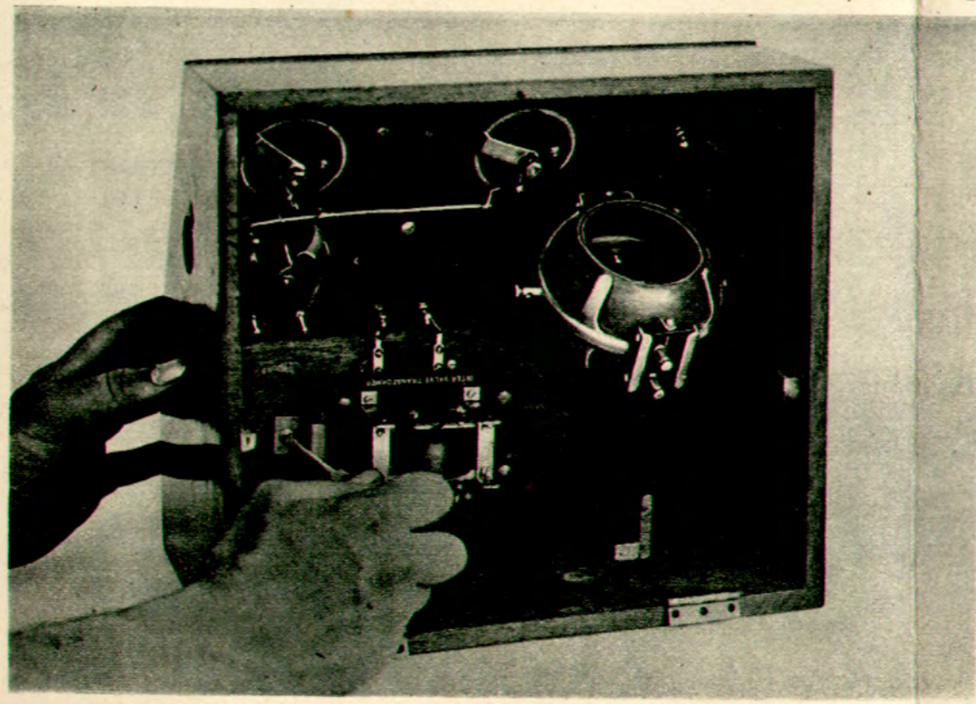


Fig. 26. How the first L.F. transformer is fixed in position with copper clips. Note the supporting block for the inductance coil under the variometer and the valve-shelf support on the right

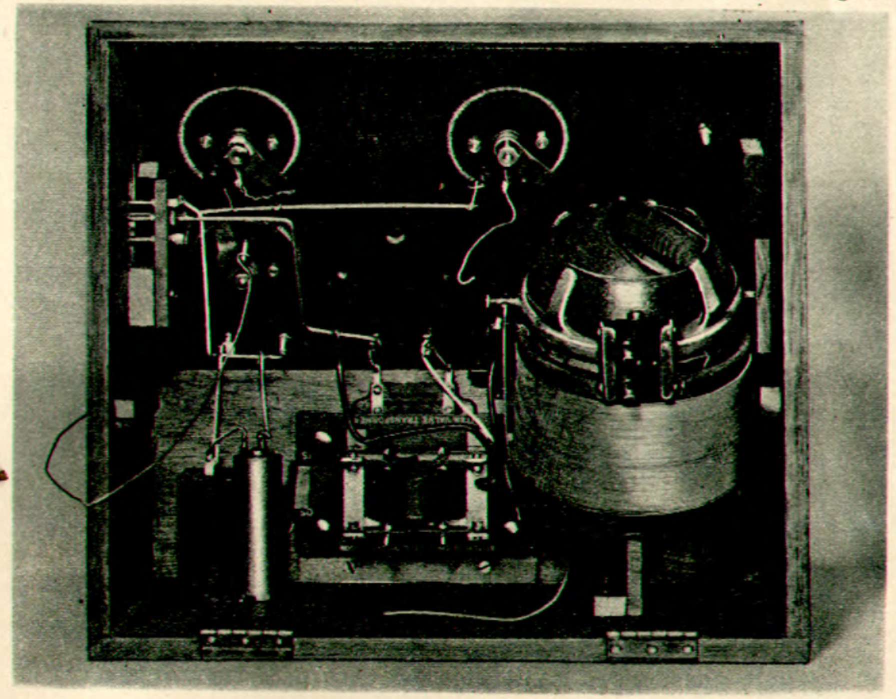


Fig. 27. Here is shown that part of the wiring which lies nearest the panel completed. This is essentially the first stage. Positions of loud-speaker condenser and choke coil are seen in this view

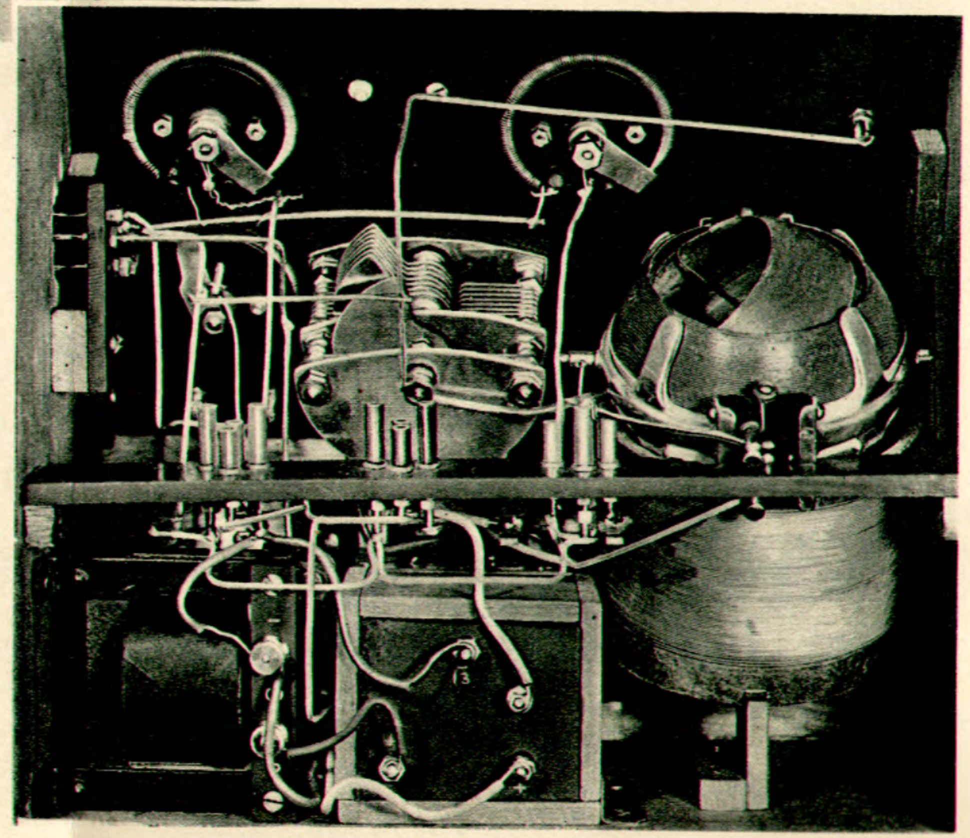


Fig. 28. The wiring is now completed. Notice the arrangement of the vernier condenser, valve shelf with valve sockets cut at different heights, second transformer, and case for grid biasing batteries

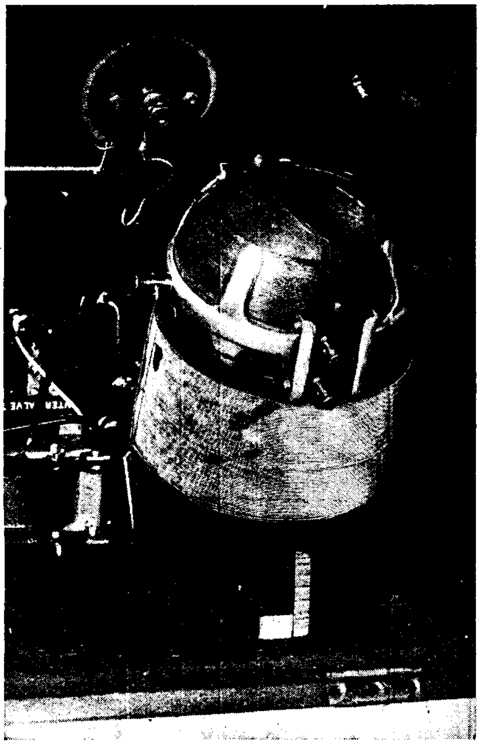
REGENERATIVE SET: STEPS IN THE CONSTRUCTION OF A MOST EFFICIENT ONE-VALVE RECEIVER INCORPORATING A TWO-VALVE LOW-FREQUENCY AMPLIFIER

To face page 1696

panel used in the particular set illustrated is 11 in. by 7 in., while the cabinet is 12 in. high, 12 in. broad, and 8 in. deep at the bottom.

The work of fitting in the components to the best advantage and of making connexions will be simplified by exceeding these dimensions.

In Fig. 25 the panel is seen drilled with the three rheostats in position and the two fixed condensers, that on the right

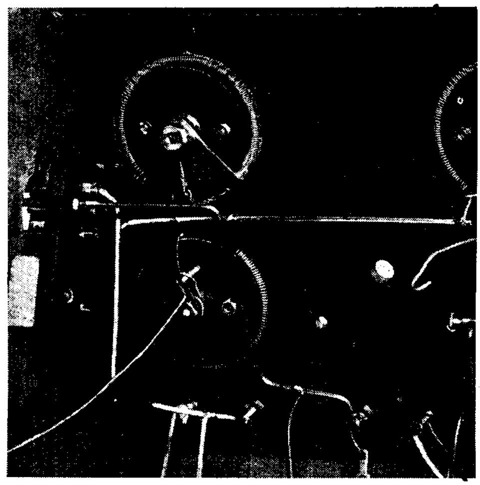


INDUCTANCE IN POSITION

Fig. 29. Here is shown how the inductance coil is supported and how smooth reaction is obtained by fitting the variometer partly inside the coil

being the ·0001 mfd. aerial series condenser, which is fastened to the panel with Chatterton's compound. In the centre is the telephone shunt condenser, of ·002 mfd. capacity.

Fig. 21 shows the inductance coil. This is wound on an ebonite or wax-impregnated cardboard former, 4 in. in diameter and about 3½ in. long. The winding consists of 74 turns of 22 gauge double silk covered wire. No shellac may be used, as it is essential to keep the capacity to a minimum. A tapping is brought out at the thirty-sixth or thirty-seventh turn, this

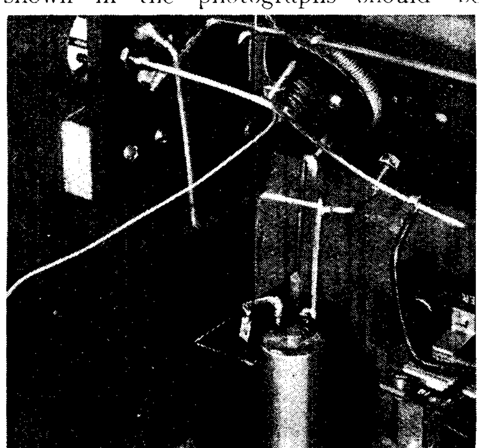


EARLY STAGES OF WIRING

Fig. 30. Negative leads of rheostats are connected, and H.T. leads soldered to valve legs on battery plug block seen in Fig. 25 of the photogravure plate

centre tapping giving aperiodic tuning. Leads are taken at either end of the coil to the two terminals of the tuning condenser. The cardboard or ebonite is cut away, as seen at the bottom of the photograph, as closely as possible to the winding so that the G.R.C. variometer used may fit in closely, as shown in Fig. 29.

The arrangements of the components in the cabinet and the method of wiring shown in the photographs should be



CONDENSER WIRING

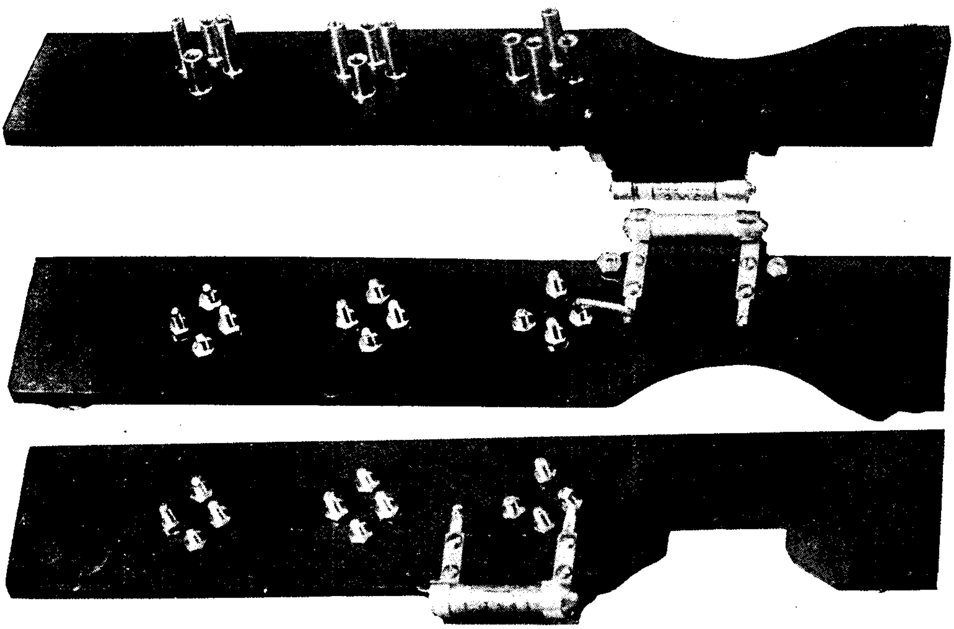
Fig. 31. Here the leads for the Mansbridge smoothing condenser are in place and the choke coil connected with loud-speaker terminals seen below the rheostat

followed. The sequence of wiring to be adopted can also be followed from the photographs, for, since it is essential that all joints should be well soldered, it will be found difficult to carry out soldering operations unless a definite sequence is followed.

Fig. 26 on the special plate facing page 1696 shows the first L.F. transformer being placed in position. Fig. 30 shows rheostat and battery plug connexions, and Fig. 31 the choke coil and smoothing condenser, which are connected across the loud-speaker terminals in the manner shown in shown in Fig. 32. The wiring under the valve shelf is displayed in Fig. 33.

It will be noticed that the grid and plate sockets are cut shorter than the filament sockets by ¼ in.; this is a safety device which ensures that the filament legs go into their right sockets before they have any chance of touching the high-tension-carrying plate or grid sockets.

The grid condenser, with its leak, is fitted underneath the shelf as shown, one terminal being connected to the grid by an extremely short lead (Fig. 32). An alternative position for the grid condenser



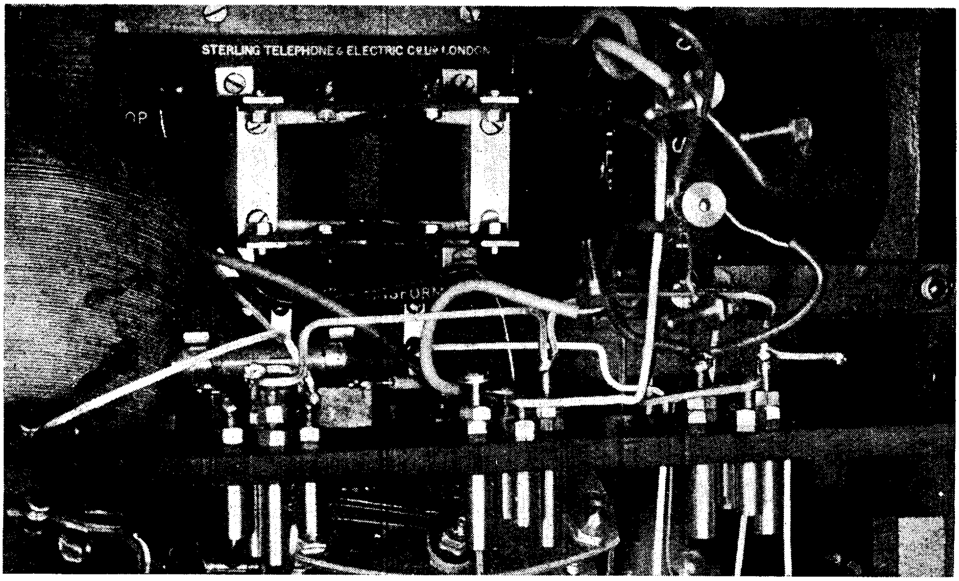
VALVE SHELF, SHOWING DISPOSITION OF HOLDERS

Fig. 32. The valve shelf is cut from ¼ in. ebonite; the top and under sides are shown above with grid condenser and leak in position. An alternative position for the grid condenser is shown in the lowest photograph, which depicts the valve shelf cut to allow it to be mounted higher in the cabinet

the circuit diagram, Fig. 19. All the components shown in Figs. 25 to 31 are at the back of the cabinet, and must be connected up while they are still accessible. Heavy gauge square-section tinned copper wire is used. Systoflex covering is not desirable on the receiving side, but may be used in the L.F. portion.

Fig. 27 shows the wiring complete at this stage. The aerial tuning condenser may now be fitted as shown in Fig. 24. It is seen in position in Fig. 28. The next step is to make the valve shelf. This is cut out of ¼ in. matted ebonite, 2 in. wide, and is fitted with three sets of valve sockets. The top and under sides are is seen at the bottom of Fig. 32, which also shows how the valve shelf is cut out to fit into the terminal plate of the variometer.

In Fig. 28 the wiring is complete, and the tuning condenser, valve shelf and second L.F. transformer are all in position. Between the transformer and the inductance coil is a case containing grid-biasing batteries, the construction of which is clearly shown in Fig. 34. Internal dimensions of the case are 2¾ in. wide by 2⅛ in. high and 2⅝ in. deep. It holds four small flash-light batteries, which are coupled together by soldering short wires across their negative and positive strips, with a cut-

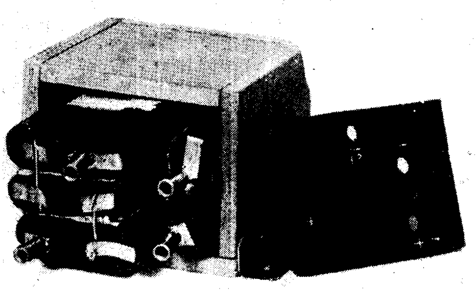


CONNEXIONS UNDER THE VALVE SHELF

Fig. 33. The grid batteries are removed to show the connexions under the valve shelf. Notice the disposition of the two transformers; they are farther apart than the photograph suggests

down valve socket at each end to provide means of tapping. The number of taps made depends upon the amount of negative bias required for the L.F. valves used. In the case of the set illustrated the second valve is a small power valve, a Marconi L.S.2, taking from 200 to 300 volts on the plate and working well with about 13 volts negative bias. The first L.F. valve is a Mullard R type, taking up to 4 volts bias. Potentiometer control can be added if required.

The high-frequency and detecting valve and the first low-frequency valve require from 60 to 100 volts high tension, whereas the third valve requires up to 200 volts. The positive tappings are therefore taken from the high-tension battery as indicated



GRID-BIASING BATTERIES

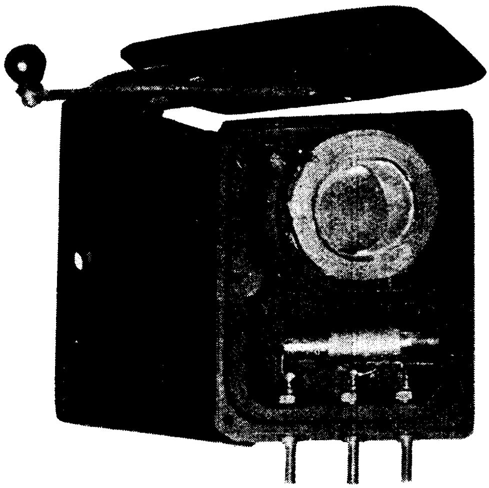
Fig. 34. Tapping is effected by cut-down valve sockets. Note the shaped case and ebonite top

in the circuit diagram (Fig. 19). The battery leads therefore number five in all, and are soldered to the four legs of the valve-holder plug—the low-tension positive and high-tension negative being soldered to one leg, high-tension 70 volt tap to another, 200 volt tap to a third, and low-tension negative to the fourth. It is desirable to use different-coloured wires for all five leads, and to scratch on the valve-holder abbreviated descriptions (thus—H.T. 70) to avoid risk of confusion when soldering leads to the corresponding legs on the bracket inside the cabinet. The method of making this battery plug is described under the heading Chatterton's Compound.—*S. G. Stubbs.*

REGENERATOR UNIT. Term used to describe a device which can be applied to a receiving set to vary or to provide a measure of regeneration.

A regenerator unit of the Marconiphone is illustrated. It will be seen that it consists of a rectangular moulded ebonite case having three pin contacts fitted at the bottom. These plug into the Marconiphone, and enable different units for different wave-lengths to be quickly changed. The handle on the right is used for varying the amount of reaction as required.

In the picture the internal arrangements are clearly shown. At the bottom, above

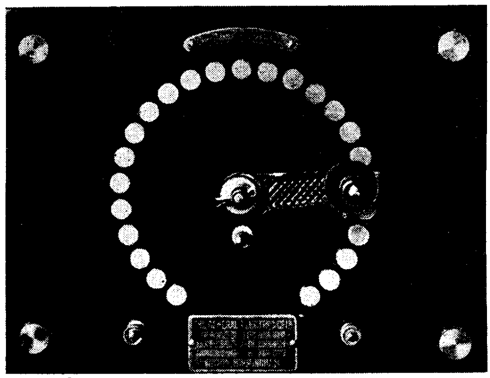


REGENERATOR UNIT
A fixed condenser is seen above the three contact pins. Beside it is a honeycomb inductance wound over a mica-covered brass tube
Courtesy Marconi's Wireless Telegraph Co., Ltd.

the contact pins, is a fixed condenser. This is of the type in which tinned copper wire is wound over a mica-covered brass tube. Below this, and held in a moulded recess in the cover, is a honeycomb-wound inductance of the required value for the particular wave-length. The inductive value of this coil is varied by means of the metal disk shown attached to the handle. This type of coupling is standard throughout the Marconiphone range, and has the advantage of extreme simplicity and absence of body capacity effects. *See* Marconiphone.

REGULATOR, FIELD. A variable resistance regulating power supplied to field magnets, and so controlling the speed of the machine in the case of a motor.

The field regulator illustrated is mounted upon a polished slate base of about $\frac{7}{8}$ in. in thickness. The studs shown are connected to a number of resistance coils mounted at the rear of the regulator. Contact upon the studs is effected by a movable arm rotating upon a spindle placed at the centre. This arm is fitted with a laminated spring blade. It is readily detachable by removal of the split-pin shown. A stop is provided which prevents the switch arm from running off the end studs. Connexion to other apparatus is effected by the terminals near the bottom edge of the board on either side of the name plate. *See* Field Regulator.



FIELD REGULATOR
Contact is effected by a movable arm fitted with a laminated spring blade. The connecting terminals are seen below
Courtesy General Electric Co., Ltd.

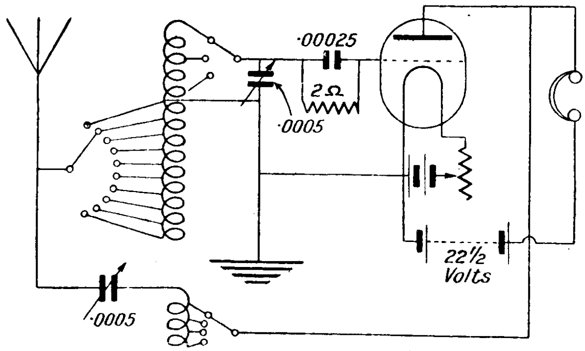
REINARZ CIRCUIT: ITS ADVANTAGES AND USE

How to Build a One-Valve Set for C.W. and Telephone Work

This is a very important circuit on the regenerative principle, and gives excellent results on one valve. Its description should be read in conjunction with the articles under such headings as Armstrong Receiver; Reflex Circuit; Regenerative Circuit. See also Cabinet; Coil, and cognate headings

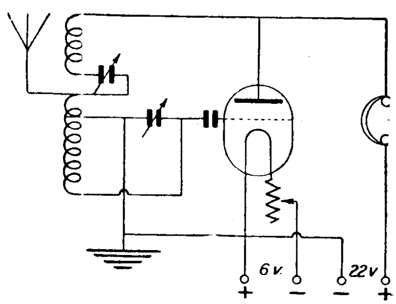
The Reinarz circuit, named after its inventor, is of the regenerative type, with magnetic reaction on to the aerial. It is very efficient for the reception of C.W. signals. Stations operating on this method of transmission can be tuned readily, and the signals held without material change in signal strength. On this class of work it is capable of reception over very considerable distances.

The reason for this is probably the ease with which the set will oscillate. The circuit of the Reinarz receiver is given in Fig. 1, and comprises two inductance coils, both wound on a single tubular former. A small space is left between the two windings, and both are tapped. A variable condenser is connected in series with the aerial and the anode coil, and another across the aerial inductance. The series anode condenser is preferably of the vernier type. Any ordinary detector valve can be used with this set, and the high- and low-tension battery voltages arranged to suit.



ORIGINAL REINARZ CIRCUIT

Fig. 1. Two inductance coils, both wound on one former, are employed. A variable condenser is connected in series with aerial and anode coils, and one across the aerial inductance



WIRING DIAGRAM OF SET

Fig. 2. Wiring diagram of the set shown in Fig. 3. Note the separate tap of first inductance leading to grid condenser and on to the grid of the valve

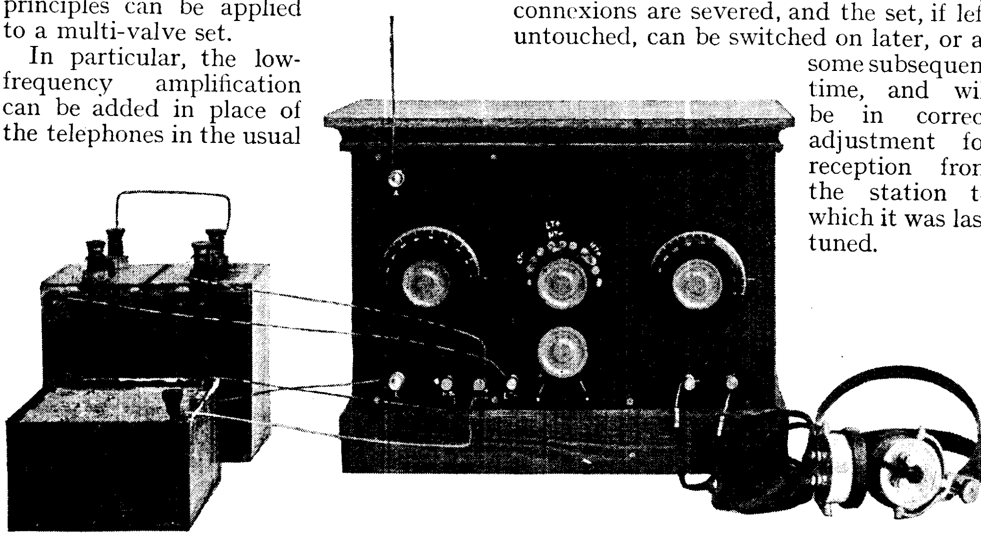
The Reinarz circuit gives good results in reception of ordinary telephone transmission, but is not such a notable performer in this respect as it is for continuous wave reception.

The construction of a simple Reinarz set is a pleasing variation to the ordinary run of sets built up by the amateur experimenter. The original Reinarz circuit called for several inductance switches and tapped inductances, which rather added to the complications of the outfit. In the present arrangement the circuit has been simplified while retaining the normal characteristic of this class of receiver. A single valve receiving set is illustrated, but it will be appreciated that the same principles can be applied to a multi-valve set.

In particular, the low-frequency amplification can be added in place of the telephones in the usual way. The appearance of the amateur-made set when completed is shown in Fig. 3, and from this it will be seen that the controls comprise two variable condensers and the filament rheostat. Consequently there is nothing very difficult about the construction.

A feature incorporated in the present design is the use of a multi-purpose switch located between the two condenser control knobs. This switch is provided to enable the high- and low-tension circuit to be cut off or switched on at will, as by so doing the set need not be altered in adjustment at the conclusion of the evening's reception.

By merely turning the switch from one side to the other, the whole of the battery connexions are severed, and the set, if left untouched, can be switched on later, or at some subsequent time, and will be in correct adjustment for reception from the station to which it was last tuned.

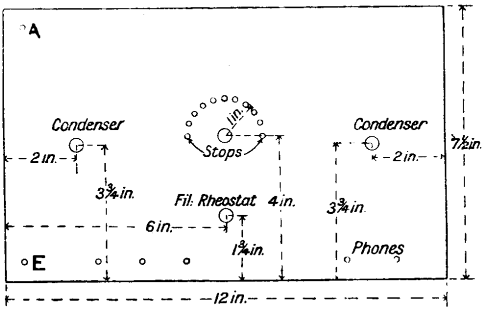


COMPLETE REINARZ REGENERATIVE RECEIVING SET

Fig. 3. It will be observed that the appearance of the set is quite conventional; the panel shows the normal condensers, contact switch and rheostat. This one-valve set gives excellent C.W. reception

The circuit diagram of the set is given in Fig. 2, from which it will be seen that a wire is taken from the aerial terminal to the inductance coil and also from the variable condenser to the second inductance coil, and thence to the plate or anode and the telephones. The lower end of the first inductance coil connects to the grid condenser and so to the grid of the valve.

A separate tap is taken from this inductance, and coupled by means of a second variable condenser to the grid leak lead and a wire taken from it to the same tapping of the inductance to earth. The remainder of the connexions are similar to those of an ordinary single-valve receiver.



DIMENSIONS OF THE PANEL

Fig. 4. Here is given the lay-out of the panel, with the measurements and relative disposition of the component parts

The next step is to prepare the panel. This should measure 12 in. in length and 7½ in. in width, and be made from high-grade ebonite, bakelite or some other insulating material, or, if preferred, components can be used which are adapted for mounting on a wooden panel. In the latter case the necessary alterations to the dimensions will have to be made to suit them.

After the panel has been marked out in accordance with the dimensions given in Fig. 4, a separate small ebonite plate should be prepared to support the valve holder, which is preferably of the flanged pattern. This plate, when prepared, is subsequently mounted on the back centre part of the panel and projects from it at right angles.

At this stage it would be best to prepare the case. This is illustrated in Fig. 6. It can readily be constructed along the lines described under the heading Cabinets. The best materials to use are good grade mahogany, walnut or oak, but if their expense is prohibitive, commercial building deal can be used and the exterior finished by staining to any desired colour and polishing or varnishing.

The case is practically a small rectangular wooden box with fixed back, sides, top and bottom. The upper part is ornamented by a moulding and the aperture closed by an upper piece, which may be of three-ply wood recessed into the moulding; the bottom of the case is surrounded by a simple plinth with a chamfered or moulded edge. The panel is simply screwed to fillets glued and pinned around the front of the case with their front faces set about ⅜ in. in front of the edge of the case.

As the whole of the components are mounted on the back of the panel, if it is desired at any time to have access to the valve or any of the components, all that is necessary is the withdrawal of four small screws, when the panel and all the components can be lifted bodily out of the case.

The panel should be carefully fitted in the opening in front of the case, and when all is correct, the construction of the various components and their assembly should be put in hand. The condensers, of which two are required, to the value of ·0005 and ·0003 mfd. respectively, may be any good quality commercial components, or may be constructed from separate parts, as described under the headings Air Condenser and Condensers. If commercial condensers are used, those with a single central fixing are to be preferred, as it is then only necessary to drill one hole through the panel and clamp the condenser in place with a central lock nut.

After the condensers have been fixed in place, they can quickly be removed at any stage of the work by undoing this one nut in each case and removing them, this being of convenience during some of the wiring operations. The filament resistance should be of good quality, and have a value appropriate to the valve which it is intended to use. Any ordinary hard valve appears to give satisfactory results. The resistance is mounted on the centre lower part of the panel and the valve panel screwed in place immediately beneath it.

The valve holder should then have four connecting wires, preferably of the square tinned copper bus-bar type, soldered to the four projecting pins, and be secured to the panel with three brass screws passed through the holes in the flange and tapped into the valve panel. One of these screws

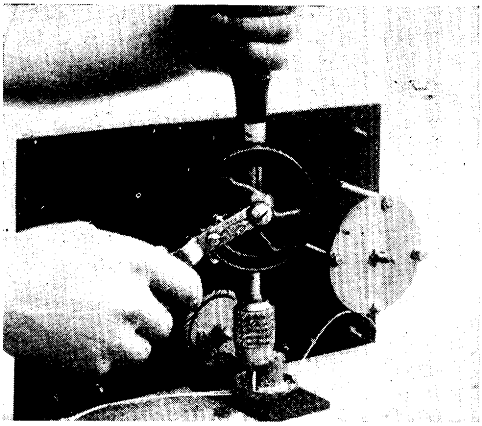


Fig. 5. One screw should be fixed first and the holes for the others drilled afterwards, to ensure alinement when the valve holder is fitted

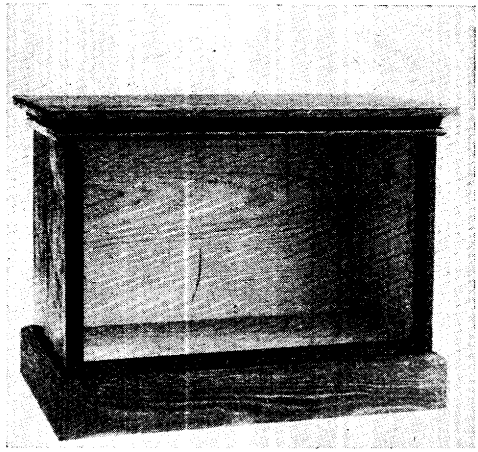


Fig. 6. Walnut or mahogany make excellent materials from which to construct the case for the Reinarz regenerative set

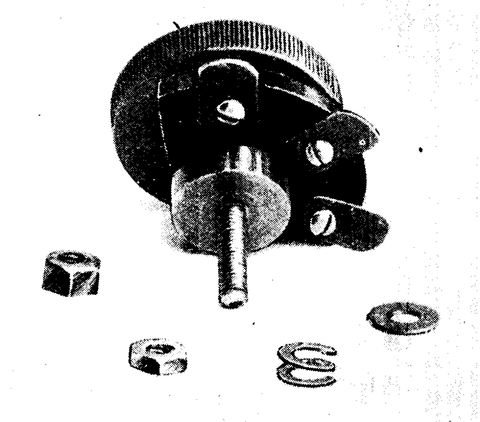


Fig. 7. Underside of the special battery switch, showing contact pieces

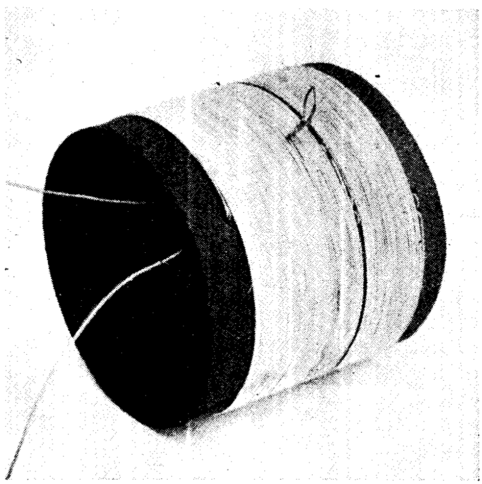


Fig. 8. The loop of the earth tapping of the combined tuning and anode inductance is shown

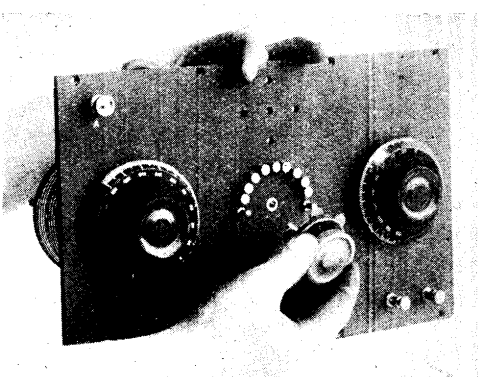


Fig. 9. Here is shown the assembling of the three-contact switch for the batteries

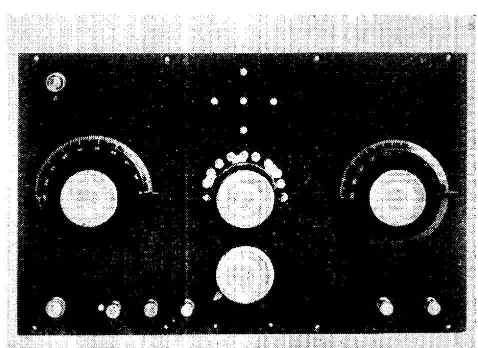


Fig. 10. The mounted panel, showing the special battery switch turned to the left

COMPONENTS IN DIFFERENT STAGES OF ASSEMBLY should be fixed first and the drill be used through the other holes in the flange, thus ensuring proper alinement. This process is illustrated in Fig. 5.

The next step is to make the special battery switch, the underside view of which is given in Fig. 7. This consists of an ordinary ebonite knob with standard screwed brass rod for a spindle. A quadrant-shaped plate of ebonite is then prepared and attached to the underside of the knob by means of a large circular brass lock nut. The spindle should be provided with a brass bush securely fixed into the panel, and the customary spring washer and lock nuts employed for maintaining contact between the brushes and the contact studs.

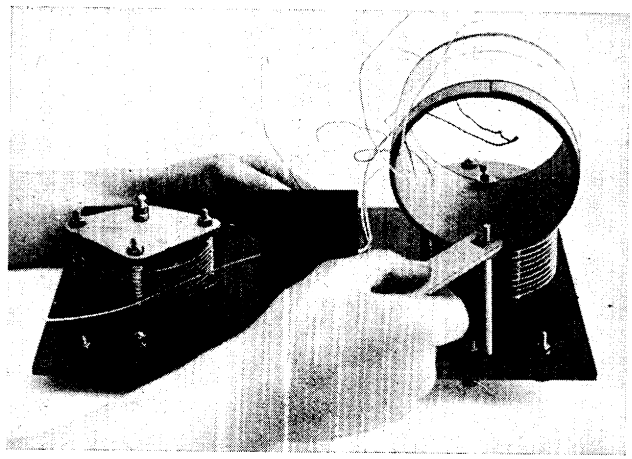
The brushes, of which there are three, are secured by screws to the underside of the ebonite quadrant, as is clearly visible in Fig. 7. These brushes project beyond the edge of the quadrant, and their width is such that they just span the distance between any two of the contact studs. The latter, of which there are nine, and two special stops, should then be assembled in their places on the panel and the switch put into position, as shown in Fig. 9.

It will then be seen that by turning it to the left, the three contact brushes will make contact with the first two of each group of three studs. By turning it to the right, the brushes will make contact with two others of each of the three groups of studs, this being more clearly visible in Fig. 10, which shows the switch turned to the left. The spring washer and lock nut should be carefully adjusted, as should the contact brushes, until the three of them make perfect contact in either position, a result best achieved by making the spindle a good fit in the bush, and the latter at least $\frac{3}{4}$ in. in length.

The next step is to prepare the inductance. This may be wound on an ebonite or cardboard former $3\frac{1}{2}$ in. in diameter and $3\frac{1}{2}$ in. in length. The winding is carried out with No. 24 D.C.C. wire, and the one former contains both of the coils. The plate or anode winding has first to be wound, and starts at a short distance from the edge of the tube. There are 24 turns in this coil. After making these turns, the end of the wire is passed through two holes and made fast in the usual way, and a sufficient length of surplus should be left over for connexion purposes, say about 12 in. The winding of such coils is fully explained under the heading Coils.

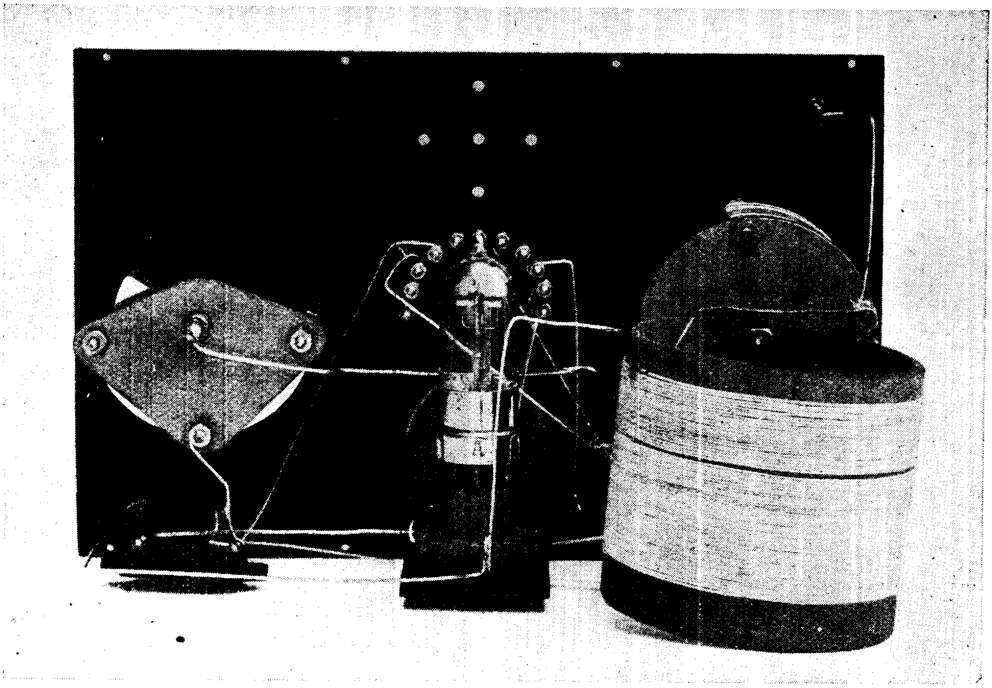
The tuning inductance is then started close up to the anode winding, and is wound with the same gauge wire and also in the same direction. Ten turns are taken, and then a tapping is made by making a loop in the wire in the ordinary way, as shown in Fig. 8. This tap is for the earth connexion. The same wire is continued from this point for 35 more turns, making 45 in all in the inductance winding, which should be one continuous winding from commencement to finish, with the single tap at 10 turns from the commencement. The ends of the wires are finished in the ordinary way.

The next step is to mount the inductance, which may be accomplished by making a special long brass pillar, tapping it into the panel and providing the upper end with a screw thread and two lock nuts. This pillar should be in line with one of the nuts on the condenser, such as the centre spindle nut or one of the side pillars. Two holes are drilled through the inductance former, the latter slipped over



FITTING THE INDUCTANCE

Fig. 11. A long brass pillar is fixed on the back of the panel: this, together with the bottom of the condenser, supports the inductance. Lock nuts on the pillar and condenser hold the coil firmly in its position



PRIMARY STAGES IN THE WIRING

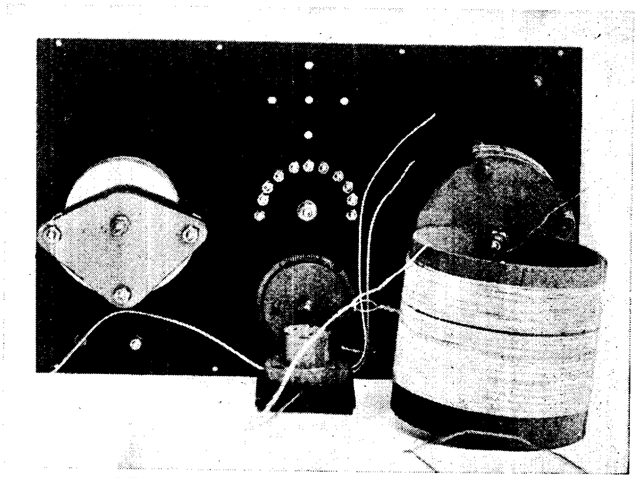
Fig. 12. The unusual simplicity of the wiring is well shown here. It will be found that square tinned copper wire is the best to use, as it makes very neat soldered connexions

the ends of the pillars and secured with lock nuts, as shown in Fig. 11. This is quite an effective way of mounting the inductance, and also facilitates the wiring, which is the next operation. The appearance of the set at this stage is shown in Fig. 13.

The wiring should be carried out in progressive order, commencing with the switch. A wire is taken from the high-tension positive terminal on the panel to the second stud on the switch; another from the low-tension positive terminal to the fifth stud, and a third from the low-tension negative terminal to the eighth stud. The stud on the left of each of those on which the wire is put is left blank, and the stud on the right is counted as if it were a terminal for the battery connexions. To avoid confusion, these studs should be clearly marked.

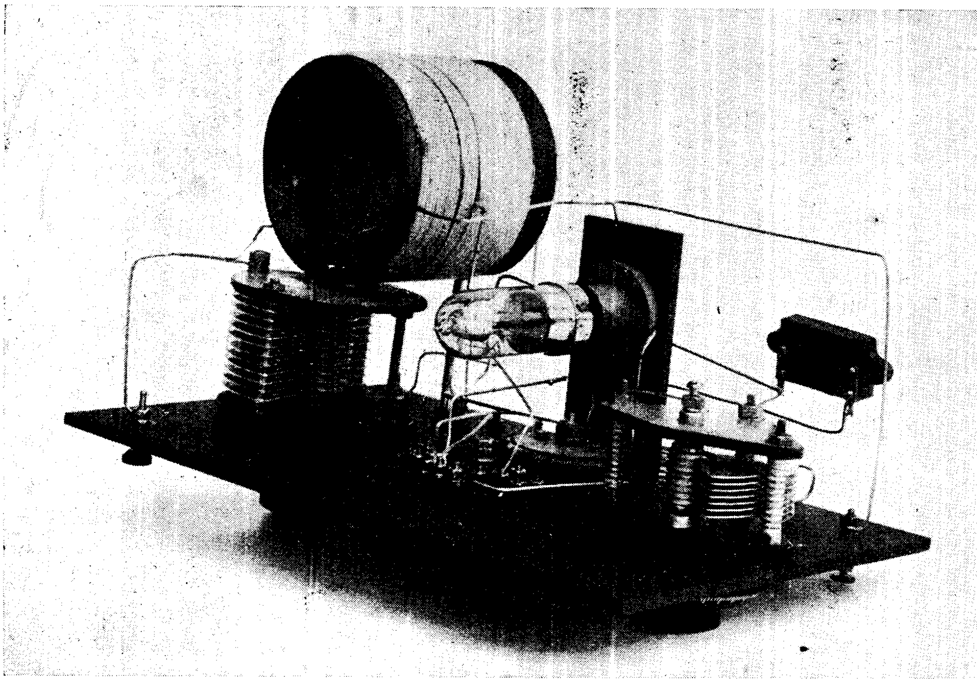
A wire should then be taken from the aerial terminal and connected to the commencing end of the inductance winding, and from this terminal a connexion is taken to one side of the anode condenser.

The tap on the inductance coil is to be



BEFORE THE WIRING IS COMPLETE

Fig. 13. The back of the panel after the inductance coil, condensers, rheostat, etc., have been mounted in their proper positions

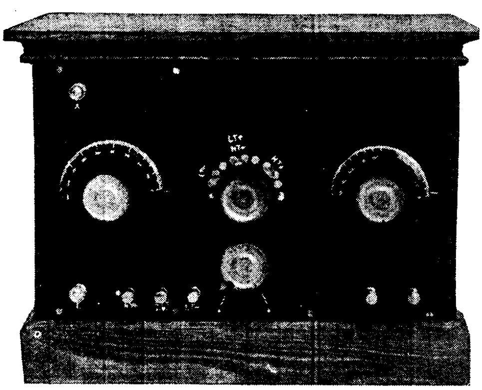


THE WIRING OF THE REINARZ RECEIVER COMPLETED

Fig. 14. All connexions having been made, and the valves having been fixed in place, the set is now ready for placing in position in the enclosing case

connected to one side of the other condenser, and also to the earth terminal. The lower or last turn of the inductance coil is connected to the other side of the aerial tuning condenser, and thence through the grid condenser to the grid terminal of the valve.

The two ends of the anode inductance are connected respectively to the anode tuning condenser and the anode terminal of the valve holder. Two leads are taken from the positive and negative sides of the low-tension battery to the filament resistance and filament terminal of the valve holder in the usual way. The telephone terminals are connected by a wire from the positive side of the high-tension switch stud, and also to the anode terminal of the valve holder. The wiring should be carefully carried out, and is shown completed in Fig. 14.



READY FOR USE

Fig. 15. The complete Reinarz set, showing its neat and compact appearance. It is a very simply made receiver

When the wiring is accomplished, the circuit should be tested for electrical continuity and carefully checked over. A valve is inserted into the valve holder, as in Fig. 14, and the panel secured in its place in the case, Fig. 15. Connexions have then to be made to the high- and low-tension batteries and the aerial and earth leads and the telephones attached. The set is then ready for use.

Tuning will be found to be distinctly sharp, and some experience is needed to get the best out of the set. When nicely adjusted, it regenerates well and gives good results. As a preliminary, the right-hand condenser is adjusted for tuning to the required wave-length, the left-hand or smaller condenser is used for control of the regeneration. The set as described tunes over the ordinary wave-length band for broadcast reception, but if required for higher wave-lengths the inductance may be bank wound accordingly.

The only trouble that is likely to occur in handling the set is a slight tendency to oscillate or squeal unless the set is properly adjusted. This can be dealt with in the early stages by placing a low value grid leak across the grid condenser, although this results in loss of signal strength, and is not needed once the operation of the set has been appreciated. Generally, the adjustment of the filament resistance will be found to be fairly critical, but by turning it down slightly, so that the filament is a little below its maximum brightness, it will usually be found to stop any tendency to squeal. The best plan is to tune the set to the required wave-length, and then build up the volume of sound with the regeneration condenser while the filament resistance is turned down, afterwards slightly increasing the brightness of the filament until the maximum signals are heard.—*E. W. Hobbs.*

REJECTOR CIRCUIT. A resonant circuit composed of inductance and capacity in parallel may under certain conditions act as a rejector circuit, and is then precisely opposite in its effects to an acceptor circuit.

If a circuit is considered having inductance L and capacity C in parallel, as in Fig. 1, the current being supplied from an alternator A through connexions of negligible ohmic resistance, the current resulting in the circuit can be arrived at in the following manner. Assume that an alternating voltage is applied at the points *a* and *b*, at a frequency of *f* cycles per second; the current components will resolve themselves as follows:

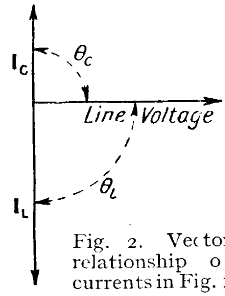


Fig. 2. Vector relationship of currents in Fig. 1

(*a*) A current I_L will flow through the inductance L, to the value of $I_L = \frac{V}{pL}$. This current will be lagging behind the applied voltage V by an angle of θ_L of 90°

(*b*) A current I_C will flow through the condenser C to the value of $I_C = pCV$. This will be leading on the applied voltage V to the extent of an angle θ_C of 90°.

Fig. 2 shows the vector relationship of these currents. The current that will eventually flow from the alternator A therefore must be the difference between the two, since they are 180° out of phase, and the resultant current is that which makes up the difference between I_L and I_C.

Since $I_L = \frac{V}{pL}$ and $I_C = pCV$, also as the resultant current is equal to the difference between the two, the resultant current I amounts to

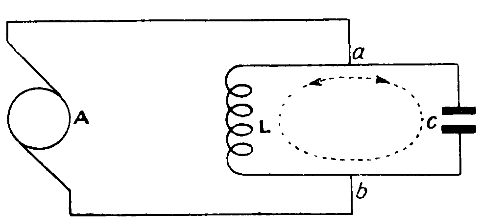
$$I = I_L - I_C = \frac{V}{pL} - pCV = V\left(\frac{1}{pL} - pC\right).$$

The natural frequency of a circuit containing inductance and capacity in parallel will be $f = 2\frac{1}{\pi\sqrt{LC}}$.

If an alternating voltage is applied at resonant frequency to this circuit $\frac{1}{pL}$ will be equal to pC, and therefore

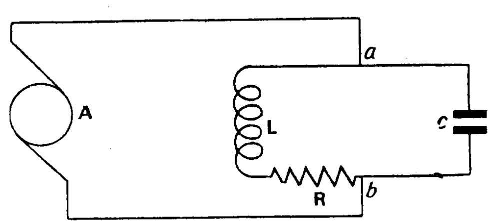
$$\frac{V}{pL} = pCV, \text{ and } I_L = I_C$$

I_L and I_C being equal currents 180° apart, that is, in opposite directions, as shown in the vector diagram, Fig. 2, the resultant current I, which is equal to the difference between the two, will, of course, be zero.



REJECTOR CIRCUIT

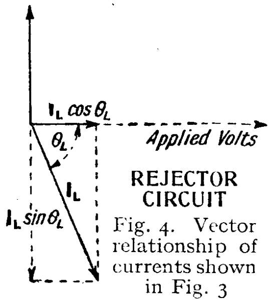
Fig. 1. Resonant rejector circuit. Inductance, L, and capacity, C, are in parallel. Current is supplied from alternator A, giving alternating voltage at *a* and *b*



RESISTANCE EMBODIED

Fig. 3. In series with inductance is a resistance of R ohms, the remainder of the circuit being exactly as in Fig. 1

The foregoing may be stated thus: if an alternating voltage at a resonant frequency is applied to this circuit no current can flow through it, although there may be a large circulating current in the sense indicated by the dotted curved arrows in Fig. 1, and this circulation or oscillation of current set up in the circuit synchronizes exactly with the pulsations of the alternator voltage.



REJECTOR CIRCUIT

Fig. 4. Vector relationship of currents shown in Fig. 3

This circulating current coincides not only in point of time but also in magnitude, so that no current at all can enter the self-contained circulating system from the supply source.

Such cases as the above are only true when the circuit is entirely devoid of ohmic resistance, which, of course, is an impossible condition in practice, although such losses can be kept down to a very small value in an efficient circuit. If, for instance, a circuit is considered, such as shown in Fig. 3, where there is a resistance of R ohms in series with an inductance L, the capacity C and the alternator A being represented as in Fig. 1, the conditions will be as follows:

The current I_L through the branch containing inductance will not now be merely equal to $\frac{V}{pL}$, but to $\frac{V}{Z}$ where the value of Z is $\sqrt{R^2 + (pL)^2}$. Instead of lagging by 90° it will now lag by the angle θ_L, whose tangent $= \frac{X_L}{R}$, whose sine $= \frac{X_L}{Z}$, and whose cosine $= \frac{R}{Z}$, X being the reactance.

The current can now be split up into two components, as in Fig. 4.

(*a*) $I_L \sin\theta_L$, 90° out of phase with the voltage, and which is partially or wholly balanced by I_C according to the circuit being in resonance or otherwise with the applied frequency.

(*b*) $I_L \cos\theta_L$, which is current in phase with the applied voltage, and which will therefore flow through the circuit from the alternator.

Similarly, if there are any resistance losses in the condenser, a current of $L_C \cos\theta_C$ amperes will flow through this circuit.

Both of these currents being in phase with the applied voltage, the total or resultant current will be

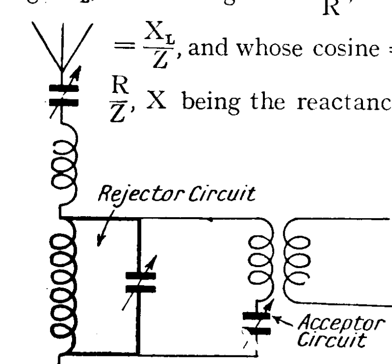
$$I_L \cos\theta_L + I_C \cos\theta_C$$

The greater the resistance in either circuit compared with the reactances of the inductance and the condenser, the greater will these two current components become.

The greater the resistance losses in any rejector circuit the greater will be the resultant current required to maintain the circulating current through the inductance and capacity in parallel.

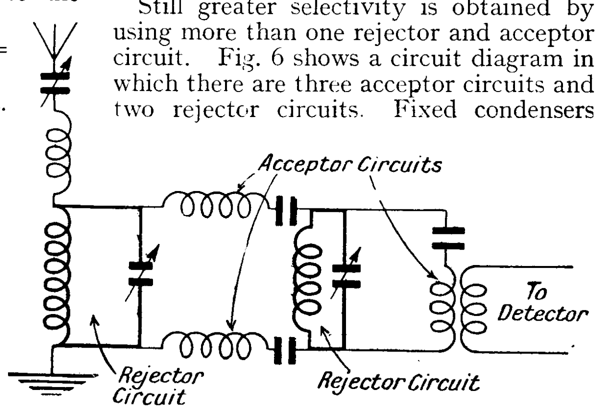
The application of the rejector circuits for the wireless experimenter is, of course, as an interference eliminator. It is a way of obtaining greater selectivity. Fig. 5 shows the principle applied to an ordinary receiving set. The rejector circuit is outlined heavily. The capacity and inductance are connected in shunt with each other and with the acceptor circuit, which is in turn inductively coupled to the receiver or detector. The rejector and acceptor circuits are both tuned to the wave-length of the receiving aerial.

Still greater selectivity is obtained by using more than one rejector and acceptor circuit. Fig. 6 shows a circuit diagram in which there are three acceptor circuits and two rejector circuits. Fixed condensers



APPLIED REJECTOR CIRCUIT

Fig. 5. Shown in heavy line is the rejector circuit as applied to an ordinary wireless receiving set

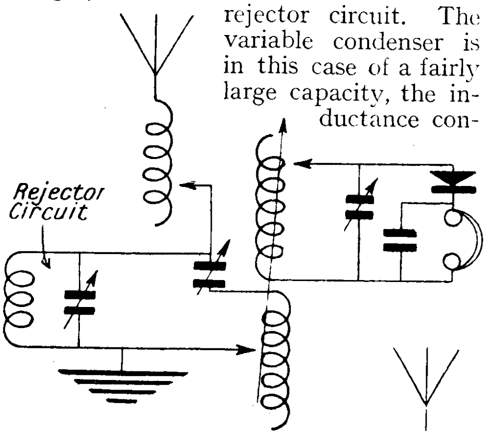


THEORETICAL WIRING OF TWO REJECTORS

Fig. 6. Greater selectivity may be obtained by using more than one rejector circuit. Two are shown here in heavy line

may be used in all cases, of course, but variable condensers give more freedom of control and allow for variations in local conditions. The rejector circuits are shown with variable condensers and the acceptor with fixed, but the latter may be all variable.

Fig. 7 shows another circuit with the rejector circuit. The variable condenser is in this case of a fairly large capacity, the inductance con-



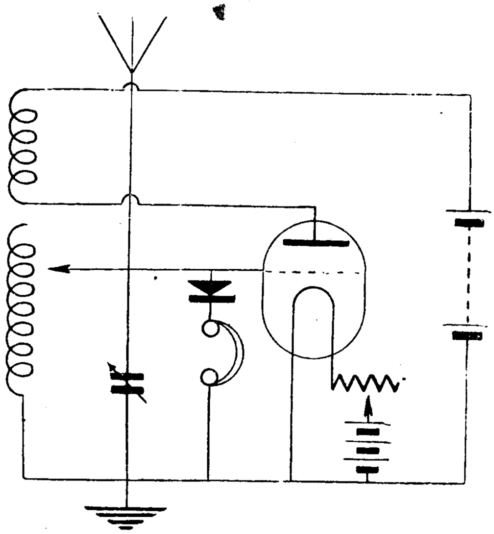
TWO FURTHER CIRCUITS

Fig. 7 (above). In this case the rejector circuit has a large capacity condenser and a small inductance coil. Fig. 8 (right). Theoretical circuit of set in Fig. 10

sisting of a few turns of thick copper wire. The wavelength to which the system is tuned affects the tuned aerial circuit in the ordinary way. But waves of a different frequency and strays pass through the rejector circuit instead of through the coupling coil and to the detector circuit.

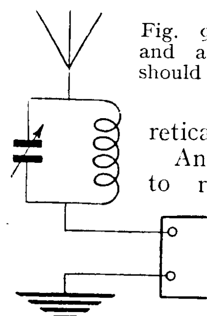
A type of rejector circuit particularly suitable for the elimination of sharply tuned telephony or continuous wave transmissions is shown in Fig. 10. It consists of a tuned circuit comprising a plug-in inductance shunted by a variable condenser.

The unit is placed in series with the aerial and the aerial terminal of the receiving set. For broadcast wavelengths a No. 50 duolateral coil shunted by a condenser of ·0005 mfd. capacity will be found suitable. A theoretical circuit diagram is given in Fig. 8.

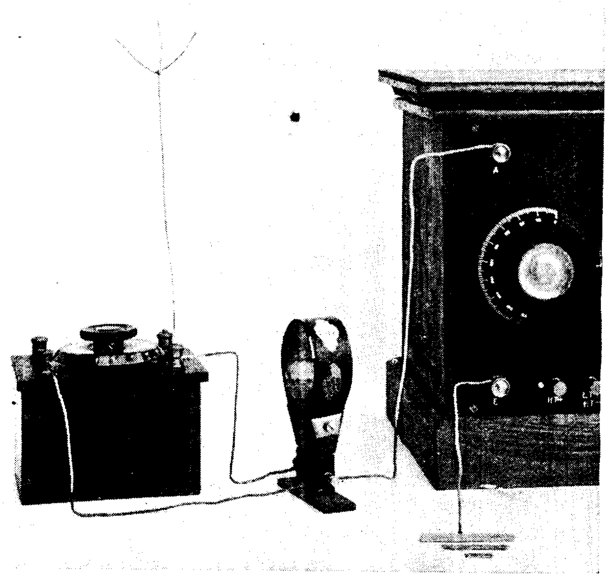


ONE-VALVE SET WITH CRYSTAL

Fig. 9. One valve is used for amplification and a crystal for rectification. The aerial should be placed as far as possible from power lines, at right-angles to them

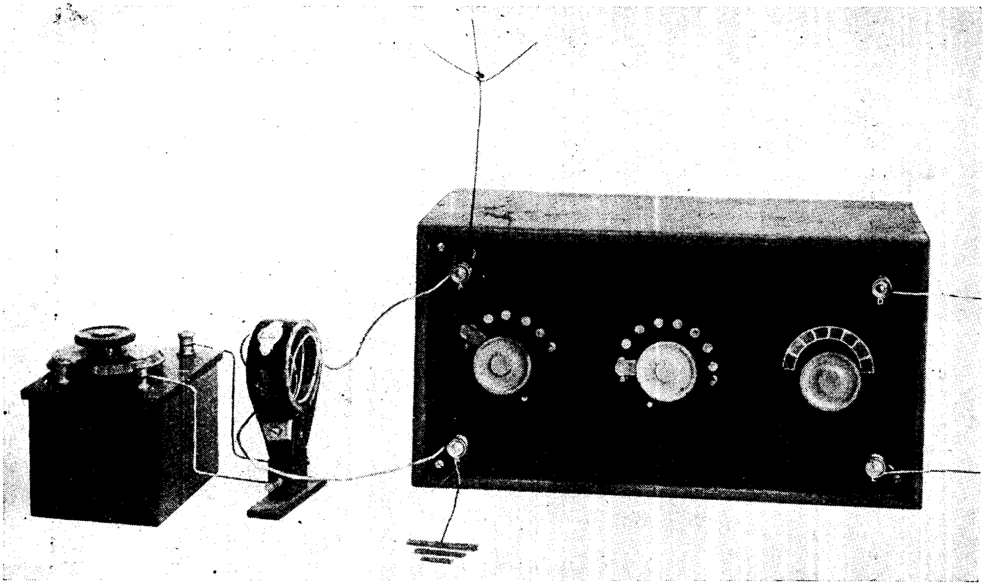


Another rejector circuit, used especially to reject undesired spark signals, is shown in Fig. 11. In this circuit a small inductance of about ten turns is inductively coupled to a closed and tunable circuit



EXPERIMENTAL LAY-OUT

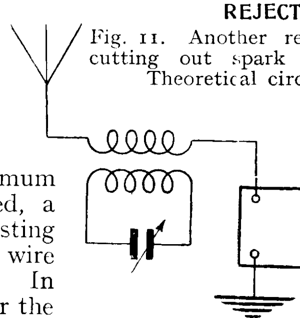
Fig. 10. A duo-lateral coil is employed here; it is shunted by a variable condenser in series with the aerial

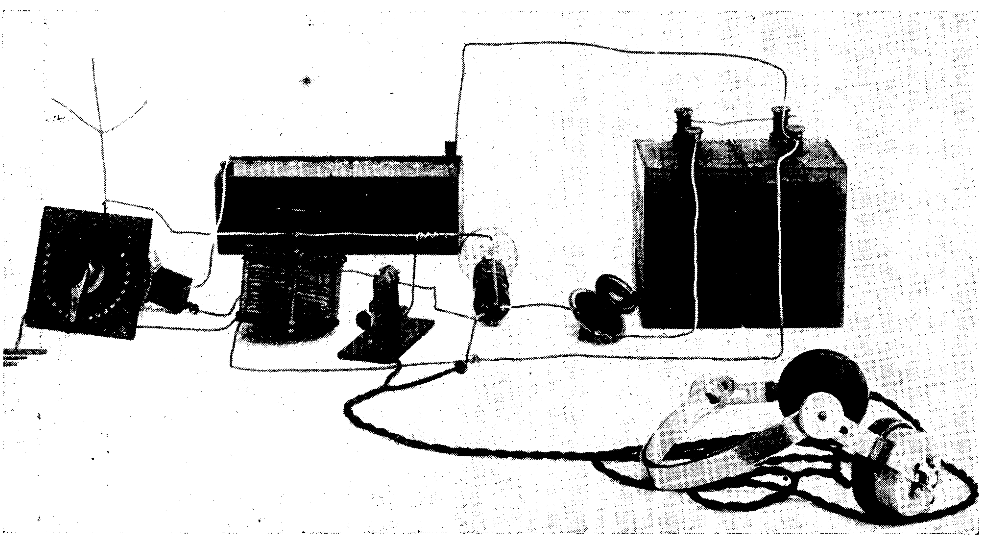


REJECTOR LAY-OUT

Fig. 11. Another rejector circuit useful for cutting out spark stations. Fig. 12 (left). Theoretical circuit of set in Fig. 11

and wired in series with the aerial and the aerial terminal of the set. If a duolateral coil is used in the closed circuit a suitable value for broadcast wave-lengths is a No. 50 Igranic or other similar coil, the aerial coil being placed to offer a maximum inductive coupling to it. If desired, a tubular inductance may be used consisting of about 40 turns of No. 26 gauge wire wound on a 3 in. diameter former. In this case a primary coil is wound over the centre of the coil. A variable condenser of ·0005 mfd. capacity is used in either case for tuning the closed circuit. This circuit is shown theoretically in Fig. 12.





FURTHER USEFUL REJECTOR CIRCUIT

Fig. 13. Where power lines prove to be troublesome, this circuit will be found very efficient in use. Square section tinned copper wire is employed for the connexions

A type of receiving set suitable where interference by induction from power lines is experienced is shown in Fig. 13. The illustration gives a lay-out of the circuit used for this purpose. The aerial tuning is effected by means of a tapped inductance shunted by a low-value condenser. Any suitable method of tuning may be adopted if desired. A theoretical circuit diagram is given in Fig. 9. Rectification is effected with a crystal and the valve used for amplification. To assist the circuit, the aerial should be placed as far as possible away from the power lines and at right angles to them. *See* Atmospherics; Direction Finder; Frame Aerial; Interference Eliminator.

RELAY. A device by means of which the input power is used to control a local source of energy and in which there is no proportional relation between the magnitudes of the controlling and of the controlled powers.

Relays may be described as electrically operated automatic switches. They are employed in almost every field of electrical engineering. Their most general use is for the purpose of making use of a feeble current to actuate one of sufficient magnitude to do an appreciable amount of work.

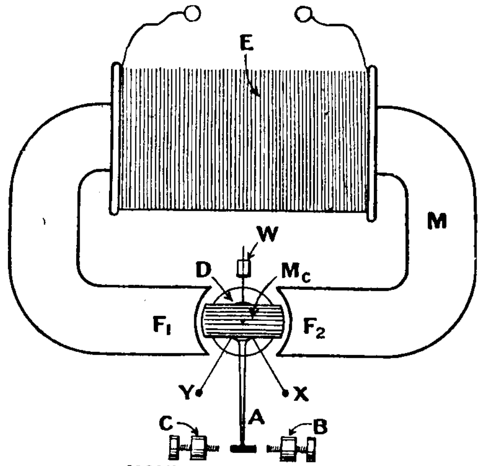
In telegraph work it was soon found that, because of resistance losses in the telegraph wires, the current was so reduced that it would not satisfactorily operate the receiving instruments.

Relays were then installed at points along the line, so that the feeble signal currents coming to the relays should automatically start strong signals along the next section of the line.

The relay is of five general types: (1) Moving coil. (2) Moving iron. (3) Hot wire. (4) Valve relays. (5) Jet relays. There is another, but little-used, type, depending on electrostatic attraction for its action.

The moving coil relay (Fig. 1) consists of a powerful field magnet, M, which may be either of the electro-magnetic type, depending for its field on a current passing through the field coil, or the magnet may be a permanent one made from hard steel and requiring no magnetizing coil.

Placed between the coils of this magnet is a cylinder of iron, D, which reduces the large air gap that would otherwise be present between the two poles, F_1 and F_2. A coil of fine wire M_c is wound on a former and pivoted to D, so that it is



MOVING COIL RELAY

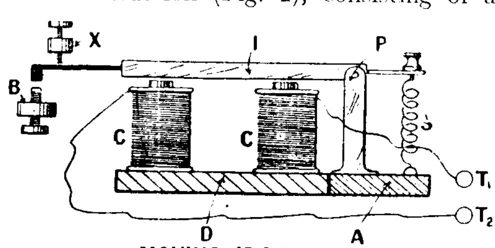
Fig. 1. M is a field magnet; D, an iron cylinder reducing the air gap between poles F1, F2. Round a former is wound the coil M_c, which pivots on D. B and C are contacts

very free to move around D. The two ends of the coil M_c are connected to two very light spiral springs, similar to the hair spring in a watch. These two springs are generally mounted one above and one below the iron core D, and serve to take the current in and out of the coil M_c, and also always to return the coil to the same place after it has once been moved from it.

The coil carries an arm, A, having a balancing weight, W, on one end and contacts on the other. A third spring of flat wire is arranged for leading in the current to the moving arm A.

Now if the field E is excited, and a very small current passed through the coil M_c, the coil M_c will move and close the contact AB or AC, depending on the direction of the current through the coil M_c. The coil will move to the off position the moment no current is flowing in it.

Moving Iron Relays. Moving iron relays are often similar to an electric bell in construction (Fig. 2), consisting of a



MOVING IRON RELAY

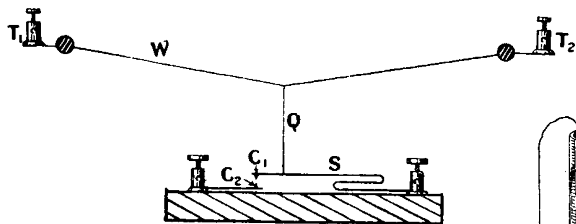
Fig. 2. I is a moving iron armature which makes and breaks the circuit. Moving iron relays are similar in construction to electric bells

moving iron armature, I, kept in the off position by means of the spring, S, which keeps it in contact with the stop, X. The two coils, C, wound on iron cores, form magnets which attract the armature, I, bringing it into contact with B. The armature I is pivoted at P and insulated from D. Current is led into I through the spring S, and out at B, whilst the incoming current to operate the relay is taken to the coils through the terminals, T_1 T_2.

Hot-wire Relays. Hot-wire relays are not generally highly sensitive, but as they depend for their action on the deforming of a metallic wire due to heat, and as the heating of this metal takes time, it follows that they will not be affected by instantaneous currents of small magnitude, but that they will accumulate the effect of many small impulses.

The instrument may be designed to operate over a very big range of conditions; in one extreme case depending on the expansion of a fine wire in a vacuum, and on the other extreme on the bending of heavy compound strips of metal due to the heat transmitted to them by a heating coil.

A non-inductive type of relay is shown in Fig. 3.

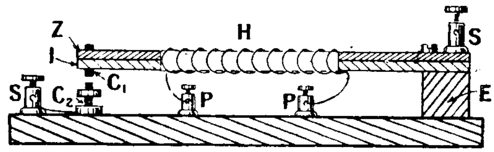


NON-INDUCTIVE RELAY

Fig. 3. Here the wire W expands when current is applied at T_1, T_2, and closes the contacts C_1, C_2 through the thread Q

The stretched wire, W, is soldered to the two terminals, T_1, T_2, whilst a silk or other thread, Q, attached to the wire W and spring S, keeps the contacts C_1 C_2 open. When a current, which may be direct current or alternating of any frequency, including the high frequencies used in wireless telegraphy, passes through the wire W, it will expand and allow the contacts C_1 C_2 to close.

The wire W is generally enclosed in a tube which gives it mechanical protection, as well as keeping it away from moving currents of air which would cool it, and so alter the current at which it would work. The coefficient of expansion of the



THERMAL RELAY

Fig. 4. Two different metals, I and Z, make up the composite bar. These are heated by the coil H, and the contacts C_1, C_2 closed

commoner metals per degree Fahrenheit is as follows:

Zinc ..	·0000163	Brass ..	·0000104
Tin ..	·0000116	Copper	·00000961
Aluminium	·000011	Gold ..	·00000841
Silver ..	·0000108	Iron ..	·0000067

Another convenient form of the thermal relay consists of the compound strip, shown diagrammatically in Fig. 4.

Two different strips of metal, having very different coefficients of expansion, are chosen, such as brass and iron, marked in the figure Z and I. These two strips are soldered together, a contact, C_1, being fixed at one end.

A thin layer of insulation is then wound over the middle, and on this a heating coil of some resistance wire is wound. The strip is then mounted on an insulating base, E, the contacts C_1, C_2 being adjusted so that they are just open.

If a current is now passed through the heating coil, H, from the terminals P, P, the compound strip will be heated, but due to the unequal expansion of the two metals the strip will bend and close the contacts C_1 C_2.

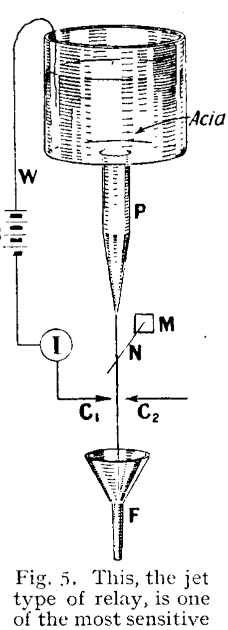
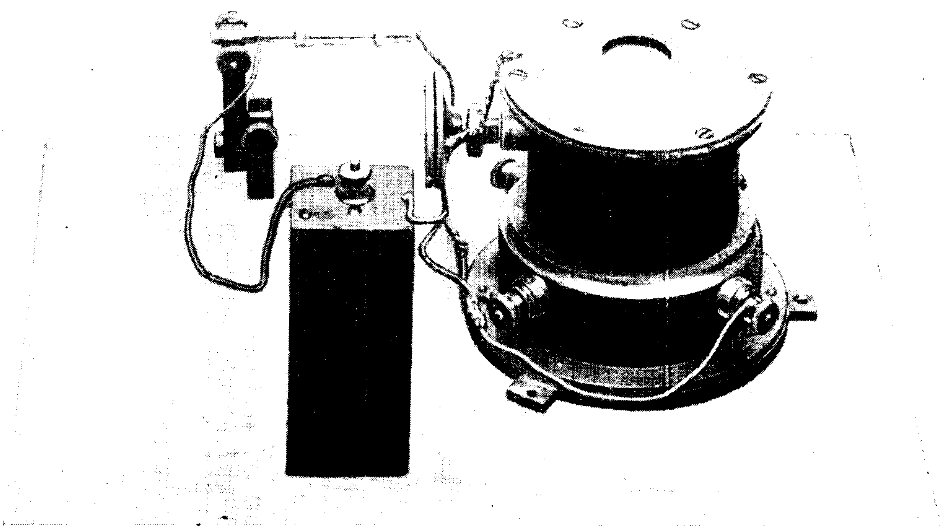


Fig. 5. This, the jet type of relay, is one of the most sensitive forms

Jet Relays. The jet relay, which is the invention of A. Orling, is one of the most sensitive forms of relay (Fig. 5).

P is a glass tube drawn out to a fine point and connected with a tank containing dilute sulphuric acid. The size of the jet hole in P is made such that a very thin but continuous stream of acid will flow from the orifice.



EARLY FORM OF MARCONI RELAY

Fig. 6. The illustration depicts one of the primitive forms of relay connected to one of the original coherers as used by Marconi; the latter is itself in reality a form of relay

C_1 and C_2 are two electrodes which are adjusted till they come quite close to the falling stream without touching it. M is a sensitive moving coil galvanometer, having a pointer, N, which is made knife-edged and adjusted so that it rests in the centre of the falling jet of acid.

It is now found that any microscopic movement of the pointer within the jet will be sufficient to deflect the stream, so that it touches one or other of the electrodes C_1 or C_2.

W is a wire connecting with the acid, B is the local battery, and I the recording instrument.

The circuit B W C_1 I is therefore opened and closed by a movement of the pointer N, although that movement may be far too small to see.

After making the contact the acid falls into the funnel F, and may be pumped back to the tank on the top of P, and used as often as required.

The stream of acid will carry a considerable current, and as the acid is circulated it may be cooled, so a current of micro-amperes in the moving coil instrument M may easily make and break one of several amperes in the local circuit. Another advantage which adds to the sensitiveness of this relay is that it has no contacts to stick because of fusing up.

Marconi Relay. Fig. 6 shows an early form of relay connected to one of the original coherers. A circuit diagram appears in Fig. 7. It will be seen from this that the coherer is connected across aerial and earth. This, in itself, is really a form of relay, for when the filings in the coherer cling together (due to the radio impulses) they close a circuit composed of the battery A and the windings of the relay. The result of this is to close two contacts on the relay, which close a further circuit, also containing a battery, which in turn allows a Morse inker or other recording apparatus to operate. Thus the feeble radio impulses are enabled to operate a machine requiring comparatively heavy currents. *See* Coherer; Hot-wire Ammeter; Moving Coil Instruments; Moving Coil Relay.

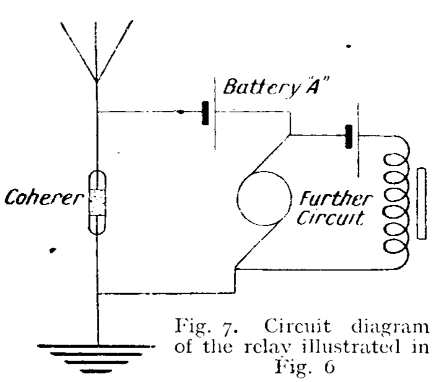


Fig. 7. Circuit diagram of the relay illustrated in Fig. 6

RELAYING FROM BROADCASTING STATIONS

How Music and Speech are Relayed by Land-lines and Wireless Methods

This article gives a brief outline of the methods by which operas, plays, etc., are relayed from one station to another or simultaneously broadcast all over the country. See also Broadcasting; High Frequency; Transmission

The relaying of broadcast matter, either by land-line or wireless, is a branch of wireless science which the British Broadcasting Company has extensively developed. The quite unforeseen difficulties which have had to be surmounted are many, and a comparison between the initial and the present simultaneous transmissions serves to indicate the enormous strides, in so short a time, which have been achieved by the wireless engineers concerned; for practically no previous data existed.

While the transmission of speech at ordinary telephone strength by land-line is a comparatively simple matter, the transmission of music is not, and even speech becomes more difficult when it has to be amplified considerably before and after wireless transmission, for amplification invariably emphasizes any distortion which may have crept in.

Inherent Difficulties in Broadcasting

The chief difficulties in the transmission of any modulated current by land-lines are in combating the inherent effect of inductance and capacity in those lines. Every conductor of any description must necessarily possess inductance and capacity to a greater or less degree, and of the two types of conductor in use, which are respectively underground and overhead, the former possesses the larger amount.

Underground cables have necessarily to be insulated by some solid insulating matter throughout their entire length, and according to the type of insulating medium used depends the amount of self-capacity in the line. Overhead wires, however, are invariably bare, and except at the small points where they are actually suspended on porcelain insulators, air is the only insulating medium. They therefore possess a very small amount of self-capacity, and if it were not for high winds and storms generally, would be almost ideal for the transmission of modulated currents.

It is impossible, unfortunately, to have the entire connexion between two points carried exclusively on bare overhead conductors, and all the land-lines at present being used are a combination of overhead and underground systems.

Storms and high winds have bad effects on all overhead lines, for they cause the lines to swing towards one another, and thus vary the relative amounts of capacity and inductance. Apart from that, messages have been known to have been transferred from one line to another by induction or even actual contact, and on one or two isolated occasions private conversations have been unintentionally transmitted instead of the proper matter.

Effects of Inductance and Capacity

Inductance and capacity both have serious effects in distorting modulated currents, for not only do they tend to alter wave formation, but they have the property of altering the actual frequency. It follows therefore, that as both the pitch and timbre of sounds are dependent upon frequency and wave-formation, the natural inductance and capacity in a line have to be allowed for. To accomplish this end, the receiving apparatus at the termini of the lines are fitted with apparatus, itself possessing inductance and capacity, which alters the received impulses into the same frequency and wave-formation as they were when transmitted. A little consideration will show that the achievement of this end is by no means a simple matter, and indeed was quite impossible until the time when certain definite lines were reserved for the B.B.C., the characteristics of which could be studied and defects corrected at the terminus.

Having outlined the general procedure and difficulties encountered, it is possible to go into the subject in detail and trace the path of the current from the microphone to any one of the distant stations where it is to be transmitted or relayed before being broadcast.

In the first place, Savoy Hill is the exchange for the whole system. From that one place all the lines radiate out to the other stations, and by a jack and plug system installed at the London studio it is possible to pass the current to any other station desired, including 2 LO.

The current, on leaving the microphone, first passes through the speech amplifier.

This consists of a number of stages of low-frequency amplification, in which resistance-capacity coupling is used. The number of stages of amplification used depends entirely on the type of matter being broadcast at the time, and an operator is always present listening to the proceedings who controls the amount of amplification according to his judgement.

From the amplifier the currents pass to the plug-board, where, by the combination of plugs and jacks which has been previously mentioned, connexion is made to any or all of the other transmitting stations. Before actually leaving Savoy Hill, however, the currents pass through one more stage of ordinary power amplification.

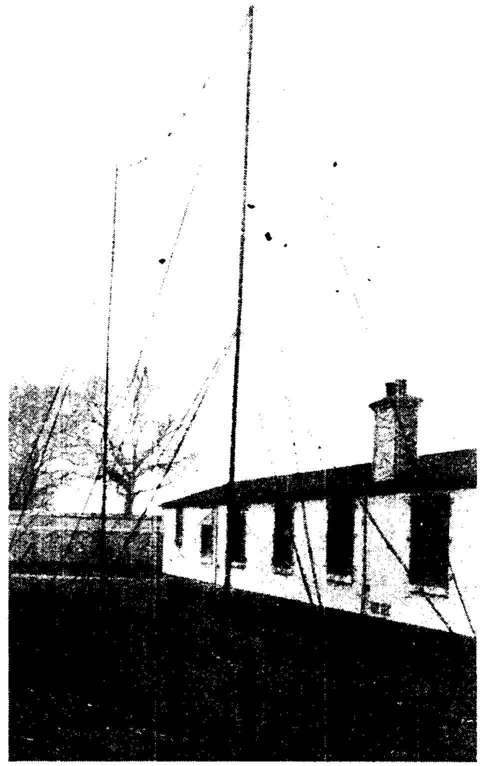
On reaching their destination the currents are again amplified and corrected for land-line losses and variations, after which they are put straight into the transmitter.

The land-lines themselves are the ordinary trunk lines of the G.P.O., but specially reserved for the B.B.C. from 6 p.m. to 6 a.m. Thus at any time during that period of the day a simultaneous broadcast is always possible at a moment's notice.

Up to the present time it is not possible actually to speak to the other stations whilst simultaneous broadcasting is in progress, unless over another line through the usual trunk system, but developments in the art of "wired wireless" (*q.v.*) will undoubtedly enable any desired speech over the same line as the broadcast matter is passing to be accomplished. This will mean an enormous advantage, for the receiving station will be able to inform the transmitter of the quality and strength of the matter being transmitted.

Another development of broadcast relaying is that of the transmission of plays, operas and dance music from the actual place of performance. Briefly, this is accomplished by placing microphones near the source of the sounds, amplifying the microphone current in the building in which the performance is being given, and passing it on to the main amplifier at the nearest broadcasting station. After this it is put into the transmitter, or relayed to the other stations in the ordinary manner.

As an actual example of the arrangements in a theatre, those at Covent Garden Opera House are the best. The first experiments in that building were carried on with four or five Western microphones

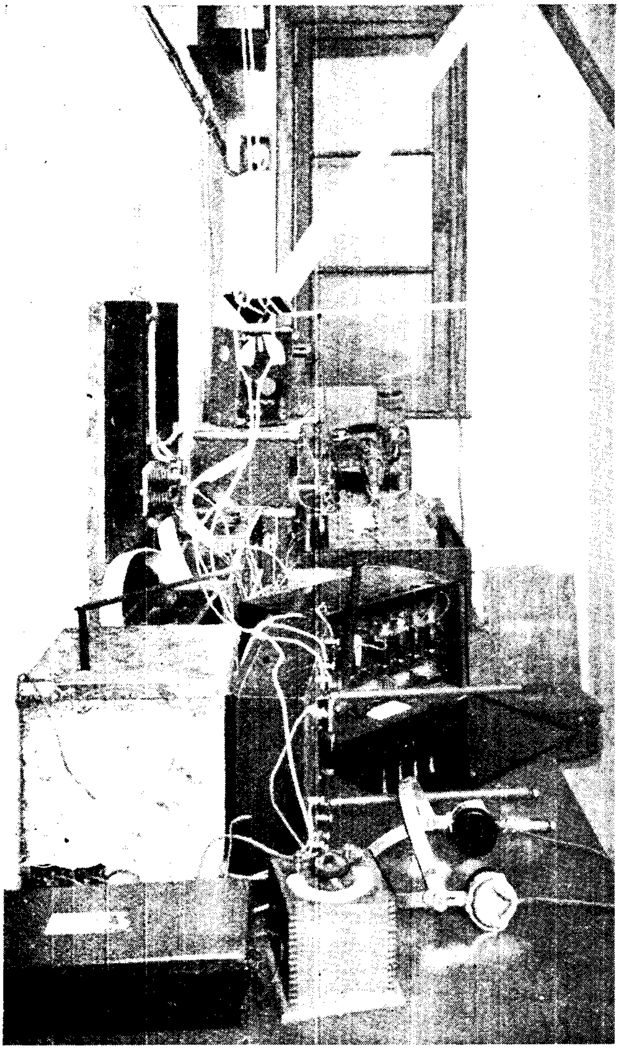


RE-TRANSMISSION OF AMERICAN BROADCAST

Fig. 1. Transmissions from KDKA, the wireless station at Pittsburg, U.S.A., were picked up on this aerial for relaying to London. The station shown is Biggin Hill

placed along the front of the stage, near the footlights. An adjustable amplifier was placed in a room beneath the stage, to which the microphone currents were passed. A member of the B.B.C. staff, who was conversant with the opera being rendered, sat at the amplifier and controlled it according to the position of the singers on the stage. Further, a score of the opera was in front of him, which he followed as the performance proceeded, and by which he was able to control the amplifier so that the loud passages were not too loud, nor the soft passages too soft.

The advent of the new Marconi microphone has altered this procedure somewhat. Only two microphones are now in use. These are placed side by side, in the centre of the front line of the stage, one facing the orchestra and the other the singers. By this means proper "balance" between orchestra and singers has been



THE INTERIOR OF THE BIGGIN HILL STATION

Fig. 2. Here is shown the frame aerial that also picked up Pittsburg. The receiving set has 17 valves, seven of which were used for high frequency

attained. Further, the amplifier control has been reduced in importance, and it is now carried on at the London studio itself, where, by means of a system of "side-tone" the engineer-in-charge is able to give secondary control while listening to the performance and following the score.

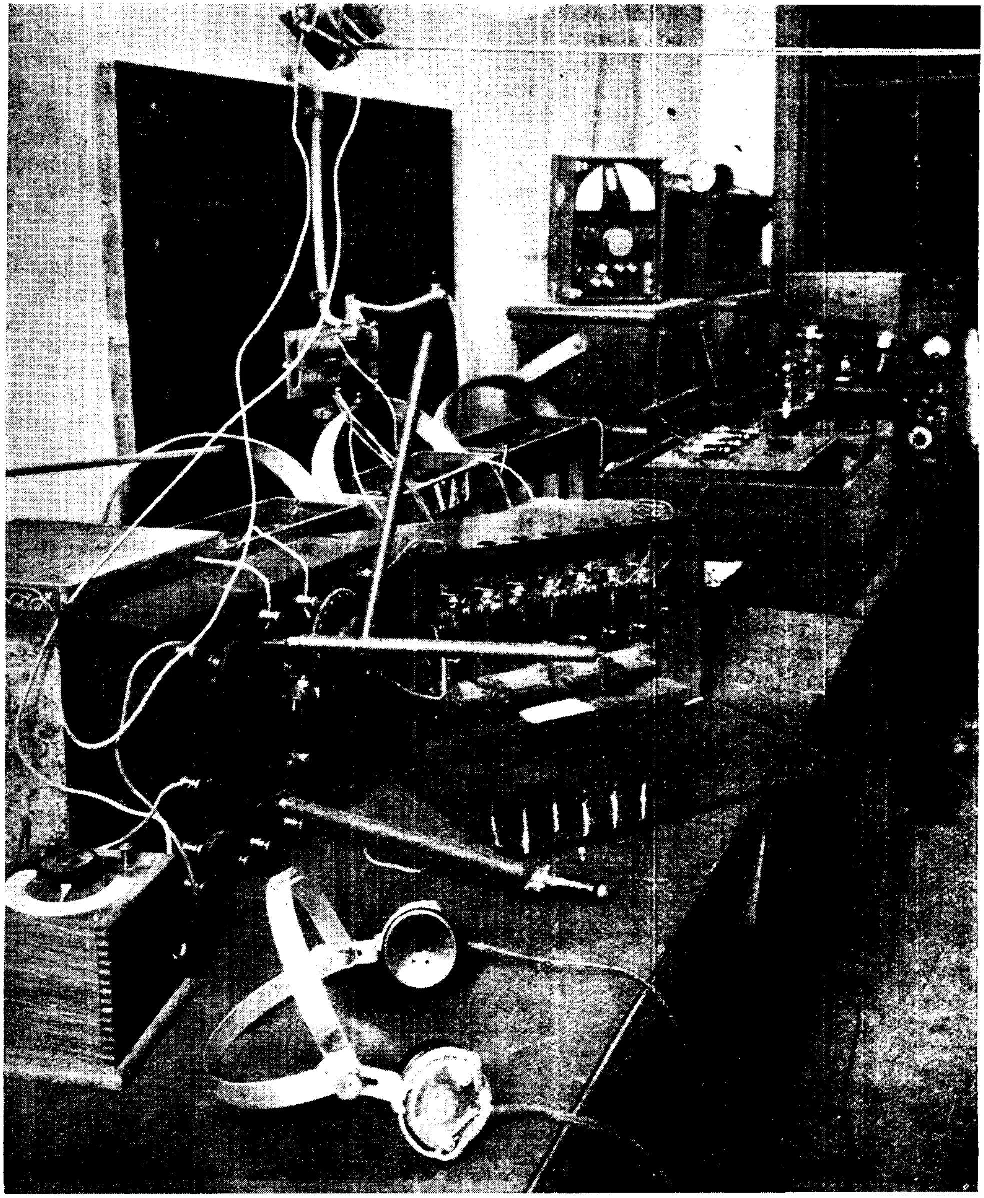
In the Savoy ballroom the microphones, which are of the Western pattern, are suspended over the platform on which the band is playing. No adjustment of amplification is necessary in this instance, for all the players are stationary, and there are not two different sources of sound which have to balance in intensity.

In one instance theatre relaying without any wire link between theatre and broadcasting station has been accomplished. This was at the Old Vic, London, which is situated on the opposite side of the River Thames to the studio, and about one mile away. Unfortunately, no direct cable between the two sides of the river at this point exists, and the shortest possible route would be by an underground cable about nine miles in length, which would distort the speech or music to too great an extent for broadcast transmission.

On this account a wireless transmitting set was made and placed at the Old Vic, where its input was connected to the microphone amplifier. This transmitter was tuned to a very short wave-length to avoid interference either from 2 LO itself or other stations. A special wireless receiver was built for use at the London studio. This is of the supersonic type, employing three valves in the main circuit and one additional valve for the heterodyne. Many wave-lengths had to be tried, for it was found that harmonics of 2 LO and other stations were very troublesome. Further, a considerable amount of absorption was found on certain wave-lengths, so that the many experiments on the correct wave-length were necessary before the final decision was made. Aerials of the single wire type, approximately 25 ft. long and 20 ft. above the roofs of the buildings, were used.

Of the more recent developments in the relaying of wireless messages, those from KDKA, Pittsburg, U.S.A., are the most notable. These transmissions are carried out by arrangement with the Westinghouse Co. of U.S.A. The wave-length on which the transatlantic messages are radiated is 100 metres, and the normal power used is 7 kilowatts.

The receiving set in England is located at Biggin Hill, near Westerham, Kent. Alternative aerials are employed, one being a single cage, with a cage lead-in, about 50 ft. long and 40 ft. high (Fig. 1), and the other a frame (seen in Fig. 2) situated in the hut beside the receiver. Up to the present time no definite set may be said to be used, but as a general rule one having 17 valves (Fig. 3) has been chiefly in service. Of these, seven are usually employed as high-frequency amplifiers. This set is easily capable of receiving the American transmissions, but atmospherics are the chief trouble. Upon the atmospheric conditions depends to a large extent whether the indoor loop aerial



PANELS AT BIGGIN HILL CONTROLLING RECEPTION OF AMERICAN BROADCAST

Fig. 3. Biggin Hill is situated near Westerham, Kent. The installation, which consists of seventeen valves, was experimental, and not of a permanent nature, though the one used has given quite satisfactory results, the only difficulty being the interference due to atmospherics

or the outside aerial is used. When conditions are bad, the former is found to give best results.

More recent experiments have shown that the use of such a large number of high-frequency amplifiers is perhaps undesirable, for they tend to increase the relative strength of the atmospherics compared with the signals. It is quite possible in the near future that only one high-frequency stage will be in use.

Transmission from Biggin Hill to 2 LO is by land-line, and from the latter station it is re-radiated by wireless and transmitted by land-line to the other stations of the B.B.C.

A number of relay stations have been opened in Great Britain, so that listeners-in in the country are not called upon to own powerful sets to pick up their nearest stations, which may be over 50 miles away.

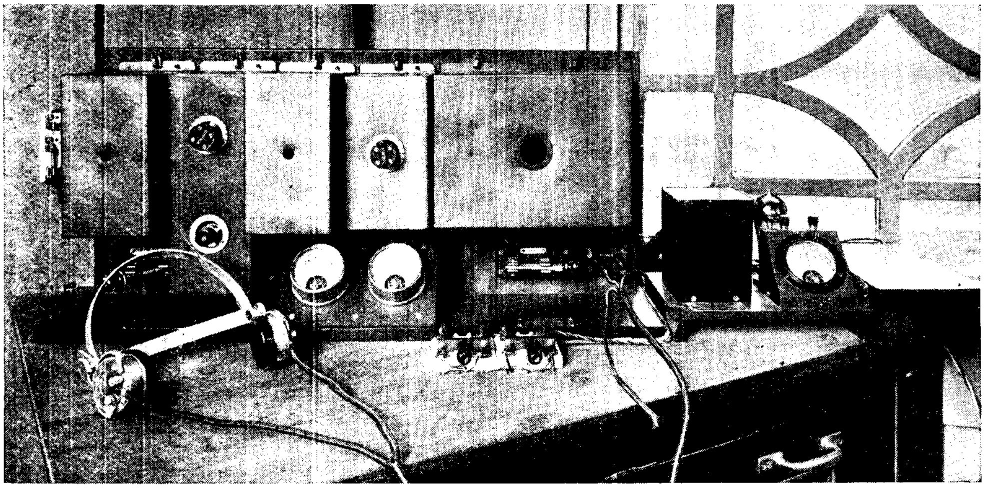
RELAYING at Wembley. The British Broadcasting Company erected a relay station and kindred plant at the British Empire Exhibition at Wembley in 1924. The whole of the plant was arranged within an octagonal kiosk situated above an artificial hill, containing the water reservoir for the Exhibition, which is the highest point on the grounds. The aerial was of the single-wire T-type, and attached to poles fixed to the trunks of two very tall trees. By this means the whole aerial was brought well above the masonry of the Stadium.

The apparatus comprising this installation was designed to allow of the greatest possible latitude in operation, and, further, duplication of all the more vulnerable and less reliable parts of the plant was carried out to ensure absolute freedom from annoyance to listeners from breakdown or other causes.

The object for which the installation was erected was primarily the broadcasting of the King's speech at the opening ceremony. In addition to this, sounds had to be collected from the massed bands (both stationary and while marching), the choirs, and also the speeches of the Prince of Wales and the Bishop of London. Again, loud speakers had to be fed at different points in the Exhibition itself in order to enable all persons present to hear.

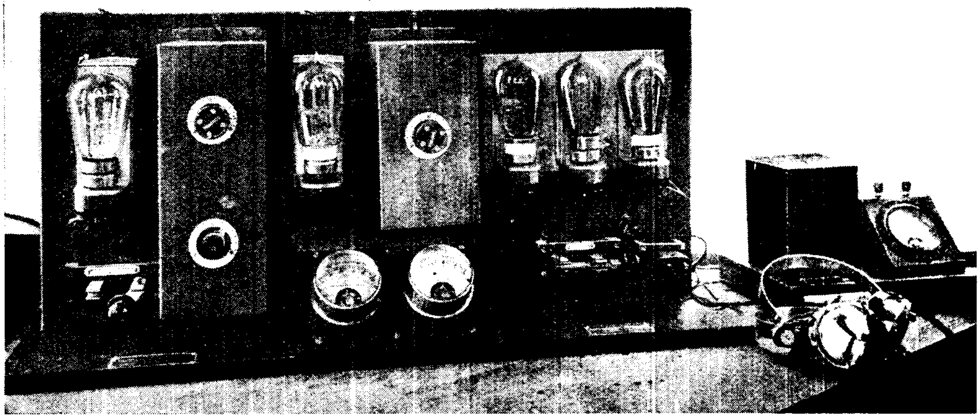
Other considerations followed, and by the apparatus as installed it is possible to transmit anything of account at the Exhibition by land-line or wireless to any of the broadcasting stations for re-radiation, and, further, the reverse is possible, by which any broadcasting station may be connected to Wembley, and the speech or music transmitted there to the public by loud speakers. The latter system is in daily use for the reception of the time signals from Big Ben, which are sent out on loud speakers every quarter of an hour.

The transmitter itself follows the standard arrangements and practice of the B.B.C., except for the fact that it is



BRITISH BROADCASTING COMPANY'S "B" AMPLIFIER AT WEMBLEY

Fig. 1. This is an external view of the "B" amplifier at the B.B.C. kiosk at Wembley. It consists of five stages of resistance-capacity coupled amplification at audio-frequency. The whole apparatus is enclosed in covers made of sheet iron. The valves are mounted on rubber to reduce all shocks due to vibration



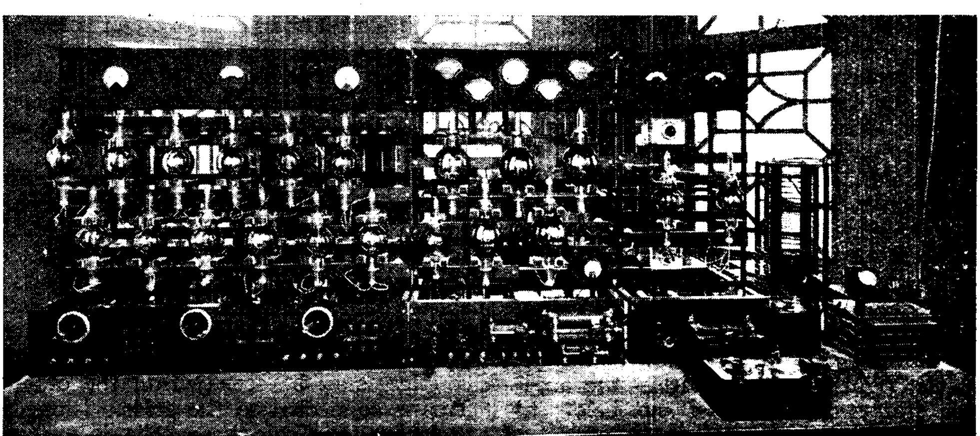
INTERIOR VIEW OF B.B.C. "B" AMPLIFIER AT WEMBLEY

Fig. 2. Covers are here shown removed from the "B" amplifier seen in Fig. 1, and the L.S.5 type valves are seen. It is interesting to note the method of attachment of the valves, which are fixed on thick slabs of "Sorbo" rubber sponge. By this means the effects of vibration are entirely eliminated, the rubber acting as a shock absorber

rated at 600 watts instead of the usual 1,500. Standard Marconi magneto-microphones are used, as are also the standard types of "A" and "B" amplifiers. The "A" amplifier is situated below the main transmitter seen in Fig. 3, and is completely enclosed within a cabinet, being a permanently fixed and uncontrollable unit. In Fig. 1 is shown an external view of the "B" amplifier. This consists of five stages of resistance-capacity coupled amplification at speech frequency. The whole apparatus is enclosed within separate covers made of sheet iron and having quickly detachable fittings. The first, third and fifth boxes contain the valves, which are of the L.S. 5 type. These are shown to advantage in Fig. 2, where the method of attachment may be seen.

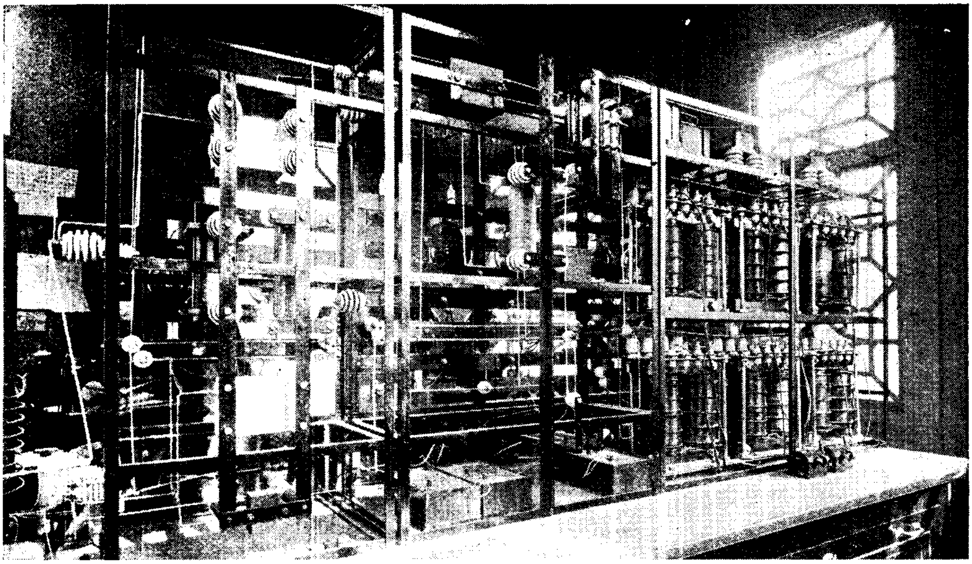
The valves are fixed upon thick slabs of "Sorbo" rubber sponge. This rubber is exceedingly flexible and springy, absorbing within itself any possible vibration which is likely to occur. Thus the valves are shielded from mechanical disturbance, and the amplifier is notably free from any microphonic noises due to vibration.

On the second and fourth panels may be seen the knobs which control the valve filaments. Below the metal cases (which also act as screens from magnetic fields) are the milliammeter and filament



MAIN TRANSMITTER OF THE B.B.C. AT BRITISH EMPIRE EXHIBITION

Fig. 3. Seen from the front the above photograph shows the main transmitter. There is a bank of rectifying valves, twelve in all, arranged in two parallel groups of six each. These are followed by five control valves and one sub-control valve and connected to two oscillator valves



REAR VIEW OF B.B.C. WEMBLEY MAIN TRANSMITTER

Fig. 4. In this view is shown the rear portion of the main transmitter at the B.B.C. kiosk at the British Empire Exhibition, at Wembley. The power supply is three-phase, 50 cycle alternating current, fed to the rectifying valves, each of which is of 150 watt capacity

voltmeter, while to the right of these is the switch for battery control. Situated on the extreme right of the shelf which supports the apparatus is the galvanometer, by which the operator may tell if "over control" is occurring, and on the right of this is a large capacity dry battery supplying high tension.

A front view of the main transmitter appears in Fig. 3, while a rear view is given in Fig. 4. Both these pictures should be studied as the description proceeds. The apparatus comprises a bank of rectifying valves, twelve in all, arranged in two paralleled groups of six each. These are followed by five control valves and one sub-control, which, in turn, are connected to the two oscillator valves.

The exhibition power supply of three-phase 50 cycle alternating current is used, and is fed to the rectifying valves. These are each of 150 watt capacity, and their filaments are lighted by the alternating current, smoothed, and reduced to correct voltage through a special transformer. The main transformers are clearly shown in Fig. 4 at the right, arranged within the angle-iron framework. Above and below the valves themselves are fitted strips of ebonite upon which are mounted respectively the current- and volt-measuring instruments and the controls for the valves. The latter consist of switches and rheostats for the filament and high-tension current. The high-tension current may be obtained from these valves at pressures of between 3,000 and 4,000 volts.

In the centre section of the valve panel are arranged the modulator or control valves. At the left of the bottom row is the small 0/50 type sub-control valve. The others are each of the 0/250 type, and are for the "control." Mullard valves are used throughout in this installation. As with the previous panel, meters and switches are arranged above and below on ebonite sheets. Fig. 4 clearly shows the arrangements at the rear of this panel.

The last panel is the oscillator, and consists of two 0/150 watt valves. These are fed with a D.C. supply.

At the extreme right of the bench supporting the apparatus is the tuner. This consists of three coils wound on well-spaced insulating supports, constructed of copper tubing. The outer coil is the aerial coil, while within it is the anode coil. A third coil, wound upon a rotating former, after the fashion of a standard type vario-coupler, may be seen within the others. This is connected to the grids. Immediately in front of these coils is a fixed condenser having well-spaced plates of copper sheet. Mounted on top of this is a meter and switch. The wave-length upon which this transmitter normally works is

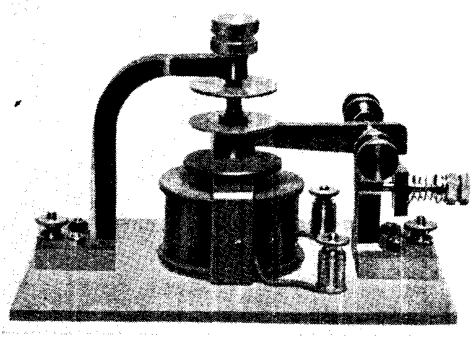
120 metres, although the tuner allows of considerable modification above and below this figure.

Some of the valves in this apparatus and also in the various amplifiers for loud speaker work have their high-tension and low-tension supplies fed from secondary batteries. These are housed in the cupboards below the main transmitter, as are also the spare valves and all other apparatus ever likely to require renewal.

Accumulator charging is always being required at the kiosk, and for this purpose a "Tungar" rectifier is used. An operator is always present, and by the simple expedient of plugging flexible leads into jacks connected for the purpose, he is enabled at a moment's notice to arrange the transmitting circuits to suit any broadcasting requirements which are likely to arise.—*R. B. Hurton.*

RELAY KEY. Form of circuit breaker used in transmitting sets. It is in reality a protecting device for the operator to prevent any shock due to H.T. current.

The figure shows a form of relay used in transmitters, and which is operated elec-



RELAY KEY
This is a form of circuit breaker as used in ships' transmitting sets
Courtesy C. F. Elwell, Ltd.

trically from the Morse tapping key. The large magnet shown centrally between the two pillars is energized when the operator depresses his key. On this occurring, the armature is drawn down. This action closes two further contacts, which being of a large size allow a heavy current to pass. On the electro-magnet becoming de-energized, the armature is drawn back to its normal position by the spring shown. *See* Morse Sounder.

RELAY STATIONS. The B.B.C. relay stations employ a power of from 100 to 200 watts. This will give an average crystal set range of approximately five miles. The transmitters employed as standard use a choke-control circuit, with the "sub-control" system as fitted to the larger transmitters of the B.B.C. Power is derived from D.C. generators, which are situated on the station premises, and themselves driven by motors employing the town current supply.

At each station there is an amplifier as used on the simultaneous broadcasting lines. This amplifier, besides increasing the strength of the current from the line, also corrects any changes in frequency or wave-form which the land-line has caused.

All the stations are fitted with a small studio, fully equipped and fitted with the Marconi-Round microphone, which is now standard with the B.B.C. This studio is normally used for the local children's hour and any news of local interest. Further, means are provided so that local political meetings, etc. can be broadcast when required.

The first stations opened were at Plymouth, Sheffield and Edinburgh. The first is connected to London (2 LO) and the second to Birmingham (5 IT). Further stations are under construction at Liverpool, Hull and Leeds.

The call sign of the Plymouth relay station is 5 PY. It was opened on March 28th, 1924, and is a reproduction, from the instrument point of view, of 2 LO. The studio is draped with sound-proof curtains, as is the studio at London, and the London programme is relayed five or six days a week, one day being devoted to local talent. The aerial is of the three-wire cage type, 130 ft. high, and the wave-length used is 325–350 metres. The power of the station is 100 watts, and the effective range for crystal sets is five miles, but the power of the station and the consequent range may be increased if it is thought necessary.

Sheffield, call sign 6 FL, was the first relay station to be opened. Originally the station was connected to Manchester, but it is now connected by land-line to Birmingham. The power of the station is 100 watts, and the wave-length used is 300 metres. The station is situated in Corporation Street.

The call sign of the Edinburgh relay station is 2 EH, and the station is situated at New University Buildings, Laurieston. The Edinburgh station will be linked with the Glasgow and London main stations, so that either programme may be broadcasted locally as required. The power used is the standard 100 watts for relay stations, and the wave-length is provisionally fixed at 305 metres.

The calls signs of the stations at Liverpool are 6 LV, at Hull 2 HU, and at Leeds 2 LS.

RELUCTANCE. Magnetic equivalent of electrical resistance. It is the opposition which has to be overcome in a magnetic circuit before the flux can be established. The reluctance of a piece of material depends upon its length, inversely on the area of its cross-section, and its permeability.

If l is the length of the magnetic path, a the cross-sectional area in which the lines of force are to be concentrated, and μ the permeability, then the reluctance $= l/\mu a$. *See* Flux; Magnetic Circuit; Magnetic Reluctance; Magneto-motive Force; Permeability.

RELUCTIVITY. Name given to the reciprocal of permeability. *See* Flux; Magneto-motive Force; Permeability.

REMANENCE. Name given to the magnetism retained after magnetic induction has ceased. *See* Magnet; Magnetism.

REMOTE CONTROL. A system of control whereby a transmitting or receiving set may be operated by a person located at any desired distance from the apparatus. It is sometimes convenient to control a number of transmitters or receivers from one central office. The most notable instance of this system is that of Marconi's Wireless Telegraph Co., Ltd.'s telegraph stations, all operated from Radio House, London.

This system is worked by land-lines connecting Radio House with the various stations. The latter are located at Brentwood, Ongar and Carnarvon. Relays are used at the distant points, which being themselves operated by comparatively feeble currents, allow heavy local currents to pass, and thus operate other apparatus.

This method of control results in enormous savings in operating expenses and time, for by its means a central telegraph receiving and distributing office in the heart of the business world is obtained, at a point where the erection of high-powered wireless stations would be impracticable.

A further advantage is that messages have not to be repeated, and thus the possibility of error is lessened, for the human element is entirely eliminated, except at the actual place of transmission, where errors may easily be checked.

Remote control has other uses, as, for instance, in cases where limitations of space do not allow a set to be in close proximity to the operator. In an aeroplane, for example, there is frequently no room in the pilot's or observer's cockpit for a complete transmitting and receiving set. It is therefore necessary to place the set in the fuselage, at any convenient point, and place the controls within the pilot's or observer's reach. The attainment of this object has been evolved after exhaustive researches into the requirements peculiar to air conditions.

In apparatus of this description the tendency of modern design is towards mechanical rather than electrical devices. Previously the system was all electrical, and it amounted to having a transmitter and receiver roughly tuned, with extended leads to a fine-tuning control within easy reach of the pilot.

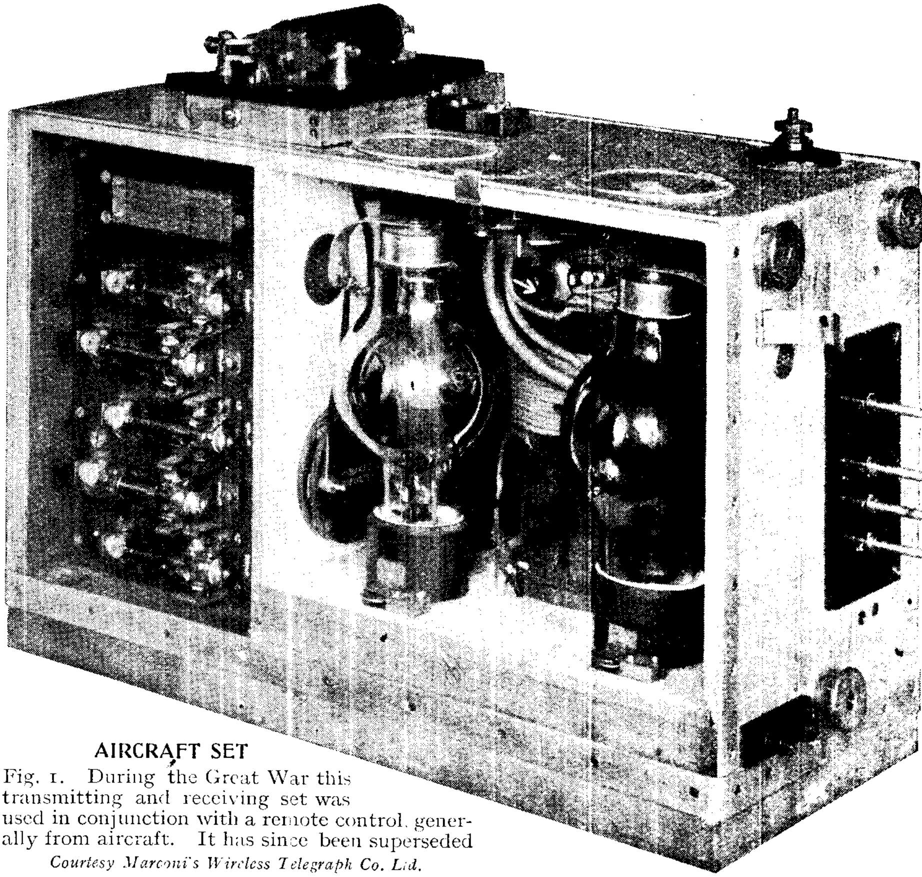
The three essential controls are a fine-tuning device for the receiver, a filament resistance, and a switch for completely changing over from "send" to "receive." These three controls are embodied in the remote control for aircraft work, used in conjunction with the transmitter and receiver illustrated in Fig. 1.

This type of apparatus was used during the later stages of the war, but is now being supplanted by a set of more modern design. Aircraft remote control systems and the apparatus used with them are so much a part of each other, that both are described and illustrated in the article.

Referring now to Fig. 1, it will be seen that both transmitter and receiver are mounted in the one cabinet, of quite small dimensions. The latter point is important for aircraft work, for not only space, but the weight of the apparatus, is usually very limited.

On the left of the cabinet is the receiver, which is a five-valve set having three H.F. amplifiers, a rectifier, and one L.F. amplifier. Filament current from the L.T. commutator of the generator, and H.T. current from the corresponding commutator, are fed through smoothing condensers mounted in a separate compartment in the main cabinet.

Coarse wave-length adjustment is accomplished by means of a three-position



AIRCRAFT SET

Fig. 1. During the Great War this transmitting and receiving set was used in conjunction with a remote control, generally from aircraft. It has since been superseded

Courtesy Marconi's Wireless Telegraph Co. Ltd.

switch. This is set when the instrument is installed on board the particular machine for which it is intended, and the remote control provides sufficient secondary adjustment.

Aerial coupling to the first H.F. valve is accomplished through an aperiodic coil loosely coupled with the A.T.I. This aperiodic coil has a natural wave-length equal to the standard aircraft wave (900 metres). A form of adjustable coupling is provided in the receiver cabinet, to allow the coupling between coil and A.T.I. to be initially corrected on installation.

An important feature of the receiver is that it is screened throughout as a protection against stray magnetic fields. To accomplish this end, all the H.F. part of the apparatus is contained within a metal box.

Sufficient reaction can be provided, if necessary, to enable C.W. to be picked up by the autodyne system, but as the principal use of the set is for telephony, reaction is not coupled too tightly. The high-frequency transformers used are of the Marconi aperiodic type, and designed to be effectively damped, thus rendering fine reaction control unnecessary.

Passing now to the transmitter, this is arranged for either telegraphy or telephony. The transmitter is quite a standard type of instrument, and consists of the usual circuits for the generation of oscillations and for speech modulation.

Wave-length may be varied from 600 to 900 metres, on the standard production, but this is not adjustable from the remote control. All inductances, etc., in the transmitter are pile-wound with stranded wire to reduce space and H.F. losses, respectively.

In the control circuits are a microphone transformer, choke and control valve, while every possible precaution is here taken to ensure stability of operation. A special type of microphone is used for the telephony working, which is designed to be as sensitive as possible to sounds other than the human voice. Side tone, *i.e.* the ability of the operator to hear his own voice electrically through his receiving telephones, is fitted. This is accomplished by connecting the earth end of the secondary winding of the microphone transformer in series with the receiving telephones.

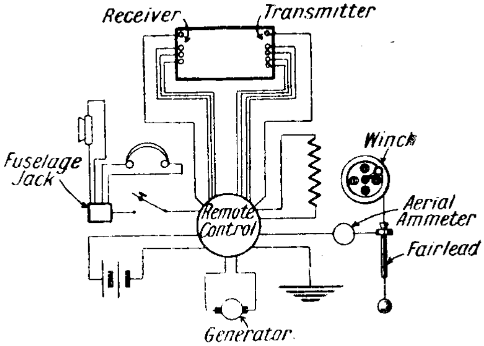
A special three-way switch is fitted to the section of the apparatus devoted to telegraphy transmission, whereby, with one movement, the pilot or observer may change over from telephony to either C.W. or interrupted C.W.

The circuit diagram of the apparatus, shown in Fig. 2, clearly shows the various units comprising the receiver and transmitter and the method of connexion.

The generator is an interesting item. It supplies both high and low tension and is wind-driven by a small air screw. As it is generally placed at some point on the aeroplane wing, it is effectively streamlined to reduce wind resistance.

A small accumulator is connected across the low-tension mains, smoothing out the commutator ripple and compensating for voltage variations due to changing air speeds.

This is important in connexion with wind-driven generators, for their speed, and to some extent their voltage, depends upon the air-speed at which the machine is travelling. Smoothing condensers are fitted in the high-tension supply, and from these condensers the power leads are connected to the remote control.



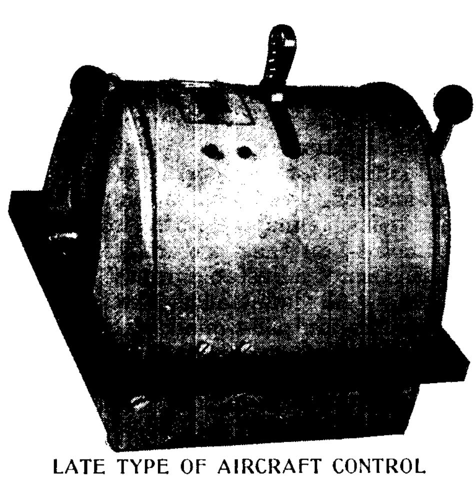
CIRCUIT DIAGRAM

Fig. 2. How the aircraft remote control of wireless transmission during the Great War was wired

The remote control is illustrated in Figs. 3 and 4, of which Fig. 3 is an external view, showing the controlling handles, and Fig. 4 is an internal view, showing the mechanism and electrical arrangements.

The central handle of the control is known as the "send-receive" switch, and according to the position in which it is placed, depends whether the power supply is directed to the receiver or the transmitter. Further, it controls the aerial circuit of both instruments, thus completely changing over, in one movement, the whole apparatus.

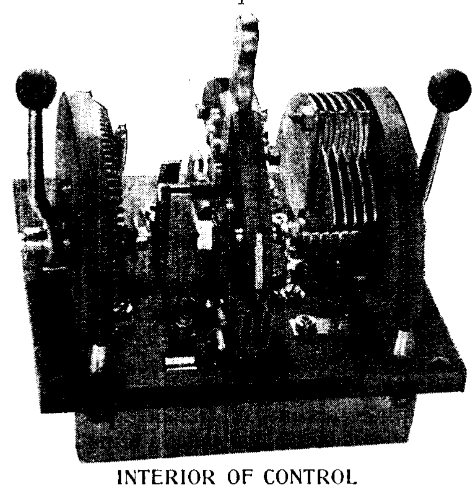
A further handle is situated on either side of the central one, and one controls a tuning condenser for the receiver, enabling wave-length changes to be made, while the other operates a filament



LATE TYPE OF AIRCRAFT CONTROL

Fig. 3. External view of the remote control fitted during the later stages of the Great War. The right handle controls the tuning condenser

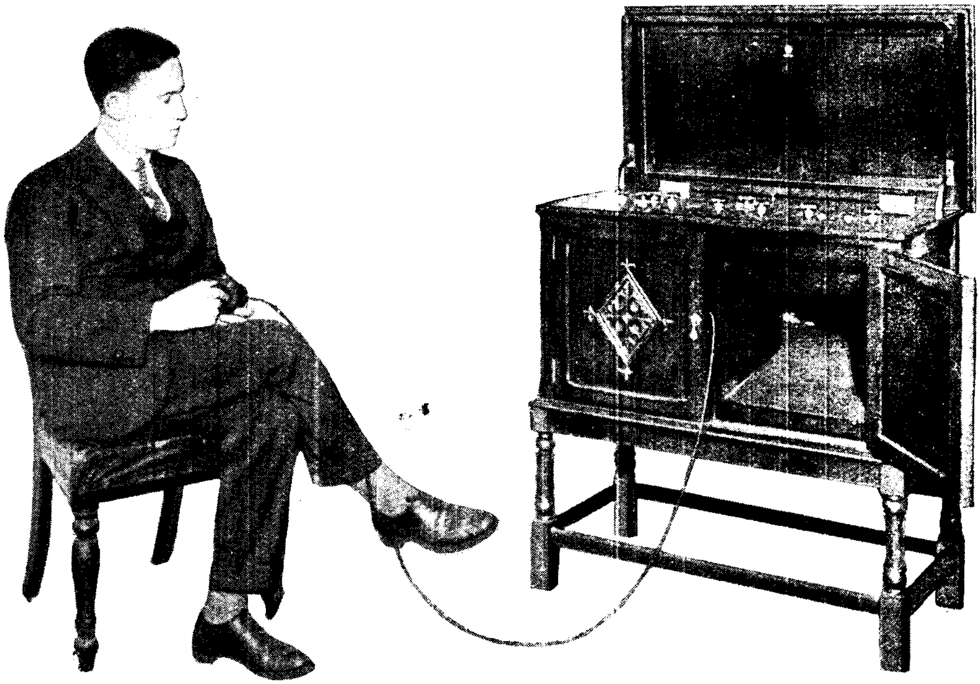
Courtesy Marconi's Wireless Telegraph Co., Ltd.



INTERIOR OF CONTROL

Fig. 4. The metal cover has been removed to show the internal mechanism. The central handle changes the control from "send" to "receive"

Courtesy Marconi's Wireless Telegraph Co., Ltd.



BOWDEN CONTROL

Fig. 5. Here is shown the Bowden wire remote control in use. It is attached to an ordinary receiving set

Courtesy Radio Communication Co., Ltd.

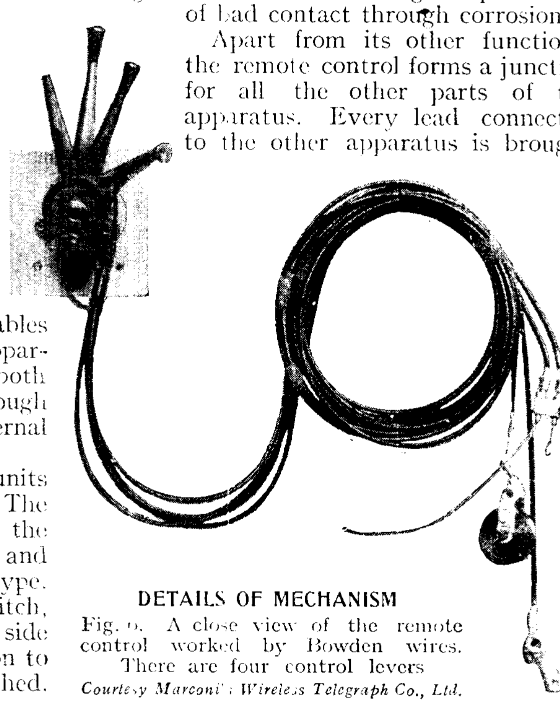
resistance, thus controlling the loudness of the received signals. The latter control is found useful when flying low and approaching a ground station which is transmitting.

Reference to Fig. 3 will show that the whole control is mounted upon a flat base, covered by a semi-cylindrical cover. The latter has a slot cut in it to allow the central handle to project through. This construction enables all the delicate parts of the apparatus to be completely shielded, both from mechanical injury and rough handling, and electrically from external fields.

The appearance of the different units may also be gathered from Fig. 4. The resistance at the left-hand side of the control is made of very stout wire, and is of the ordinary sliding contact type. In the centre is the change-over switch, having contacts arranged on either side of the sector-shaped centre portion to which the operating handle is attached.

To the right is the tuning condenser, which is of the 90° sector-shaped type, having six fixed and five moving plates. Contact to the moving plates is made by a spring ligament, thus eliminating all possibility of bad contact through corrosion.

Apart from its other functions, the remote control forms a junction for all the other parts of the apparatus. Every lead connected to the other apparatus is brought

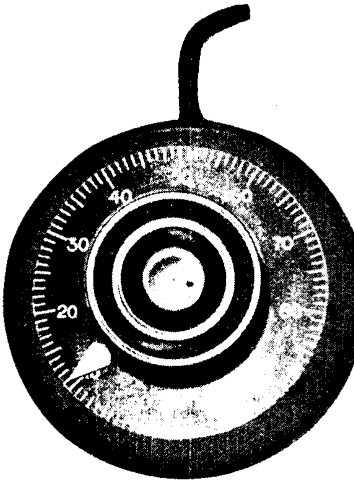


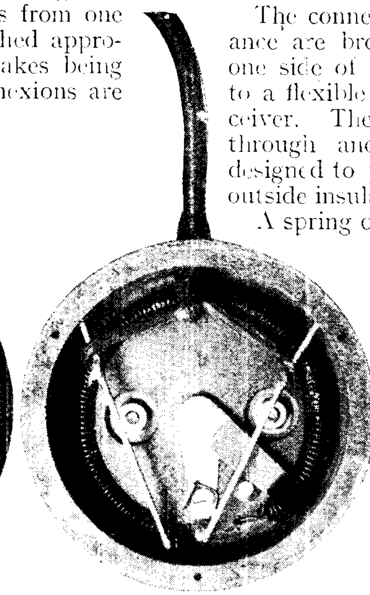
DETAILS OF MECHANISM

Fig. 6. A close view of the remote control worked by Bowden wires. There are four control levers

Courtesy Marconi's Wireless Telegraph Co., Ltd.

to the control through an aluminium flexible casing. The latter is earthed, and forms a screen against magnetic fields. Each set of conductors from one unit in the apparatus is bunched appropriately, which prevents mistakes being made on assembly. Plug connexions are





EXTERIOR AND INTERIOR VIEWS

Fig. 7. Close-up view of the outside of the control seen in Fig. 5. It is a special form of filament resistance. Fig. 8 (right). An interior view of the instrument

Courtesy Radio Communication Co., Ltd

used throughout to ensure no loss of time or mistakes, should the apparatus have to be disassembled or assembled quickly.

Fig. 6 is a photograph of a later type of remote control. This is a Bowden wire-operated mechanism, specially adapted to the requirements of radio work. Back-lash and all other forms of mechanical lost motion are reduced absolutely to a minimum. The connexions to this type of instrument are readily detachable should necessity arise.

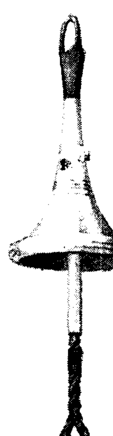
A general view of a remote control adapted for a broadcast receiver appears in Fig. 5. This device enables the tone volume of the receiver to be adjusted some distance away, in the comfort of a chair.

A close-up view of the outside of the control is given in Fig. 7, and of the interior in Fig. 8. A study of these pictures will show that the control is a filament resistance, designed to be held conveniently in the hand. The resistance is of the usual type, but the wire is wound over a solid former of insulating material, thus ensuring freedom from bad contact due to the coil losing its original circular cross-section. A graduated dial is fitted on the outside, enabling any position to be remembered and reset at any time.

The connexions from the resistance are brought to a bushing in one side of the case, and thence to a flexible lead to the main receiver. The entry to the latter is through another bush, which is designed to prevent fraying of the outside insulation of the wire.

A spring of light tension is fitted to the reel on which the wire winds when being replaced within the cabinet. This spring is of such a tension that it will not of itself cause any noticeable pull on the lead, but it is sufficiently strong to enable the wire to be wound on the reel automatically when the operator gives it a slight push.
--*R. B. Hurton.*

RENDAHL INSULATOR. Name given to a form of insulator designed by Rendahl and largely used by the Telefunken Company. As the illustration shows, the Rendahl insulator is a form of strain rod insulator which is designed to withstand a heavy mechanical strain. This type of insulator is also designed to withstand severe weather changes.



Rendahl Insulator, a type designed to resist mechanical strain

The high-pressure end of the insulator is made of aluminium and shaped like a funnel. The object of this is to spread the potential stress more uniformly along the stem of insulating material than is the case with most forms of insulator. The stem is made of wood impregnated with oil and covered with a tube of porcelain or similar material. These insulators are used in connexion with the guying of the Rendahl mast, a type of lattice steel mast largely used by the Telefunken Company. *See* Bradfield Insulator; Insulation; Insulator.

RESIDUAL CHARGE. Charge left in a condenser after the first momentary discharge. It is due to electric absorption. *See* Condenser.

RESIDUAL MAGNETISM. Magnetism retained by a piece of iron after the magnetizing force has been withdrawn. Hysteresis is the name given to the disinclination of a magnetic substance to become demagnetized or magnetized immediately the demagnetizing or magnetizing forces are applied. There is a lagging behind, as it were. *See* Hysteresis ; Magnet ; Magnetism.

RESIN. Name of certain vegetable and mineral substances. Most resins are translucent solids at normal temperatures, melt easily, and are generally aromatic. Resin is soluble in alcohol and oil, but insoluble in water. Its general constituents are various combinations of carbon, hydrogen and oxygen. Commercial resin is chiefly obtained from vegetable resins, especially that obtained from pine-trees.

Resin is used in wireless work as one of the constituents in various lacquers and varnishes. The substance is also used as a flux with certain soldering operations, its use in this case being described under the heading on soldering. Resin has other applications in frictional experimental electricity. One effect is that when a piece of resin is rubbed with a piece of dry silk cloth it acquires a form of static electricity. *See* Soldering.

RESINOUS ELECTRICITY. This was the name once given to negative charges of electricity. It was so given because it was produced by rubbing resinous substances with fur. *See* Electricity.

RESISTANCE. When Dr. Joule, of Manchester, made his famous experiments which established the conservation of energy, he was not satisfied with mechanical experiments alone. He investigated the energy of electric currents also, and proved that the heat production of a current in a given conductor was proportional to the square of the current in that conductor ; the rate of production of heat being equal to the resistance of the conductor multiplied by the square of the current. Hence the resistance of a conductor at any moment, and under any circumstances, may be defined as the heat produced in it per second divided by the square of the current it is carrying at the moment. The ordinary definition in terms of Ohm's law is complicated by the possibility of other opposition electromotive forces besides that due to friction. The expression RI^2t gives the work that is done by the current in producing heat. If resistance is in ohms, and current in amperes, and time in seconds, the work comes out in joules ; each of which is a unit of energy equal to 10^7 ergs. To get the number of heat units, one must divide by the mechanical equivalent of heat.

A rough experiment on Joule's law is easily made by driving a measured current through a thin spiral wire of known resistance, immersed in water, with a thermometer to show how fast the temperature of the water rises.

Every known substance possesses resistance in a greater or less degree, and in every case the passage of electricity through a body results in an increase in temperature, depending on the current and the strength of the resistance. For this reason it is not strictly accurate to regard substances as being divided into "conductors" and "insulators," for the latter will conduct, given the application of the necessary electrical pressure. It is of the utmost importance to remember this fact when calculating the resistances of so-called insulators, otherwise results are apt to appear misleading.

The measurement of resistance will be readily understood when it is realized that with a given potential difference the current is inversely proportional to the resistance. That is, the less the resistance the greater the current, and vice versa. This fact is universally called Ohm's law. Resistance is measured in ohms, and the ohm is defined as being that amount of resistance which, when impressed with a potential difference of one volt, will allow a current of one ampere to flow. The Board of Trade Standardizing Laboratory possesses coils of platinum-silver wire which at a temperature of 15·4° C. possess a resistance of one ohm.

From the last statement it will be gathered that temperature plays a part in resistance, and, indeed, this fact is of fundamental importance. Generally speaking, the resistance of metals increases with a rise of temperature, and becomes less as temperature falls. Non-metallic substances possess, like carbon, the opposite quality, for their resistance decreases with a rise in temperature.

The amount by which the resistance of a body varies with temperature is known as the temperature coefficient. This may be defined as the increase in unit resistance per unit rise in temperature. In all cases the unit of resistance is the ohm, and the unit of temperature the degree centigrade. An average figure for pure metals may be taken as ·0038, and for mercury ·00075.

There are four laws relating to resistance which apply equally to substances commonly called conductors or insulators, and the latter in this article, unless specifically stated, will be classed as conductors. These laws are as follows:

(*a*) The resistance of a conductor is proportional to its length.

Thus, if a conductor of an even cross-sectional area and molecular structure possessed a resistance of 1 ohm in a length of 10 feet, then lengths of 5 ft., 15 ft. and 25 ft. would possess resistances of ·5 ohm, 1·5 ohms and 2·5 ohms respectively.

(*b*) The resistance of a conductor is inversely proportional to its area of cross-section.

Resistance Depends on the Material

Thus, two conductors of equal length and cross-sectional area will possess one-half the resistance of one, three will possess a third, and so on. Similarly, given two conductors of equal length and material, but one having twice the cross-sectional area of the other, then the thin one will possess a resistance of twice that of the thick one.

(*c*) The resistance of a conductor is dependent upon the material of which it is composed.

An illustration of this is given when it is realized that if a piece of silver possessed unit resistance, then a piece of platinum of the same dimensions would possess a resistance of 6·022 times that amount.

(*d*) The resistance of a conductor depends upon its density, hardness, molecular structure, purity, etc.

For instance, an increase in the density of metals is frequently accompanied by a decrease in resistance. Again, the annealing of metals also frequently results in diminished resistance, while conductors subject to mechanical strain, such as tension, etc., are often found to obtain increased resistance, through becoming hard and crystalline under the strain. Metallic alloys generally possess a resistance greater than the combined resistance of the materials of which they are composed.

It will be seen from the foregoing that a means of comparison of resistance value between different specific substances is necessary, and this measure is known as "specific resistance" or "resistivity." The former term is by far the more widely used. Specific resistance is generally accepted as being that resistance which is found to exist between the two opposite faces of a centimetre cube of a substance at a given temperature. Thus, annealed silver possesses a specific resistance of 1·468, and copper 1·561, etc.

While in the majority of instances the presence of resistance in an electrical circuit is a thing to be avoided, in some cases it is of great utility. The most notable use of resistance in ordinary electrical work is for heating purposes, whether for rendering the filaments of lamps incandescent, or to raise the temperature of air or water for domestic heating. In wireless work, resistance is applied in the design of valves for filament heating, and in the set itself for controlling the current supply to the filaments. Again, high, non-conductive resistances of the graphite type are frequently used for grid leaks and inter-valve couplings.

How Resistance is Measured

In the laboratory, resistance may be conveniently measured by what is known as "bridge" or "balance" methods. Briefly, this method consists of comparing the value of the unknown resistance with others of known value. Very accurate results indeed may be obtained by this method, and, further, little in the way of mathematical calculation is necessary. Bridge methods of measurement are fully described in this Encyclopedia under the titles of the respective bridges. It is important to note that resistance measurement should always be conducted with the aid of direct current of a perfectly steady nature, *i.e.* without ripple, such as is obtained from primary cells. Furthermore, the cells used should possess the property of yielding sufficient current for the purpose, but unless extreme care is exercised, secondary cells (accumulators) should not be used.

In this connexion it must be understood that all cells possess an internal resistance of a value depending on the type. Upon the value of this internal resistance depends the current-yielding capacity of the cell in question. In the case of primary cells internal resistance increases with polarization (*q.v.*). Accumulators have a low internal resistance, and for this reason, when placed in circuit with another low resistance value, they discharge very heavily, with resultant damage to themselves through the buckling of plates, and to apparatus in the external circuit through heating. On the other hand, primary cells do not, as a rule, cause or suffer damage through being short-circuited, and will generally recuperate their current-yielding properties.

RESISTANCE OF COPPER WIRES.

Size, standard wire gauge.	Resistance at 60° F. in standard ohms per yard.	Size, standard wire gauge.	Resistance at 60° F. in standard ohms per yard
50	30·60	30	0·199
48	11·95	29	0·165
46	5·313	28	0·139
44	2·989	26	0·094
42	1·913	24	0·076
40	1·329	22	0·039
38	0·850	20	0·023
36	0·529	18	0·013
35	0·433	16	0·007
34	0·361	14	0·0047
33	0·306	12	0·0028
32	0·262		

As one of the commonest series of factors required in wireless work the resistances of copper wires of standard gauge are given in the table above.—*R. B. Hurton.*

See Bridge; Ohm; Ohm's Law.

RESISTANCE BOX. In measuring the values of unknown resistances it is necessary to have standards for purposes of comparison. The fixing of values for such standards has been a source of much controversy among various scientific bodies, and several units of resistance, all differing slightly from one another, have been adopted from time to time under the name of the Ohm. The value definitely recommended by the advisory committee to the Board of Trade in 1892 was defined as follows: "The resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice, 14·4521 grammes in mass, of a constant cross-sectional area, and of a length of 106·3 centimetres, may be adopted as one ohm."

In the following year this value was adopted unanimously by the Chamber of Delegates, composed of members representing the United States, Great Britain, France, Italy, Germany, Mexico, Austria, Switzerland, Sweden and British North America, and for the purpose of distinguishing this unit from any other it was decided to call it by the name of "International Ohm."

The international conference on electrical units and standards held in London in 1908 confirmed this valuation.

For the purpose of satisfying small discrepancies between theory and practice the British Association introduced another standard slightly varying from the preceding, known sometimes under the name of "Legal Ohm."

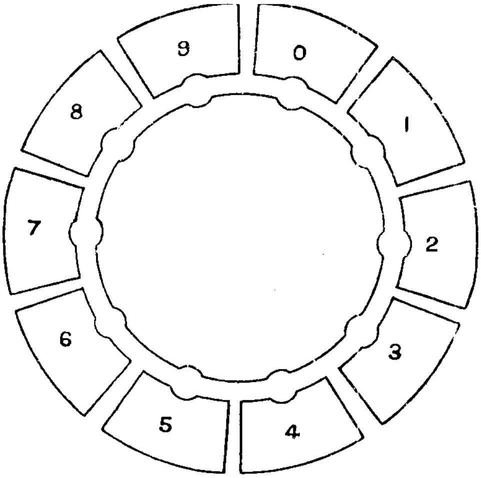
The relationship between the B.A. unit and the International unit of resistance is expressed as follows:

1 International ohm = 1·0136 B.A. units.
1 B.A. unit = 0·9866 international ohms.

Apparatus for the measurement of unknown resistances, whether of the Wheatstone bridge type, the ohmmeter, or the Post Office form of bridge, all require a set of standard resistances for comparative purposes based upon the values fixed for unit resistance as above, and since the mercury column type of resistance is not practicable for workshop purposes it has become the custom to make standard resistances, whether of one ohm value or any other multiple of one ohm, of special high-resistance wire, choosing for that purpose some alloy which possesses a negligible temperature error, such as Eureka, Platinoid, Manganin, etc.

Sets of coils, made in multiples and submultiples of an ohm, grouped together with suitable means for joining them in series and mounted in one containing case, are known as resistance boxes. The groups are usually arranged either in dial form or in bar form, shown in Figs. 1 and 3. The contact plates on top of the resistance box are composed of heavy brass or copper strip, the underside of which is usually cut away so as to lengthen the leakage surface and eliminate possible errors through moisture on the ebonite panel, or leakage through other causes.

The short-circuiting plugs shown separately in Fig. 2 are of brass or copper, tapered to fit in tapered holes and provided with an ebonite top. The plug portion is accurately ground into its hole so as to obtain as perfect a contact

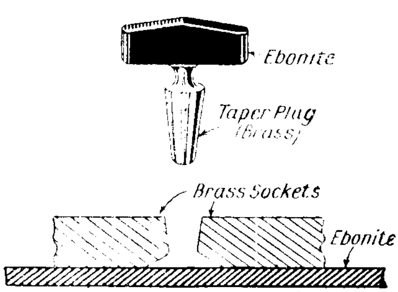


DIAL PATTERN RESISTANCE BOX

Fig. 1. Sets of coils are grouped together within the containing case in dial form

as possible, and in inserting the plug it should be given a slight twisting motion so as to exercise a self-cleaning effect and remove any tarnish or oxidation that might increase the contact resistance. This precaution is particularly necessary in dealing with very low resistance values, since in order to preserve accuracy of measurement it is imperative that the short-circuiting plug contact resistance itself should be negligible.

Whether the resistance box takes the form of the dial or the bar pattern, it will be seen that resistance steps are put in series by the simple expedient of unplugging them, so that any combination of ohms can be obtained by suitable manipulation within the range of the box. With a box containing nine resistance coils, for instance, ranging from 1 ohm to 9 ohms, the resistance between the two

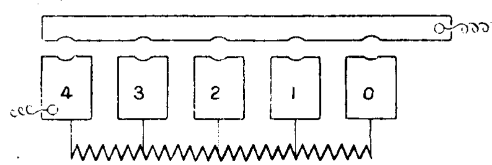


TERMINAL BLOCK AND PLUG

Fig. 2. Short-circuiting plugs, of brass or copper, are tapered to fit the brass sockets. The top is covered with ebonite

terminals with all plugs in would be nil. If 17 ohms were required, plugs 8 and 9 would be removed. If 20 ohms were required, plugs 7, 8 and 5 would be taken out, and so on.

The larger resistance boxes are usually arranged in rows of units, tens, hundreds and thousands. In the Post Office pattern of combined bridge and resistance box, for instance, it will be seen in Fig. 4 that there is a "ratio arm" at the top, usually with a set of coils divided up into 1, 10, 100 or 1,000 ohms respectively, and a measuring arm, the first bar being divided in units of 1, 2, 3, 4 and 10, giving by addition any intermediate value between 1 and 10, the second bar divided into multiples of 10, variable in the same way, and the third bar into multiples of 100, while the last bar carries the range up to 4,000.

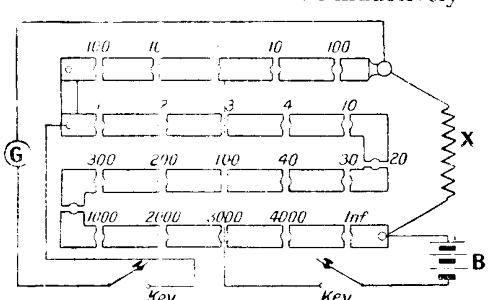


BAR TYPE RESISTANCE BOX

Fig. 3. The bar form of coil mounting in resistance boxes is an alternative to Fig. 1. A resistance unit is shown connected

Any intermediate value, such as 9,137 ohms, would be obtainable by unplugging 4,000, 3,000, 2,000, 100, 30, 4, and 3, the addition of which summed up makes the desired value. Apart from this, the ratio arms of the bridge give multiplying effects of ten or one hundred times to the actual resistance unplugged, resulting in a very comprehensive range of measurement in this type of resistance box.

It is customary in making resistance units to wind the coils non-inductively—



POST OFFICE PATTERN

Fig. 4. The above instrument is a combined bridge and resistance box. At the top is a ratio arm divided into 1, 10 and 100 ohms

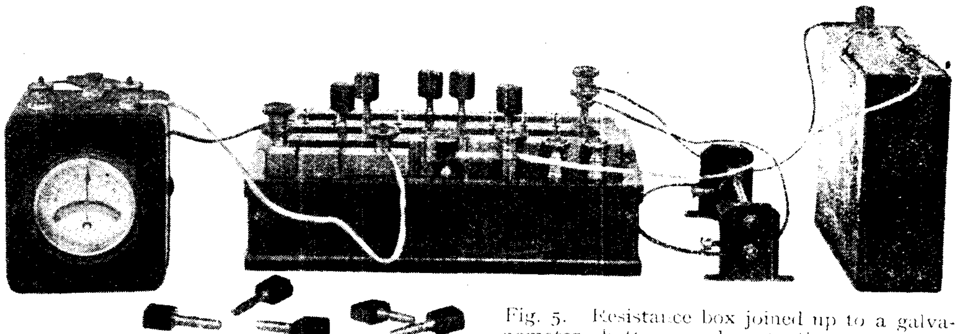


Fig. 5. Resistance box joined up to a galvanometer, battery and potentiometer, whose resistance is being found

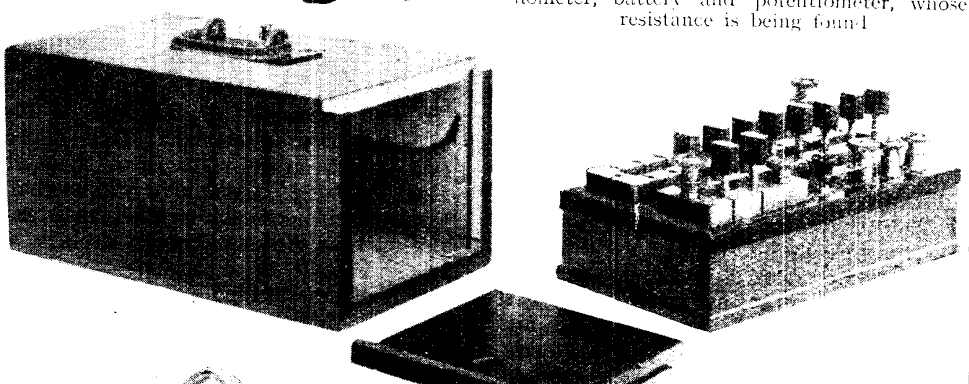
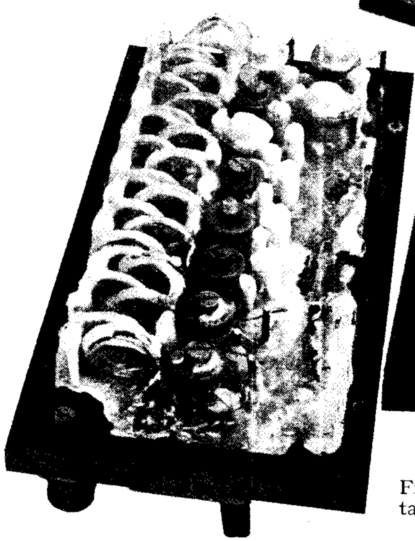


Fig. 6. The case in which the resistance box is usually kept to preserve it from dust is shown here



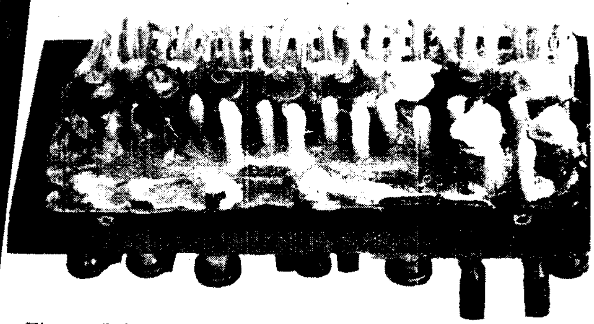


Fig. 7 (left). Interior showing resistance coils and contacts. Fig. 8 (right). How the whole of the wiring is heavily protected with an insulation of wax

EXTERNAL AND INTERNAL STRUCTURE OF THE RESISTANCE BOX

that is, the resistance wire is doubled back upon itself before being coiled on its supporting bobbin, the reason being that no external magnetic effects are then apparent, which might in certain forms of galvanometer used in conjunction with a resistance box give rise to errors in reading owing to stray magnetic fields from the current-carrying coils of the resistance units affecting the galvanometer movement.

Fig. 5 shows a smaller type of resistance box than the Post Office, but on the same pattern, joined up to a battery and galvanometer and a potentiometer, whose resistance is being measured. A number of the taper plugs can be seen in the foreground. Fig. 6 shows the resistance box and the case in which it is kept to keep it free from dust, and Figs. 7 and 8 show the internal construction. The resistance coils are very clearly seen; these are all thoroughly insulated by means of a covering of wax. *See* Foster Bridge; Wheatstone Bridge.

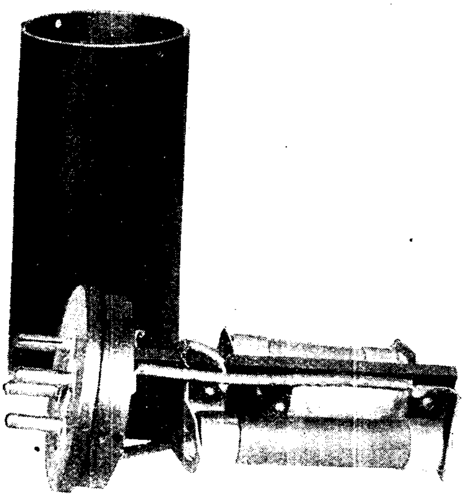
RESISTANCE-CAPACITY UNIT. An appliance adapted to be placed between two valves to act as a high-frequency amplifier, and containing the needful resistance and condenser. Such an appliance with the appropriate values of resistances is very convenient for use in multi-valve sets intended for reception of long-wave signals. Commercial patterns are generally put up in two forms, one for coupling between a H.F. valve and a detector valve, the other type for coupling between two H.F. valves. The method is, as a rule, restricted to reception on wave-lengths of 1,000 metres and upwards.

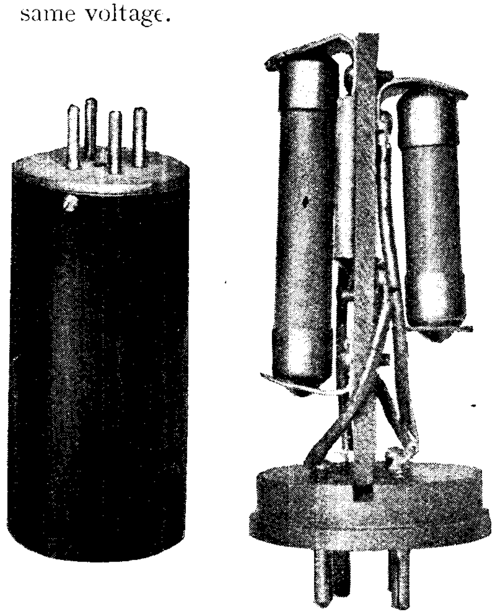
A standard form of resistance-capacity unit, mounted upon a four-pin socket, is illustrated in Fig. 1. The resistance and condensers are housed in the ebonite container shown. The cap at the bottom forms a mounting for an ebonite standard, on either side of which the resistances are attached. This construction is shown in Fig. 2, which is a close-up view of this part of the apparatus. Between the long resistance and the flat pillar is a small fixed condenser. Both resistances are attached by clips in a manner similar to grid leaks, so that their removal and substitution of another of different value is an easy and quick operation.

RESISTANCE COIL. Any coil of wire specially made to possess the property of electrical resistance. A number of such coils of known resistance value are of great use, since they may be used as standards for the measurement of other resistances. Another use to which they may be put is for connecting in series with the windings of moving-coil voltmeters to enable a higher range of volts to be measured by the one instrument.

In such a case it is necessary to ascertain the exact resistance of the voltmeter findings, and then add any multiple of that value in series externally. Thus, if it is desired to measure voltages of twice the value that the instrument will normally indicate, it is necessary to add a resistance equal to that of the voltmeter itself.

As the scale of a moving-coil instrument is evenly divided, it is only necessary to multiply the normal reading by two. The deflection of the needle of moving-coil instruments is always inversely proportional to the ratio of the instrument's own resistance and the added resistance for the same voltage.

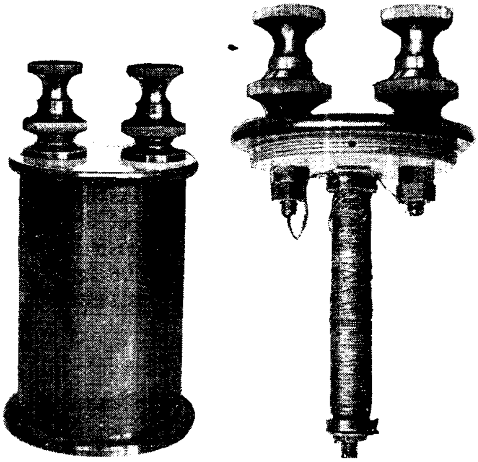




CONSTRUCTIONAL DETAILS OF A RESISTANCE-CAPACITY UNIT

Fig. 1 (left). Resistance and capacity unit which may be placed between two valves for H.F. amplification purposes. Fig. 2 (right). Internal construction; note the resistances (in appearance like grid leaks) and the small fixed condenser

Courtesy Peto-Scott Co., Ltd.



RESISTANCE COIL

Fig. 1 (left). Exterior of a resistance coil, the standard of measurement for other resistances. Fig. 2 (right). The interior, showing the windings of the non-inductive calibrated coil

Courtesy J. J. Griffin & Sons, Ltd.

The external view of a typical resistance coil is illustrated in Fig. 1. The case is made entirely of ebonite, and massive terminals are fitted. The latter are necessary, for it is of the utmost importance to cut down all resistance external to the coil for obvious reasons. In this connexion it should be noted that the leads used in conducting resistance measurements should be of exceptionally large size, in order that they may have a low resistance.

Fig. 2 is an internal view of the same coil. It will be seen that the coil itself is wound upon a cylindrical former and suspended from the top end-plate. The windings are wound non-inductively, two wires being wound together side by side. It is important to note that such coils are calibrated at a certain definite temperature. The latter is always engraved on the coil, and for accurate results it should be used only at that temperature.

RESISTANCE-COUPLED AMPLIFIER: THEORY & CONSTRUCTION

An Exceedingly Efficient Receiver Easily Made at Home

Here are given full details of the theory of the resistance-coupled amplifier, and also a copious description of the making of a receiving set embodying its principle. The reader should also consult such related headings as Amplifier; High-frequency Amplification; Low-frequency Amplifier, etc.

A resistance-coupled amplifier is a form of amplifier in which resistance inter-valve coupling is used. Such amplifiers may be either for radio- or audio-frequency, although for the former purpose this type is not recommended for use below a wave-length of 1,000 metres. For high-frequency working on the higher wave ranges, resistance coupling is considered to be quite efficient. Moreover, it is easy and inexpensive to manufacture and requires little skill in operation. The resistances used are of the fixed, non-inductive type, which are comparatively cheap and are reasonably accurate in stated value. Furthermore, good brands of this type of resistance are remarkably stable.

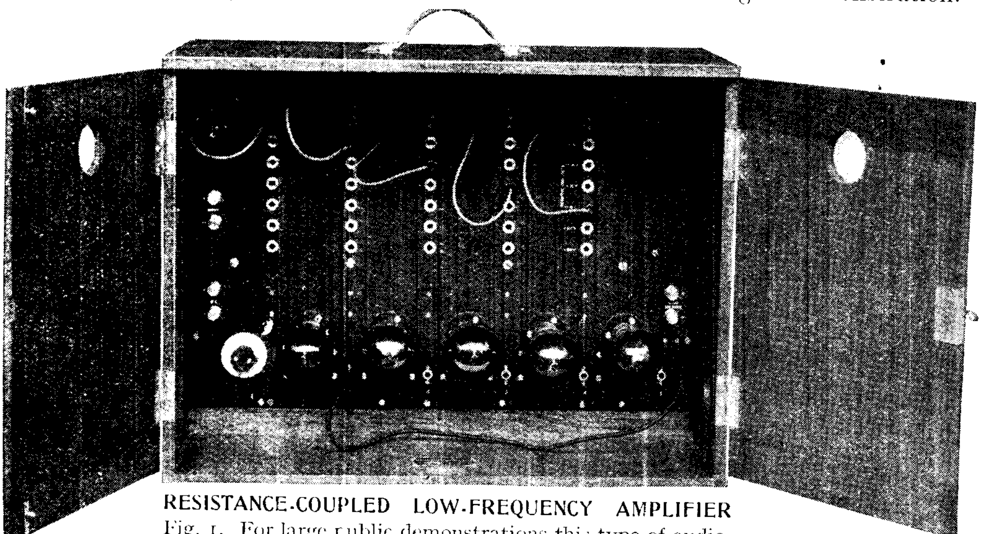
The application of resistance coupling to low-frequency amplification, however, is attended with a little complication as regards circuits and batteries, particularly the latter. Further, the amplification per valve is nothing like so high in value as that obtained from transformer coupling. Despite these disadvantages, resistance coupling is frequently employed where really distortionless amplification is desired and battery power is not a serious consideration. In some instances distortionless amplification is absolutely essential, and when this is so, resistance coupling is used.

In this connexion it should be realized that pure distortionless amplification in broadcast receiving sets using loud speakers is not always so desirable as is frequently imagined. The reason for this is that the great majority of loud speakers are designed to be used with iron-cored transformer-coupled amplifiers, and the manufacturers, realizing this, have added qualities to their loud speakers which compensate for this distortion. While it must not be gathered from this statement that distortion during amplification is a desirable quality, it should be understood that loud-speaking apparatus is made to give the best results with other apparatus which the average amateur usually has at his disposal.

One of the instances where distortionless amplification is an essential, however, is that of the amplification of the microphone currents in a broadcasting station before being put through the transmitter.

In all the B.B.C. stations this amplification is obtained through resistance coupling.

Another instance is where large volumes of sound sufficient to fill a large hall are required. In such cases the extra amplification is frequently accomplished by a multi-stage resistance-coupled instrument. An example of such an instrument is that shown in Fig. 1. This is a five-valve audio-frequency amplifier used by the Marconiphone Co., Ltd. for large public demonstrations. It is possible that three nexion plugs are inserted in the holes for 2, 4, 8, 12 and 17 negative volts for each valve respectively. Only one filament resistance is fitted, this controlling the low-tension supply for all valves. Input and battery terminals are fitted to the left-hand side of the panel, and output (loud-speaker) connexions on the right. A noteworthy detail of the cabinet design is that holes for the leads are provided in the cabinet walls, thus allowing the doors to remain closed during a demonstration.



RESISTANCE-COUPLED LOW-FREQUENCY AMPLIFIER

Fig. 1. For large public demonstrations this type of audio-frequency amplifier is used. Note the tappings for impressing the grid with a negative potential for each valve, and the wander plug, for the loud speaker, to any number of valves

Courtesy Marconi's Wireless Telegraph Co., Ltd.

stages of transformer coupling would give as much amplification, but in this instance the resistance coupling was chosen despite its added cost and trouble in upkeep. From the illustration it will be seen that the amplifier is arranged on a large rectangular ebonite panel, mounted within a wooden cabinet with double doors.

The five valves are arranged horizontally near the lower edge of the panel. A jack is placed after each valve, and a plug attached to a flexible lead is fitted so that any number of valves from one upwards may be selected as desired. Above the valves are five rows of hollow brass sockets. These constitute tappings in a series of grid batteries, and the design is such that each individual valve may have its grid impressed with any desired negative potential from 2 to 24 volts, mainly in steps of 4 volts.

In the photograph the grid voltage con-

Fig. 2 shows a completed resistance-coupled receiver consisting of one stage of high-frequency amplification and valve rectification. The cabinet shown in Fig. 3, with the front panel removed, is made according to the article on Cabinets in the Encyclopedia. It is 12 in. high, 9 in. wide, and $5\frac{3}{4}$ in. from back to front. The measurements given represent internal sizes. A moulded top and bottom are provided to the cabinet, and give it a pleasing appearance.

At a distance of 5 in. from the underside of the top of the cabinet a shelf is fitted, the front edge of which is made flush with the front edges of the cabinet. Fillets are attached to the side and back of the cabinet to which the shelf is fixed. The lower half of the back is a fixture, while the top half is hinged at the top to allow inspection of the upper compartment. The lower half of the cabinet forms a

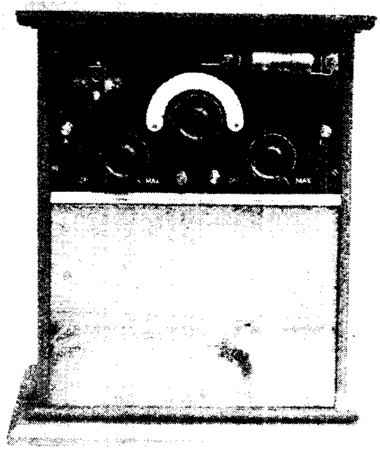


Fig. 2. Complete resistance-coupled amplifier receiving set. The lower half of the cabinet contains the high-tension and low-tension batteries, making the set self-contained

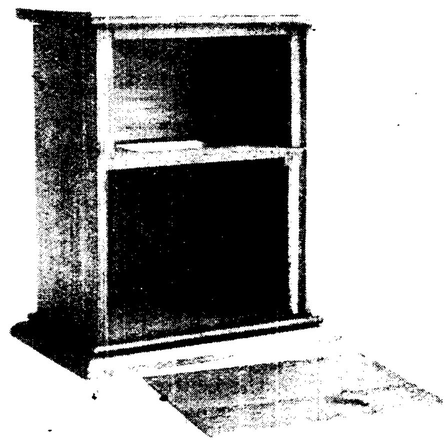


Fig. 3. Cabinet for the set. The upper half takes the valve panel and components. The battery leads to the H.T. and L.T. below are taken through a hole in the partition

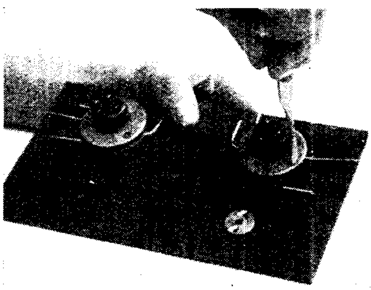


Fig. 4. Connexions to the valve holders should be made before mounting them to the panel

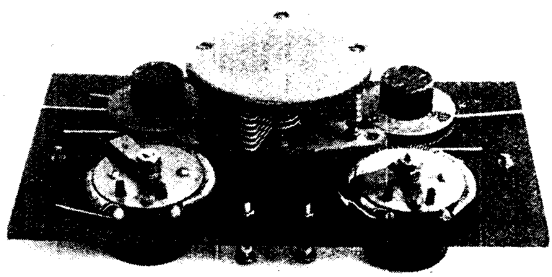


Fig. 5. Back of panel, showing variable condenser, filament resistances and valve holders in position before the wiring is begun

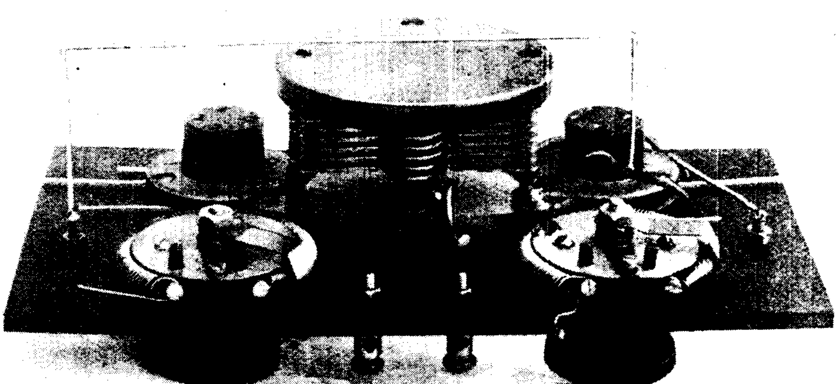
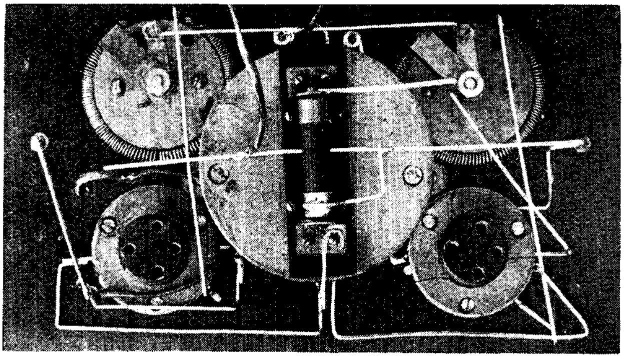


Fig. 6. How the wiring is begun. The aerial tuning circuit here is shown completed

CONSTRUCTION OF THE HOME-MADE RESISTANCE-COUPLED AMPLIFIER compartment in which are the high- and low-tension batteries, leads to the latter being taken through an oblong hole cut in the centre of the shelf.

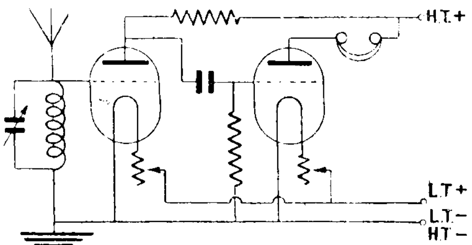
A wooden front is fitted to the lower half of the cabinet and is a push-in fit to obtain occasional access to the batteries. An ebonite panel is fitted to the upper half, to which all the parts of the set are attached. The panel, which is cut from $\frac{3}{16}$ in. ebonite, measures 9 in. by 5 in. A $\frac{3}{8}$ in. hole is drilled in the centre of the panel, through which the spindle of a ·0005 mfd. variable condenser is fitted.

At a distance of $2\frac{1}{4}$ in. from either of the shorter sides and 1 in. from the top two flanged-type valve holders are placed, while the same dimensions taken from the bottom of the panel serve to locate the positions for the two filament resistances required. The aerial and earth terminals are placed, as shown in Fig. 2, to the left and right side of the panel respectively.



REAR VIEW OF PANEL

Fig. 7. The positions of the grid leak and the condenser are seen in this view of the wiring

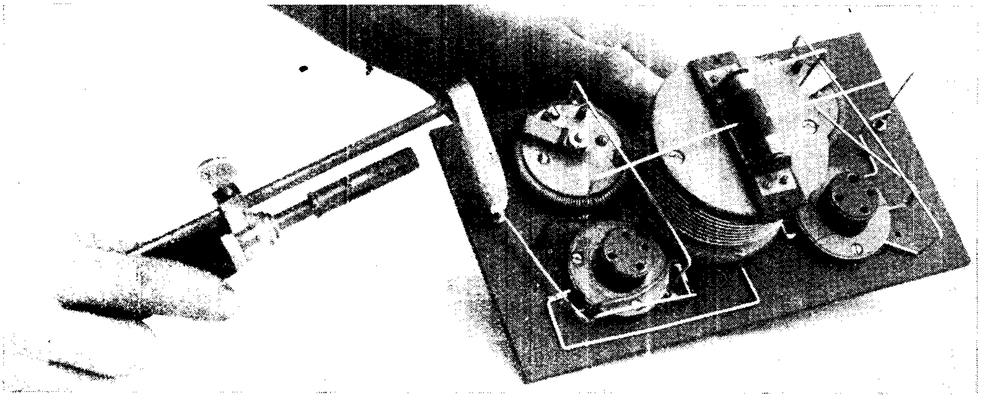


THEORETICAL CIRCUIT

Fig. 8. Wiring diagram of the resistance-coupled amplifier

The positions of the valve holders are somewhat unusual, these being attached to the inside of the panel. These may be attached by cutting off the legs flush with the underside of the base and soldering leads to them before the valve holders are mounted. A circular pad of rubber or felt is placed under the valve holder, and is useful in absorbing a certain amount of vibration to which the valves may be subjected. Fig. 4 shows the operation of fitting these components.

The method of mounting the variable condenser and filament resistances depends on the types purchased, and these occupy the positions shown in Fig. 5, which gives a back view of the panel before the wiring is commenced. A coil holder is placed on the front of the panel, and is shown in Fig. 2, to the left of the condenser and above the filament resistance to the left-hand side. The high-resistance leak shown on the outside of the panel in Fig. 2 is placed to the top right-hand side of the



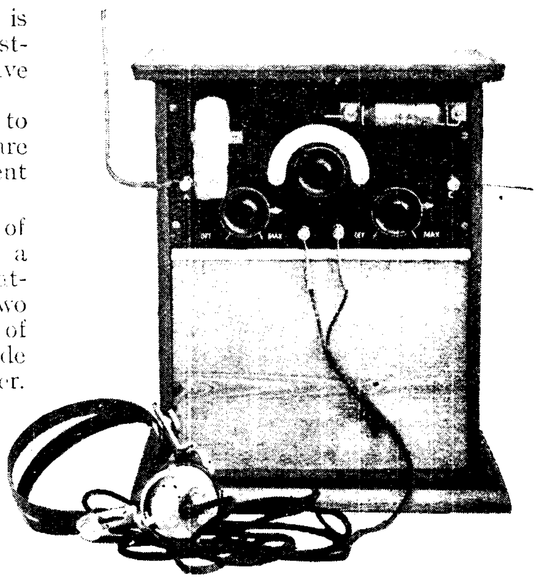
WIRING THE CONNEXIONS OF THE SET

Fig. 9. Wiring in the resistance-coupled set is effected with stout-gauge square-section tinned wire. Here one wire is being soldered to a terminal

panel, where it is easily accessible if it is desired to change the value of the resistance. A suitable resistance should have a value of about 70,000 ohms.

Telephone terminals are attached to the panel at its lower edge, and are centrally placed between the filament resistance control knobs.

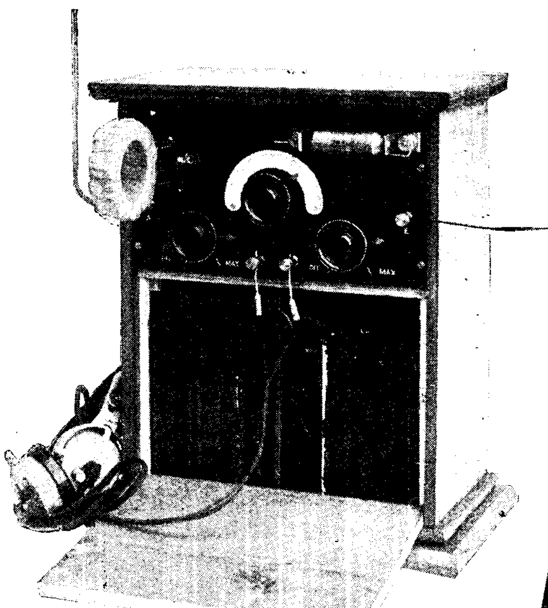
The grid leak has a resistance of 2 megohms, and the grid condenser a capacity of ·0003 mfd. The leak is attached to the condenser by means of two brass brackets, but for the purpose of this circuit it is necessary that one side shall be insulated from the condenser. This is effected by placing a small fibre washer between the end of the leak and the condenser bracket. Both leak and condenser are mounted at the back of the variable condenser, and are kept in position by the stiffness of the wires which are soldered to them.



COMPLETE SET WITH TELEPHONES

Fig. 10. Aerial, earth and condenser positions are lettered in white on the panel when the set has been assembled

The wiring diagram is given in Fig. 8. Fig. 6 shows the commencement of the wiring, which is carried out with $\frac{1}{16}$ in. square tinned wire. In soldering, a small iron should be used, and withdrawn from the terminal to which a wire is being soldered as soon as the solder has melted. This is done to heat the terminal as little as possible, and avoids making the terminal loose through the ebonite melting underneath it. The wiring partially completed, with the soldering iron in use, is illustrated in Fig. 9.



ACCESSIBILITY OF BATTERIES

Fig. 11. A tight-fitting hinged front permits of access to the batteries below the panel

BACK VIEW OF SET

Fig. 12. Behind the set, a hinged door lifts to permit of inspection of components inside

The completed wiring is shown in Fig. 7, which gives a back view of the set in this stage of its construction. Leads to the batteries are made with flexible insulated wire, such as is used in house lighting, and are taken from any convenient point in the wiring. These leads are passed through the hole in the centre of the shelf and connect with the batteries in the lower division.

Fig. 11 shows the front of the set with the front partition removed, showing the batteries in position. This set lends itself well to the use of dull emitter valves in conjunction with dry batteries for filament lighting. The back of the set, with hinged portion of the back open, showing the interior and valves in position, is seen in Fig. 12, while the completed instrument, with aerial and earth and telephones attached, is shown in Fig. 10. Suitable plug-in coils for use with wave-lengths from 2,000 to over 3,000 are the Igranic Nos. 200, 250 and 300 duo-lateral coils.

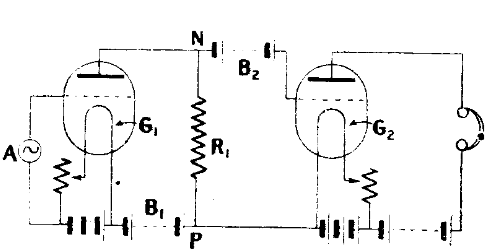
RESISTANCE COUPLING. A method of coupling valves to obtain amplification. It may be applied to both radio-frequency and audio-frequency amplifiers. The resistances employed must be of the non-inductive type, and usually have a resistance of from 50,000 to 100,000 ohms.

Briefly, a resistance is connected to the anode of a valve, and the usual varying potential to the grid. Thus the latter causes currents to be impressed on the anode in step with those on the grid. As the resistance is connected in the anode circuit, the fluctuations of current in that circuit cause a varying P.D. across the resistance, and this varying P.D. is applied to the grid of the next valve. As the variations of P.D. across the resistance are greater than those applied to the grid of the same valve, it follows that amplification is obtained.

The method of operation of such a resistance-coupled amplifier may be best understood if reference is made to the diagram, Fig. 1. This is a theoretical wiring diagram of a resistance-coupled amplifier, in which an alternator, A, is used to produce the original current fluctuations. A resistance, R_1, is connected to the anode circuit of the first valve. It will be seen that this resistance is placed right across the anode to the filament circuit of the second valve, and that at the point N, which is the negative end of the resistance, the wire from the anode is continued past the resistance to join on to the negative terminal of a high-tension battery, and thence to the grid of the second valve. The other parts of this circuit follow standard practice, except that another high-tension battery, B_1, is connected between the other end of the anode resistance (point P) and the positive side of the first filament battery.

Referring now to the anode circuit of the first valve, let us assume that a current of approximately 1 milliampere is normally flowing round it. This current, which is an electronic current due to the first valve, will flow from the anode to the filament via the resistance R_1 and the battery B_1. It follows, therefore, that there will be a potential difference across the points N P, and that as the current flows from N to P, the point N will be negative with respect to P. The drop in volts across the resistance will be quite considerable, depending on conditions in the circuit.

Consider now the whole electronic circuit of the first valve. It will be seen that in reality there are two resistances: one, the resistance of the valve itself between filament and anode, which is variable, and the other the resistance R_1, which is fixed. The resistance of the valve is altered by varying the grid potential, this being increased when the grid is made negative, and decreased when it is made positive.



RESISTANCE COUPLING

Fig. 1. Alternator, A, produces current fluctuations. Resistance, R_1, is joined across the anode and filament circuits as shown

From this it will follow that the values of potential applied to the first grid will alter those across the resistance, for by giving a positive potential to the grid the anode current is increased, and the P.D. across the points N P will become greater.

It is now necessary to consider what happens when a positive potential is applied to the first grid. In the first place it will reduce the electronic flow through the first valve, and give a correspondingly lower potential across the resistance R_1. Thus the point N is now less negative with respect to point P than formerly. But normally the voltage of the battery B_2 is such that it just opposes that across N P, and normally, therefore, the grid G_1 will have zero potential. Now if the voltage across N P is reduced, the battery voltage (B_2) still remains constant. Thus the voltage of the battery now exceeds that across the resistance, and since the grid G_2 is connected to the positive end of B_2, it follows that the grid G_2 is positive.

From the foregoing it will be seen that since the step-up ratio of a valve between grid and anode is about five times, and since this increased value is applied to the grid of the second valve, and then amplified another five times by the second valve, a step-up effect of approximately 25 times is obtained by the use of resistance coupling.

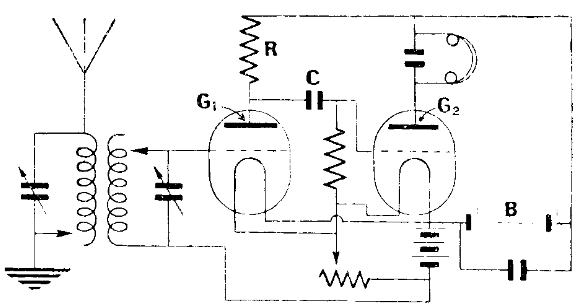
The diagram, Fig. 2, shows resistance coupling applied to an ordinary two-valve set in which the first valve acts as a high-frequency amplifier and the second as a detector. It will be seen that the application of the resistance involves no complication. The resistance is connected between the anode side of the condenser C and the telephones. High-tension positive is also connected to the same side of the telephones, and the opposite side of the latter to the anode of the rectifier valve.

Radio impulses from the aerial via the tuner are applied to the grid of the first valve. These are then transferred to the anode of the same valve, and thence to the grid of the second by way of the condenser C. The resistance R is in the anode circuit of the first valve, which includes the high-tension battery B. Thus the anode current from the battery has perforce to pass through the resistance, and therefore the potentials which occur across the resistance are applied to the grid of the second valve, and there rectified by the usual condenser and leak method. The condenser, however, in this circuit has another use besides assisting rectification, for it prevents current from the high-tension battery from being directly applied to the grid G_2.

High-frequency amplifiers of this type are frequently used for wave-lengths over 1,000 metres, but are not so useful on the higher frequencies corresponding to the shorter wave-lengths. The reason for this is that the comparatively small capacity existing between the filament and anode of the valve is sufficient to allow these high frequencies to pass, and as these electrodes are really shunted across the resistance, lower variations of potential are obtained across the resistances, with consequently poor amplification.—*R. B. Hurton.*

RESISTANCE WIRE. Wire specially manufactured to resist the passage of electricity. Such wires are invariably composed of alloys, for the latter always possess a resistance in excess of the metals of which they are composed. Further, alloys have the advantage of possessing a considerably lower temperature coefficient than pure metals, and are therefore more reliable, from the point of view of keeping a constant resistance value under normal conditions of service.

German silver (an alloy of nickel, copper and zinc) is frequently used as a resistance wire. It has a temperature coefficient of ·00044, which is approximately one-ninth that of an average of pure metals, and a specific resistance of 30 microhms per centimetre cube.



RESISTANCE COUPLING FOR A TWO-VALVE SET

Fig. 2. Here the first valve acts as a high-frequency amplifier and the second as a detector. Resistance is placed between condenser and telephones

One of the best-known and most widely used forms of commercial resistance wire is given the trade name of Manganin. This wire possesses the property of increasing in resistance with temperature from 0 degrees to 35 degrees centigrade, and slightly decreasing with temperature above that value. At all temperatures, however, its variation is so small that for all practical purposes it may be considered negligible.

Manganin is composed of 84 per cent copper, 12 per cent manganese, and 4 per cent nickel.

Another commercial form of resistance wire is Resista. This is an alloy consisting of 80 per cent iron, 15 per cent nickel and 5 per cent manganese. It has a specific resistance of four times that of german silver, and a temperature coefficient of ·00109.

Resistance wire may be obtained in all gauges generally used, either bare, or covered with cotton, silk or enamel. Its cost is somewhat greater than for a corresponding size of copper wire.

In wireless work one of the principal uses of resistance wire is for the windings of filament resistances and potentiometers. In both these cases bare wire is necessary. Resistance wire is invariably fairly hard and of a springy nature. It is therefore necessary to allow for this when winding a helix such as is used in filament resistances. Generally it will be found that it is necessary to make the mandrel on which the wire is to be wound about 20 per cent smaller than the finished size. If the wire is pulled very tightly during the process of winding, the finished product will be approximately of the correct diameter.

When winding resistance wire upon a solid former, such as ebonite or slate, it is a good thing to heat the wire slightly whilst it is being wound. This will cause it to expand, and thus, when fully wound, it will cool, contract in the process, and grip the former very tightly. If this is not done, it is quite probable that in the finished article the wire will be loose, with resultant bad contact with the slider and a poor appearance. The heating of the wire during the process of winding may best be accomplished by placing a lighted bunsen burner between the point where the wire leaves the hand and the point where it is being wrapped round the former.

Relative resistances of commonly used metals at a given temperature of 6° F., compared with silver at 1·00:—

Silver	1·00	Iron	6·6
Copper	1·05	German silver	16·0
Aluminium	1·96		approx.
		Platinoid wire	24·0

Resistances of platinoid wire per yard:—

	Ohms per yard.		Ohms per yard.
No. 26 S.W.G.	2·28	No. 20 S.W.G.	0·56
„ 24 „	1·52	„ 18 „	0·32
„ 22 „	0.94	„ 16 „	0·18

Eureka resistance wire has 15 per cent higher resistance than platinoid. Safe carrying capacity of resistance wire (platinoid):—

	Amps.		Amps.
No. 26 S.W.G.	0·5	No. 20 S.W.G.	2·5
„ 24 „	0·8	„ 18 „	4·0
„ 22 „	1·5	„ 16 „	8·0

See Wire.

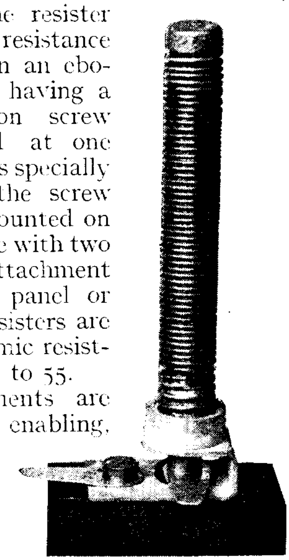
RESISTER (BURNDEPT). Fixed resistance used in place of a filament resistance.

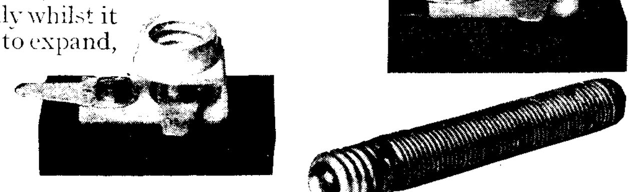
Figs. 1 and 2 are views showing the Burndept resister in and out of its socket, respectively. The resister itself is a coil of resistance wire wound upon an ebonite former and having a miniature Edison screw holder attached at one end. The holder is specially made to take the screw fitting, and is mounted on a block of ebonite with two screw holes for attachment to any desired panel or cabinet. The resisters are supplied with ohmic resistances of from ·03 to 55.

These instruments are very useful for enabling, say, an M.O. D.E.3 valve to be run off a 6 volt accumulator. To calculate the resistance required, it is first necessary to consider the voltage drop necessary. In this case it is from 6 volts to 3 volts, *i.e.* 3. The rule to be followed is

$$\frac{\text{Volts to be dropped in resister}}{\text{Amperes taken by valve}} = \frac{3}{\cdot 06} = 50 \text{ ohms.}$$

This figure includes the filament resistance, if any, and therefore the latter figure must be deducted.





BURNDEPT RESISTER

Fig. 1 (above, right). Complete resister fixed in its base
Fig. 2 (below). Resister coil apart from its socket. It is wound on an ebonite former

Courtesy Burndept, Ltd.

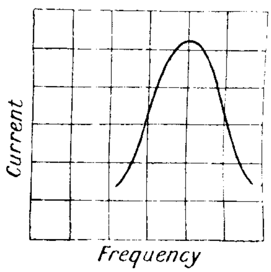
RESONANCE. A condition existing in an electrical circuit where the frequency of the electro-motive force applied is the same as the natural frequency of that circuit. The effect of this is to make the current co-phasal with the electro-motive force.

An effect of resonance in a circuit is to bring the reactance due to inductance to be exactly neutralized by the reactance due to capacity; therefore there is zero reactance and the impedance is equal to the resistance.

The term resonance is extended to apply to two or more circuits, in which case circuits are said to be in resonance when they both possess the same natural frequency. *See* Beat Reception; Frequency; Heterodyne; Lag; Oscillation; Power Factor; Syntony; Tuning.

RESONANCE CURVE. This is a curve showing the relationship between the current induced in an oscillatory circuit and the frequency of the inducing current.

It is well known that if two oscillation circuits are placed near each other so that they have a mutual inductance, then if oscillations are set up in one circuit, oscillations are induced in the other circuit. These oscillations in the second circuit may be feeble or strong, depending upon whether the second circuit is out of tune or in tune with the first. By varying the capacity or inductance of the second circuit it may be brought into tune with the first.



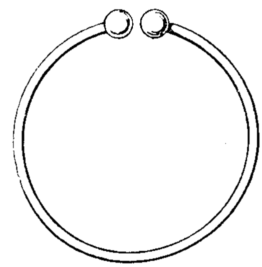
RESONANCE CURVE

Curve showing relationship between current induced in an oscillatory circuit and the frequency of the inducing current

If the current in the second circuit is measured at any series of instants and the oscillation constants are also noted, then the resonance curve can be plotted, the ordinates representing the current, and the abscissae the corresponding natural frequency of the second circuit. The figure shows such a curve. It will be noticed that it rises sharply to a peak and then falls again. The maximum value of the curve is at that point where the second circuit is in tune with the first. An oscillation in which the capacity and the inductance or either may be altered so as to give the circuit any known oscillation constant is known as a cymometer or wave-meter. *See* Cymometer; Wave-meter.

RESONANCE TRANSFORMER. Any transformer possessing the property of resonance. The term might conceivably be applied to any form of loose-coupled tuning inductance with a variable condenser in both primary and secondary circuits. In an arrangement of this sort the secondary circuit is "tuned with" or brought into resonance with the primary. When this is done the coupling between the circuits is at its point of maximum efficiency and signals are heard at their greatest strength. *See* Transformer.

RESONATOR. Device for detecting by resonance oscillations produced by an oscillator. The Hertzian resonator ring consists merely of a circle of stiff wire which is broken in one place by a small pair of spark balls, as shown in the figure, and was given the name of resonator by Hertz. He used it in conjunction with his open circuit oscillator to detect electro-magnetic radiation. The resonator detected on very much the same principle as the modern form, the frame aerial, does as a direction finder. As the position of the plane of the resonator was varied relative to the position of the oscillator, so sparks were made to pass between the balls of the resonator when it was at a certain predetermined distance away from the oscillator.



RESONATOR

Hertzian resonator ring used to detect electro-magnetic radiation

The term resonator is also used in connexion with a low-voltage incandescent bulb of the carbon filament type placed in inductive relation to a part of the aerial circuit. When the latter is energized the filament will glow, and it will reach its climax of incandescence when the greatest amount of energy is being radiated. *See* Hertzian Oscillator; Oscillations.

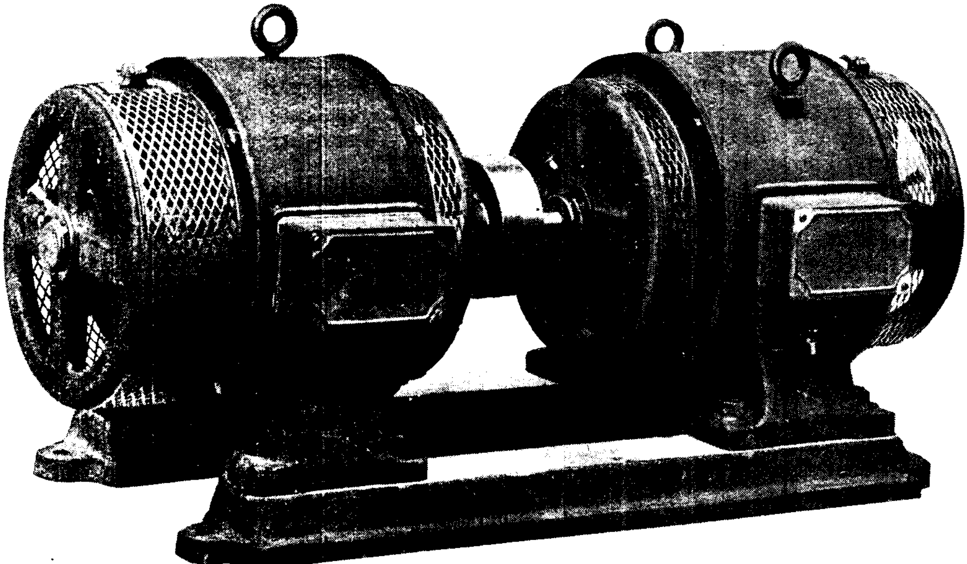
RESPONDER. This is the old name once used by De Forest for his detecting valve. *See* Audion.

RETENTIVITY. The property of retaining magnetism possessed by soft iron and other materials. *See* Residual Magnetism.

RETROACTION. This is an expression which is sometimes used instead of regeneration (*q.v.*).

RETURNED CURRENT. That portion of the current which flows back to the source of supply upon the discharge of a circuit having electrostatic capacity.

REVERSIBLE BOOSTER. Name given to a booster used in generating stations to raise the pressure of accumulators during discharge, and to raise the pressure of the generator during their charge. The photograph is an illustration of a reversible booster by the Crypto Electrical Co., Ltd. It will be seen that the machines are of the semi-enclosed type and directly coupled, being mounted on a common bed. The covers on the brush ends of the machines are quickly removable for inspection of the brush gear, and they are perforated to allow of efficient ventilation. Both machines run on ball bearings, which allow of very long running periods without attention or constant lubrication. A flange coupling is employed between the two machines. *See* Booster.



REVERSIBLE BOOSTER

Above is shown the semi-enclosed type of reversible booster, in this case directly coupled. The machine is used in power stations to raise the pressure of accumulators during discharge

Courtesy Crypto Electrical Co., Ltd.

R.F. This is the usual abbreviation for radio-frequency. H.F. or high frequency is the same thing. *See* High Frequency.

RHEOSTAN. Name given to an alloy of copper, zinc, nickel, cobalt and manganese used for resistances. The composition percentages vary considerably, with a corresponding variation in the electrical properties of the alloy. Taking copper as unity, its resistance varies from 30 to 62, and its carrying capacity compared with copper varies from ·13 to ·183.

RHEOSTAT. Any variable resistance, joined in series, used to vary the current flowing in a circuit. In wireless the name is generally used as a contraction for filament rheostat or filament resistance, and under that heading in this Encyclopedia a number of types of such resistances are described.

Rheostats are used with electric motors, for starting them and for controlling their speed. These motor rheostats are built on a much larger scale than other resistances, and the resistance elements are in the form of cast grids of iron or resistance alloy for heavy currents, or in the form of woven sheets of resistance wire and asbestos or of wire embedded in earthenware and similar forms for smaller currents. Special resistance wire is used for winding the ordinary filament resistances used in wireless.

A type of commercially made rheostat is shown in Figs. 1 and 2. The resistance wire is wound on a slate former of oblong construction, and is bolted to the panel, the bolts passing through holes at the ends of the former. To prevent movement of the wires when the contact arm runs over them, they are laid in channels in the former.

The contact arm is shown in Fig. 1, the spindle of which is centrally situated and a little distance from one side of the

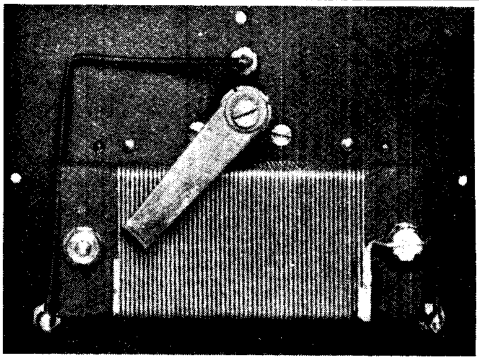


Fig. 1. Contact arm and oblong resistance are mounted on ebonite in this rheostat. The former is made of slate

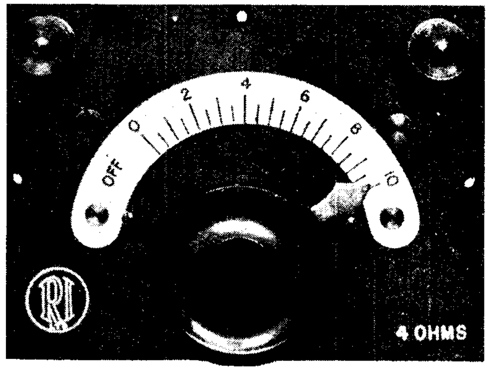


Fig. 2. Front view of Fig. 1. The instrument has a maximum resistance of 4 ohms

Courtesy Radio Instruments, Ltd.

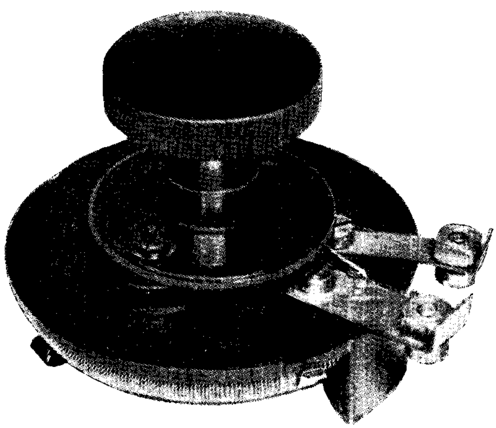


Fig. 3. Two resistance coils, placed on either half of the former, are used in this Burndept dual rheostat for different resistances

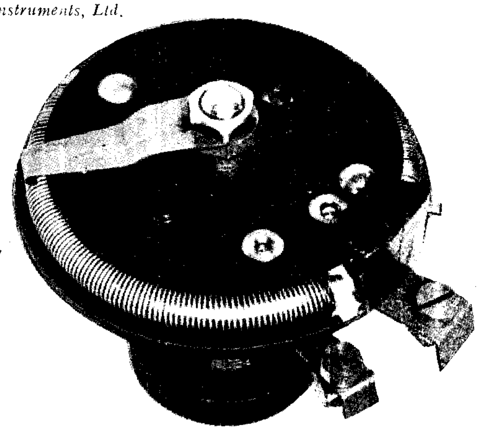


Fig. 4. One coil in the Burndept dual rheostat is of high resistance and the other low, thus making it practicable to use it with different types of valves

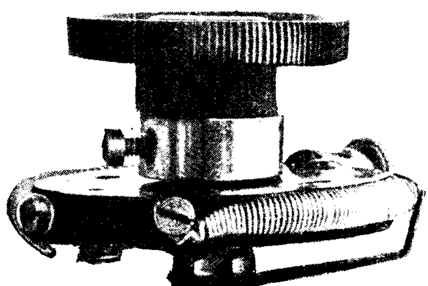
COMMERCIALLY MANUFACTURED RHEOSTATS

resistance former. Connexions to the terminals seen on the outside of the instrument, in Fig. 2, are made to the contact spindle and one end of the resistance wire.

A knob and pointer are attached to the spindle, the latter moving over a graduated dial. This type of rheostat gives a smooth action, and owing to its robust construction is not likely to get out of order.

A type of dual rheostat is shown in Fig. 3. In this, two resistance coils are used, and are placed on either side of the resistance former. The rotating arm seen in Fig. 4 is capable of movement over either resistance coil as desired. Connexion to the instrument is made to two small bolts attached to the ends of two brass strips secured to the resistance former. This rheostat is useful in filament circuits where different valves are likely to be used, as either a low or high variable resistance is available.

A novel and easily constructed rheostat is shown in Fig. 5. Two resistance springs



HOME-MADE RHEOSTAT

Fig. 5 Two separate resistance coils are used, both being wound on a single former are arranged on either side of an ebonite former, one having a considerably higher resistance than the other. One end of each spring is held under the bottom of a terminal screwed to the edge of the resistance former. The other ends of the resistance wires are tapered and secured to the resistance former by means of two small screws. The usual form of contact arm is provided, the off position of which is found between the resistance springs. A stop peg is provided between the commencement of each spring, and retains the contact arm in either section of the resistance former. A hole in the panel to which the rheostat is fixed enables the stop peg to be operated from the outside of the panel.

This type of rheostat is of particular use where a coarse and fine adjustment is required. It also permits the use of valves requiring different voltages, such as the ordinary R and the dull emitter valve.

From the above description, and with the assistance of the illustration of the completed rheostat in Fig. 5, the common commercial types of rheostat may be adapted for the purpose.

For an entirely home-made rheostat, a disk of $\frac{1}{4}$ in. ebonite is cut to a diameter of 2 in. and a groove made in its edge having a radius of $\frac{1}{8}$ in. The resistance springs will remain in this groove without further support when fixed at either end.

A central hole of $\frac{3}{16}$ in. diameter is drilled through the centre of the resistance former, on either side of which a small hole is drilled so that the two fall in a line with the central hole.

These holes may be countersunk on one side, and are used for fixing the rheostat to

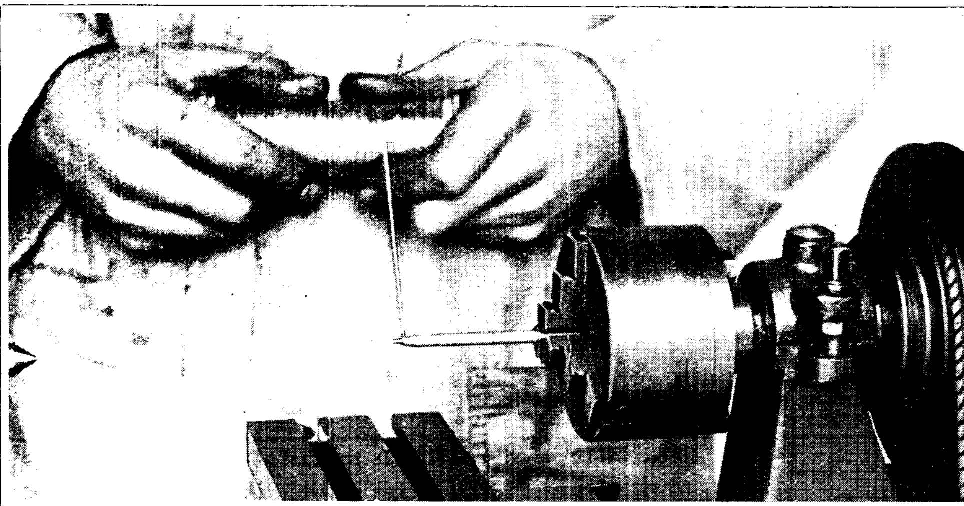


Fig. 6. A lathe is used in winding the resistance coils. The wire is wound on a steel rod former

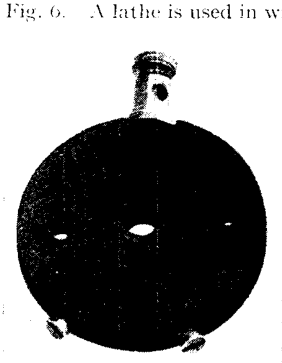


Fig. 7. The terminal is seen fixed on the former ready for the attachment of the resistance coils

Fig. 8. Binding the end of the coil under a round-headed screw. The two screws are about $\frac{1}{2}$ in. apart

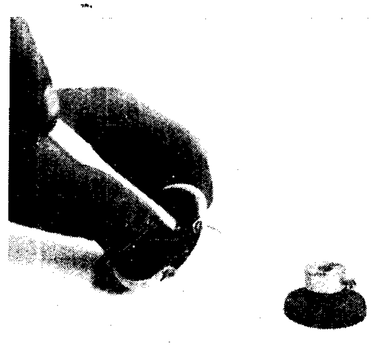


Fig. 9. Here the brass strip, by which contact is made to the spindle, is being fixed in position

BUILDING UP THE HOME-MADE RHEOSTAT

a panel or other mounting. The former ready for attachment of the resistance wires is clearly shown in Fig. 7.

The gauge of wire to be used on the resistance will depend on the purpose for which it is required. For ordinary purposes No. 26 Eureka resistance wire will be found suitable for the higher resistance coil, using as much wire with as little spacing between the turns as possible.

The coil of lower resistance may consist of No. 20 or 22 Eureka resistance wire. The coils are wound on steel rod formers and are best wound in a lathe. This operation is shown in Fig. 6, where the steel former is gripped in the lathe chuck, the commencement of the wire being wedged during the winding process between the chuck jaws. The external diameter of the finished resistance should be about $\frac{1}{4}$ in. to $\frac{3}{8}$ in.

It follows that the steel former used for the coil of thicker wire will be of smaller diameter in order to obtain the same external diameter in both coils. The end of the winding in each case is finished off with a spiral in order to obtain a smooth contact when the contact arm is moved on to the coil. The spiral ends of both coils are attached to the rheostat former by two small round or cheese-head screws placed $\frac{1}{2}$ in. apart in the bottom of the groove.

Both coils are now wound round the former and secured at equal distances on the other side of it by a terminal, to which connexion from the battery is made. Fig. 8 shows the fixing of the resistance wires to the former. The contact arm is made from springy sheet brass and is clamped between two locking nuts on a short length of 2 B.A. screwed rod. A spring washer is slipped over the spindle, which is now pushed through the central hole. It is secured on the other side by a large round washer locking rigidly with a brass-bushed ebonite knob. If an indicating pointer is desired it is clamped up between the round nut and the knob.

Contact to the rheostat is made to the terminal and the centre spindle. In the latter case contact may be made with an insulated flexible lead soldered to the end of the spindle. Alternatively, a brass or copper strip may be slipped under the contact arm locking nuts; this is held by a small screw at the other end, and connexion made by a wire fastened under the screw head. The assembly of the contact arm is shown in Fig. 9. *See* Filament Resistance; Resistance; Resistance Box; Resistance Wire.

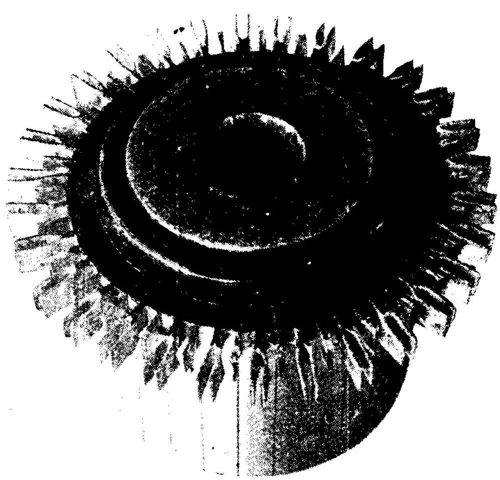
RHEOSTENE. Name of a nickel-steel alloy which is largely employed in the making of resistances. Its conductivity at 0° C., silver being taken at 100, is 1·92. Its specific resistance in legal microhms is 77·07.

RIGHT-HAND RULE. Rule for determining the mutual directions of magnetic lines, the movement of a conductor cutting these lines, and the direction of flow of the induced current. *See* Fleming's Rule.

RING ARMATURE. This is another name for a Gramme armature, which has its windings wound spirally round an annular ring or cylindrical core. *See* Converter, Rotary; Gramme Ring Armature.

RISERS. Metallic strips attached to one end of commutator bars to which are attached the ends of the armature windings.

The photograph clearly indicates the construction of commutator risers. It will be seen that the rear of the commutator segments are of larger diameter than the main body. A saw-cut is made into the centre of each extended portion and into each saw-cut are soldered two strips of copper. The open ends of each strip are bent outwards as indicated, in order to receive the ends of the armature conductors. Between each segment the mica insulation is extended between the metal risers. By this means further insulation, external to the commutators, is provided. *See* Commutator; Dynamo; Generator.



COMMUTATOR RISERS

These metallic strips are attached to one end of the commutator bars and the armature windings are fixed to them

R.M.S. This is the usual abbrevation for root mean square (*q.v.*).

ROBERTS, JOSEPH HARRISON THOMSON. Born in 1890, he was educated at Liverpool and Cambridge Universities, where he took first-class honours in physics and was made a fellow and given a lectureship in physics. He carried

DR. J. H. T. ROBERTS
Well-known scientist and inventor, and expert in electrical sciences. He is a contributor to this Encyclopedia

out much physical research at the Cavendish Laboratory, Cambridge, for several years, and has done a large amount of work on thermionics and other wireless problems. He is a doctor of science and a Fellow of the Institute of Physics; an inventor with several wireless patents to his credit, and an expert in electrical, optical and acoustical sciences.

Dr. Roberts practises as a scientific consultant, being scientific adviser to several industrial concerns. He has written largely on technical subjects, and has contributed the articles on Electricity, Magnetism, and the Quantum Theory to this Encyclopedia.

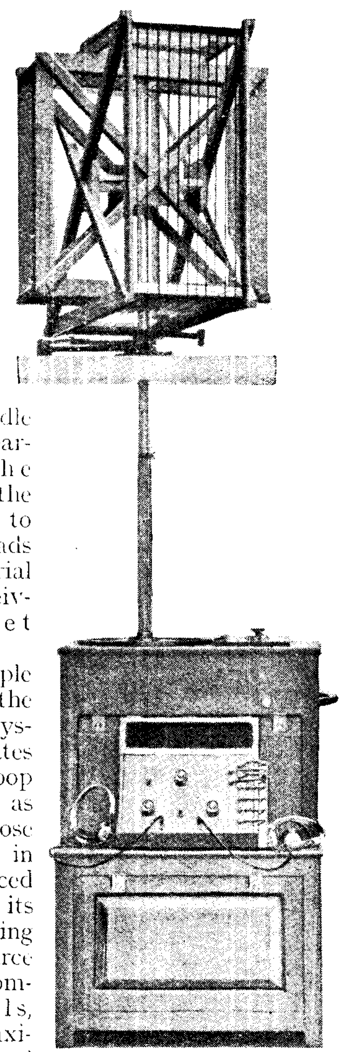
ROBINSON, JAMES. British wireless inventor. Born in 1884, he was educated at Durham and Göttingen Universities. He was appointed lecturer in physics at Durham University 1906–7, lecturer in physics, Sheffield University, 1910-12, and lecturer in physics at the East London College, London University, 1912-15. He made a study of wireless, and was appointed chief experimental officer at the Instrument Design Establishment, Biggin Hill, 1920–22, and chief of the department for wireless at the Royal Aircraft establishment, Farnborough, 1922.

Robinson is well known for his direction-finding apparatus, separately described in this Encyclopedia. He is a member of the Radio Society of Great Britain.

ROBINSON DIRECTION FINDER. Type of direction finder due to Dr. Robinson and manufactured by the Radio Communication Co., Ltd. It differs from the Marconi system in that the aerial system itself rotates.

The aerial system of the Robinson direction finder is illustrated in Fig. 1. Two frame aerials are used, and they are arranged at right angles to one another. The relative position of the aerials is rigidly fixed, and the whole is mounted on a vertical tubular spindle with ball bearings. The interior of the tube is used to carry the leads from the aerial to the receiving cabinet below.

The principle upon which the Robinson system operates is that if a loop aerial, such as one of those illustrated in Fig. 1, is placed with one of its edges pointing to the source of the incoming signals, then maximum signal strength will be obtained. Conversely, if



ROBINSON D.F.
Fig. 1. Two frame aerials, set at right angles to each other, are employed

the aerials are placed at right angles to the plane of the incoming signals, then no energy will be picked up and no signal will be heard. Only the directional plane of the signals is located and not the actual direction.

From this it follows that there are two obvious ways of ascertaining the directional plane of signals. The first is to note the plane in which the aerial is pointing when signals are at a maximum strength, and the other to note its plane when signals are at a minimum strength, and add or subtract 90 degrees. The latter is known as the null point method.

It is upon the former system that the Robinson apparatus works, and it is claimed that this is the better method for three reasons. The first is that when the aerial is in the null position and the signals are weak, the null point may extend over a considerable number of degrees on either side of the correct point. Secondly, signals are so weak when in that position that they cannot always be read; and, thirdly, given weak signals and strong atmospherics, the latter are likely to render the signals inaudible.

In the standard Robinson direction finder the aerials used are approximately 2 ft. 6 in. square, and on normal work it will produce a signal of audible strength. Both aerials are connected in series, but a switch is fitted by which the connexions of the second may be reversed at will. Thus, should a signal be picked up in the loops, the induced voltage may be the sum or difference of that in the two coils, depending upon which way round the second aerial is connected.

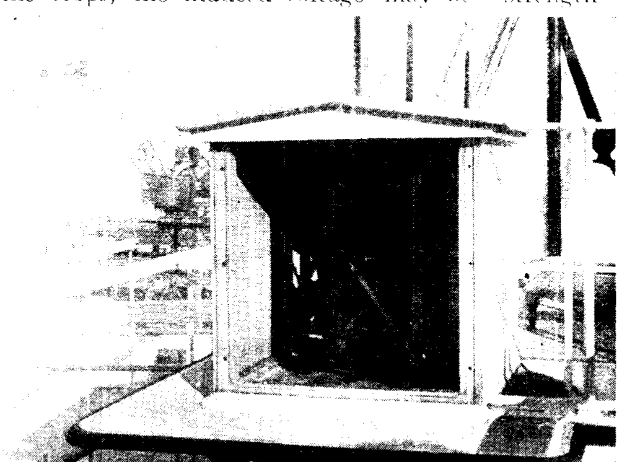
Generally, it will be found that signals will be stronger with the switch in one position than in the other, and should the coils be rotated so that the induced voltage in the loop connected to the switch is zero, then it follows that no change in signal strength can possibly occur through reversing the switch. It is when the aerials are in that position that bearings are taken, for in that position only will no change in signal strength be felt.

Reference must again be made to Fig. 1. Here is shown how the aerial spindle is attached to the top of the receiving cabinet. At the bottom of the spindle and surrounding it is a large dial, divided into 360 degrees. The latter is fixed after erection in the ship, and its zero to 180 degrees diameter is placed in a direct line with the keel of the ship. A pointer moves with the aerials and indicates the relative positions with the fore-aft line of the ship.

DIRECTION FINDER IN USE

Fig. 3. Six valves are employed in the receiver used in conjunction with the direction finder. The telephones are seen plugged in

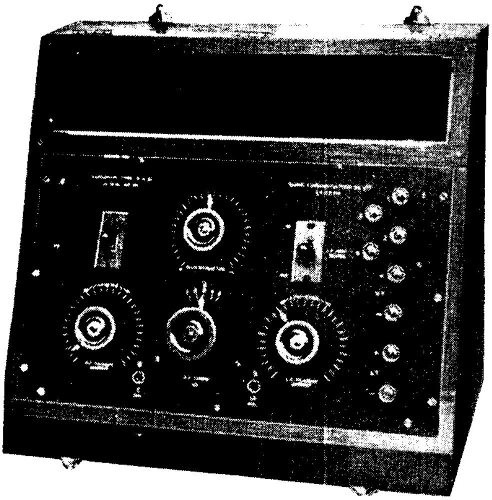
Courtesy Radio Communication Co., Ltd.



DIRECTION FINDER COMPARTMENT

Fig. 2. The aerials are housed in a special watertight compartment situated on the roof of the chart-room of the vessel

Courtesy Radio Communication Co., Ltd.



ROBINSON RECEIVING SET

Fig. 4. Used with the Robinson D.F. this valve amplifier has one stage of rectification and five stages of amplification

The Robinson system provides only for ascertaining the directional plane of the signals, and not the actual direction of the source, so that when taking bearings the aid of a compass is called for. The apparatus is under direct supervision of the navigating officer, and is located in the chart-room. Fig. 2 shows how the aerials are housed in a watertight compartment situated on the chart-room roof.

A good general idea of the receiver cabin is given in Fig. 3. The tuning arrangements of this receiver are very simple, being mainly operated by a condenser and variometer. A normal wave-length range of 600–800 metres is given. Fig. 4 is a close-up view of the receiver-amplifier. The receiver has one rectifying valve and five amplifiers employed for the H.F. and L.F. sections, and a switch for the low tension is fitted. The latter affects all valves. *See* Bellini-Tosi Aerial; Direction Finder; Frame Aerial.

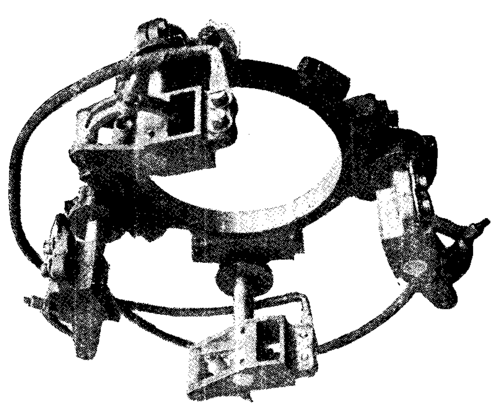
ROCKER. A casting which is fixed to the casting of a dynamo or motor with insulated standards for retaining the brush holders in position. It is capable of variation in position in order to obtain correct commutation.

The photograph is an illustration of a standard form of brush rocker by the Crypto Electrical Co., Ltd. The brush holders are supported on pins attached at equal spaces around a main circular casting. The latter is split at one point, and the tightening screw fitted in order that it may be set at any required position round the motor body casting.

Insulation is fitted between the main casting and the points at which the brush-holder pillars are attached. Thus each brush is electrically isolated as regards the main casting. At the end of each of the four pillars will be seen the box castings forming the carbon brush holders. The brushes are made a sliding fit within the holders, and are pressed against the surface of the commutator by the spring-tensioned levers shown. No brushes are fitted in the rocker shown in the illustration. Opposite brush holders are connected by the heavily insulated cable which can be seen in the photograph. *See* Brush.

ROD OSCILLATOR. Name sometimes given to the ideal form of oscillator, which consists of two equal and opposite electric charges on two small spheres separated by a short linear conductor which has a spark gap in it. This ideal form is useful for discussing the theory, but in actual practice the nearest approach to it is the vertical wire or rod having a spark gap at its lower end and the lower spark ball connected to the earth. It is really only half a complete linear oscillator. *See* Electrolines; Hertzian Oscillator; Oscillation.

RONTGEN RAYS. Phenomena which occur when an electric charge passes through a highly rarefied vacuum, as in a Crookes's tube. The discovery of these rays was announced by Röntgen, and called by him X-rays. Röntgen found that these



BRUSH ROCKER

Supported on a main circular casting, the brush holders occur at equal intervals round the circle

Courtesy Crypto Electrical Co., Ltd.

rays penetrated many substances which were opaque to ordinary light, as wood and paper and human flesh, while other substances, as bone and metals, were comparatively opaque to the rays. Moreover, the rays affected a photographic plate, so that it was possible to obtain a photograph of the hand or any other part of the human body, showing a dim outline of the flesh and a strong outline of the bones or any foreign metallic substance, as a bullet, embedded in the body, a discovery of great importance in surgery.

Röntgen showed that the rays emanated from the portion of the tube on which the cathode rays impinged and generally whenever the cathode rays encountered an obstacle. Sir G. G. Stokes has formulated a theory of the rays which has received experimental confirmation. He suggested that the rays are electro-magnetic waves produced by the sudden stoppage of the electrons which form the cathode rays. *See* Cathode Ray; Oscillograph; X-rays.

ROOT MEAN SQUARE. The root mean square value of an alternating current is the effective value of the voltage or amperage of the current.

The root mean square value of an alternating current is a convenient way of expressing the effective value of the current. Both the voltage and amperage of a current delivered by an alternator are constantly varying from zero to a maximum value, and at any instant of time it is clear that the measurements of these two values would not give the real output of the machine.

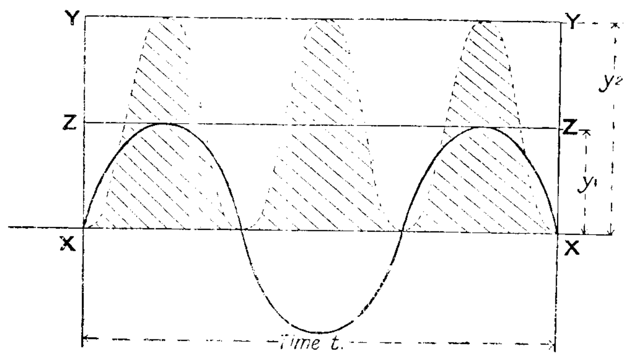
As an example, an alternator may be rated to produce current at 100 volts, and it will indicate such a voltage on a voltmeter or will light lamps of this voltage. It is the effective voltage of the alternator, but it is not the maximum voltage which would be given by a voltage curve. As a matter of fact it is only 70·7 per cent of the maximum, so that the true maximum of the alternator is 100/·707 volts, or 141·4 volts.

This constant ·707 by which the maximum value of the voltage or amperage must be multiplied to give the effective voltage or amperage is called the square root of the mean squares, or the root mean square, and the effective voltage or amperage is called the root mean square voltage or amperage. It is so called because it can be obtained by squaring a number of instantaneous values in a cycle, finding the average of these squares, and taking the square root of this average.

The root mean square value of an alternating current can be obtained by comparing the current with a direct current which produces the same heating effect in a conductor. In actual practice the maximum value of an alternating current, that is, the value it reaches at the top of each half-cycle of the current curve, is not measured. If an alternating current were passed through a moving coil ammeter or voltmeter, the coil and the pointer would receive a rapid series of impulses first in one direction and then in the opposite. These impulses are so rapid that the coil is unable to respond to them in the time, with the result that in actual practice it would remain stationary, and the pointer would register no voltage or amperage. That is why the value of the current is obtained by its heating effect upon a known resistance.

A suitable instrument for the purpose is the hot-wire ammeter. In this case, though the alternating current is continually varying in value from zero to a maximum and back again, there is an average heating effect which enables a reading to be obtained. This average heating effect gives the average value of the alternating current, as it were.

The way this average heating effect is connected to the root mean square value is as follows: The power expended



ROOT MEAN SQUARE

The sine curve appears in heavy line; X X is the line of reference; Z Z represents a steady current of *y* amperes in producing heat by a current of I amperes in a resistance of R ohms is I^2R watts, that is to say, the heating effect varies as the square of the value of the current.

Now consider the diagram. X X is the line of reference, and the usual sine curve representing the alternating current is shown in heavy outline. Z Z is a line parallel to X X representing a steady current of y amperes, and Y Y is a line drawn parallel to the axis at a distance y^2 from it.

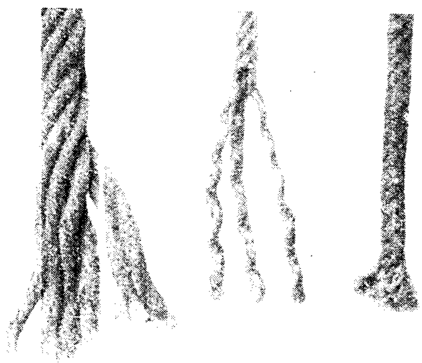
The alternating current rises to a maximum value of y amperes. Now, if the values of this alternating current at all points on the heavily lined curve are squared and a new curve plotted, we shall obtain a curve shown in dotted outline and shaded. This rises to a maximum of y^2 and falls to zero; but is always positive, since the square of a negative quantity is positive as well as the square of a positive quantity. The shaded curve then represents the squares of the value of the alternating current at all points in its cycle, while the straight line Y Y represents the squares of the constant value of direct steady current of y amperes.

But it has already been pointed out that the heating effect of a current varies as the square of its value. The shaded curve, therefore, represents the heating effect of the alternating current, and the straight line Y Y of the steady current. Each of the three shaded portions represents the heat produced by one and a half cycles of the alternating current.

It may be shown that the shaded area is equal to half the area X Y Y X. Also if the alternations of current shown take place in t seconds the area X Y Y X equals I_m^2Rt joules where I_m is the maximum value of the current. Now the heating effect is given by the effective value of the current, which we have said is the root mean square value. This value has been called I, and the shaded area is I^2Rt joules. But this shaded area is half that of the area X Y Y X. Therefore I^2Rt must be equal to half I_m^2Rt, or I^2 must equal $\frac{1}{2}I_m^2$. That is I, the root mean square value of the current, must equal I_m divided by the square root of two, or $\cdot707I_m$. This value, it will be noticed, has been obtained from the shaded curve which was obtained by plotting the squares of all the values of the alternating current curve. In other words, I is the square root of the mean of all the squared values given by the curve, and is for this reason called, shortly, the root mean square value. It is also spoken of as its effective or virtual value.

The root mean square value of an alternating current is used for power calculations, and for finding the sizes of cables necessary to carry certain currents. Where it is a question of calculating the thickness of an insulation necessary or the strength of a dielectric and similar things, the maximum values of the alternating current are taken. *See* Alternating Current.

ROPE. Usually, ropes are made with hemp, jute or other material which is spun into yarn. The yarns are wound and then made into strands, from which the rope itself is made. The term is generally applied to cordage that is larger than 1 in. in circumference, but the expression is rather loosely employed.



ROPES FOR WIRELESS

Three useful types of rope: right, plaited cord; centre, three-strand rope; left, ordinary seven-strand cable

In wireless work, ropes are chiefly used for the support of an aerial, for staying the mast, or for similar work. Three types that can be employed in this connexion are illustrated. The simplest form is the three-strand rope shown in the centre. On the right is a plaited cord, and on the left a seven-strand cable.

A hawser-laid rope is made of three strands of hawse made of hemp. The rope is laid out or twisted either right- or left-handed, according to the way in which the strands are laid. The rope is always twisted in the opposite way to the strands. Shroud-laid rope consists of four strands and a heart or centre, and is usually laid out right-handed. Cable-laid rope consists of three hawser-laid ropes laid out left-handed. The plaited rope or cordage is generally used in wireless work for light duties, such as the halyards for hauling up aerial spreaders and such work.

Wire ropes are made from steel wire and some commoner qualities from galvanized iron wire, which can also be used for support for an aerial mast. Flexible steel wire rope is very much stronger than the corresponding size of hempen rope. The strength of a rope is that of its weakest part. A splice in a rope weakens it by about 15 per cent. A practical rule for ascertaining the strength of hawser-laid ropes is to multiply the circumference in inches by itself and divide by 6, the result being the working strain in tons.

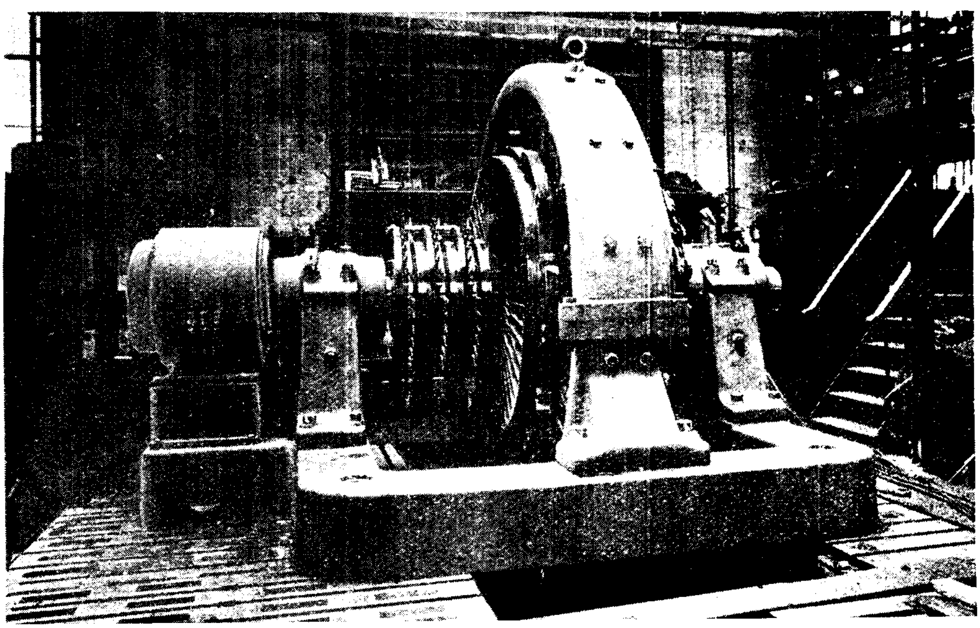
The experimenter will always do well to use a rope with an ample margin of safety. The ropes are often tarred or treated with linseed oil to add to their longevity, this being a desirable procedure to follow when the rope is to be placed in an exposed position, as it virtually increases its strength.

As regards the strength of ropes, this is best ascertained from the merchant at the time of purchase, as it is found to vary with the material. Normally, a good, tarred hemp rope 2 in. in circumference, weighing about half a pound to the yard, would have a breaking strain of about one ton. The equivalent size of ordinary galvanized wire rope with an equivalent breaking strain would be 1 in. in circumference. Tough steel wire rope with an equivalent breaking strain would only measure about $\frac{5}{8}$ in. in circumference and weigh about 3 oz. per yard of length. For these reasons the use of wire rope for aerial mast support is preferable, as there is less windage, greater durability and less weight for a given strength. *See* Cordage; Wire.

ROTARY CONVERTER. Machine for converting alternating current into direct current or vice versa.

There is very little difference, electrical or mechanical, between A.C. and D.C. generators or D.C. motors, and a rotary converter may be described as a combination of all. Therefore, in order to understand the working of a rotary converter, it is necessary to consider briefly the principles of these other machines.

In the first place, a dynamo generates current because of the conductors in the armature cutting the lines of force due to the field magnets, and A.C. and D.C. machines are the same in that respect. Fundamentally, the only difference is that the former have a commutator (*q.v.*)



LARGE ROTARY CONVERTER

Fig. 1. Direct current is converted into alternating current by these machines, and the one shown is capable of dealing with very high voltages. In the photograph the A.C. end of the machine is more clearly visible than the D.C. end

Courtesy General Electric Co., Ltd.

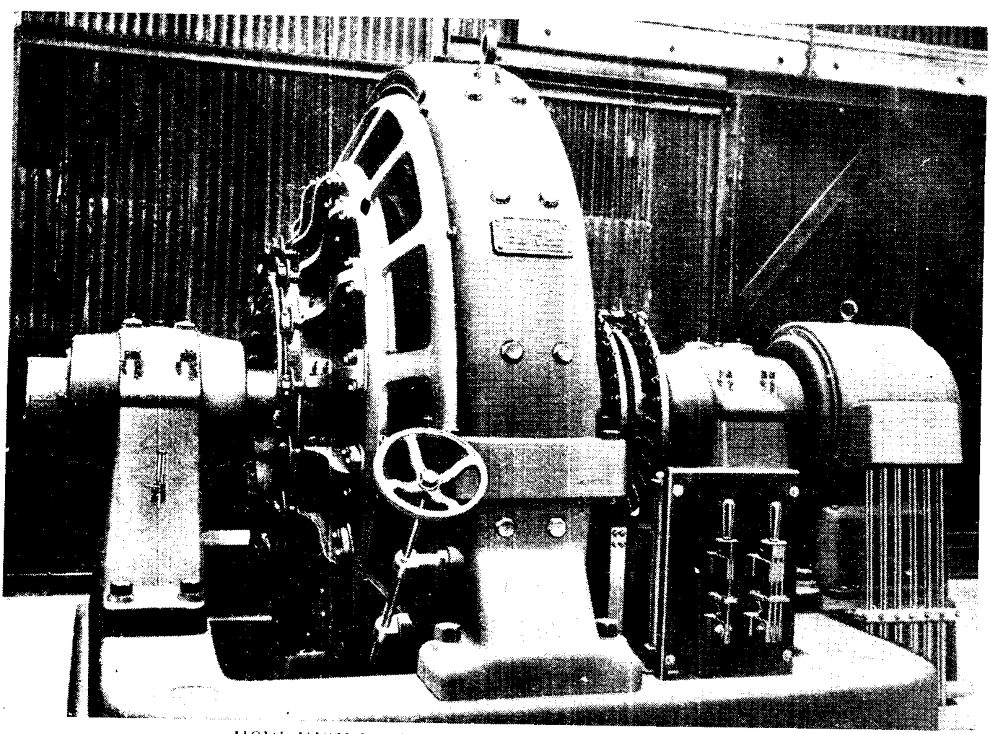
and the latter slip rings (*q.v.*). Moreover, if a machine were constructed having a commutator at one end of the shaft and slip rings at the other, the latter connected to certain points on the windings, then it would be a machine capable of delivering both A.C. and D.C. Such a machine, if driven by an engine or turbine, would be known as a double current generator.

In the rotary converter, however, direct current is applied to the commutator through the medium of brushes, and by this the machine is made to rotate. Thus the D.C. part of the machine is used as a motor. Then, the slip rings at the other end of the machine are connected to a suitable external circuit, and alternating current is drawn from them, and thus that end of the machine becomes an alternator.

Two views of a large rotary converter, suitable for the conversion of heavy currents at comparatively high voltages, are given in Figs. 1 and 2. Fig. 1 shows the A.C. end more clearly, and Fig. 2 the D.C. end. An interesting point is the relative sizes of the collecting gear for the different kinds of current. This machine has a separate dynamo at one end of its armature shaft, which generates D.C. for energizing the fields.

Fig. 4 shows a small rotary converter of the commutating type, manufactured by S. W. Woods. This machine is specially made to supply the wants of the amateur who wishes to charge his own accumulators from the A.C. mains. It is made in a variety of different input and output voltages, so that individual requirements may be met.

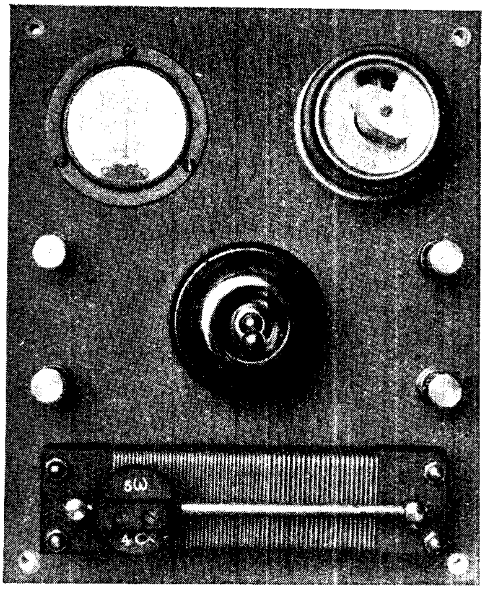
The machine consists of a small synchronous motor mounted upon a heavy cast-iron box-bed, which contains a step-down transformer. As the motor is not self-starting, it is necessary to give the hand wheel, at the farthest end of the armature spindle, a turn by the fingers immediately after closing the starting switch shown on the side of the bed-plate. Immediately this is done the motor runs up to synchronous speed, driving with it the commutator shown on the left-hand end of the shaft. The segments of the latter



HOW HIGH-VOLTAGE CURRENT IS CONVERTED

Fig. 2. Another view of the large rotary converter illustrated in Fig. 1; the D.C. end here is more prominent. A separate dynamo is fitted for generating D.C. to energize the fields

Courtesy General Electric Co., Ltd



CHARGING BOARD

Fig. 3. On this charging board the charge and discharge Weston ammeter is shown on the top left corner of the slate mounting

Courtesy S. W. Woods, Ltd.

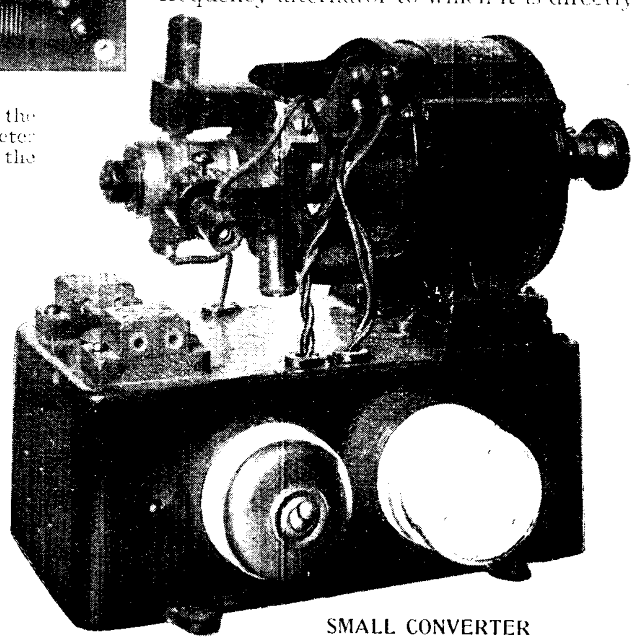
are so arranged that when alternating current is fed to it, the motion of the commutator passing beneath the brushes immediately causes the current to be changed from A.C. to D.C. The degree of rectification obtained is quite sufficient to permit of the efficient charging of accumulators.

This machine has long bearings and a comparatively large diameter shaft, which allows it to be run for long periods without undue wear. Lubrication is effected by inverted screw-up grease cups fitted with a capillary feed. A fuse is mounted on the side of the bed-casting, near the feed, which prevents any possibility of the windings being burnt out.

A charging board made for use with this machine is illustrated in Fig. 3. This is mounted on a slate base, and is fitted with a combined charge-discharge Weston ammeter, switches, and a charging current resistance or regulator. *See* Accumulator; Charging Board; Homcharger.

ROTARY DISCHARGER. A form of discharger or spark gap in which one set of electrodes rotates and another set is fixed, or both rotate. Some forms of the rotary discharger have three disks, the first a small one with a vertical axis, behind which is a larger disk with a horizontal axis, and the third another one similar to the first. A diagrammatic representation of this form of gap is given in Fig. 2. It will be seen from this diagram that the spark passes from disk 1 to 2, and from 2 to 3. This form of rotary discharger is in use in several high-powered spark transmitting stations.

A photograph of a type of rotary discharger suitable for smaller powers is illustrated in Fig. 1. This discharger is shown attached to the spindle of a high-frequency alternator to which it is directly

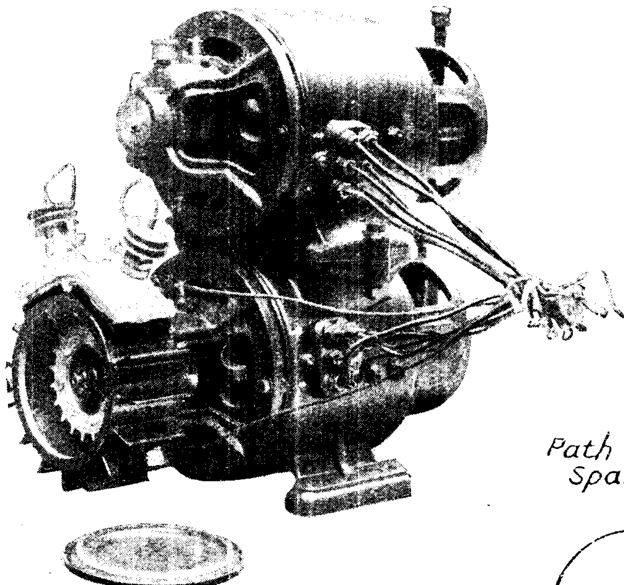


SMALL CONVERTER

Fig. 4. The amateur will find this type of converter suitable for charging accumulators from the A.C. mains. It is made in several input and output voltages

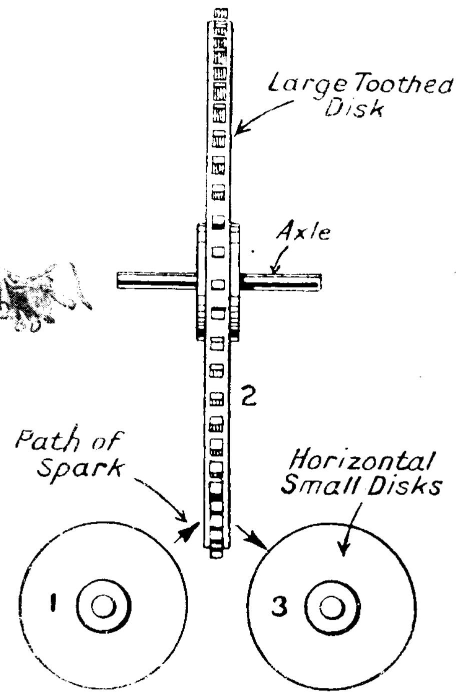
Courtesy S. W. Woods, Ltd.

coupled. The central or rotary electrode is a toothed ring, and has as many teeth as there are pairs of poles in the machine. The two fixed electrodes are situated below and in line with the large insulators shown on top of the discharger casing. An adjustment is provided which enables the gap to be synchronized with the alternator. Fins are cast on to the exterior of the casing, which allow the heat generated by the discharger to be freely dissipated.



ROTARY DISCHARGER

Fig. 1. Direct coupling connects the discharger with a high-frequency alternator. Above is a direct current generator for use if the alternator breaks down



THREE-DISK DISCHARGER

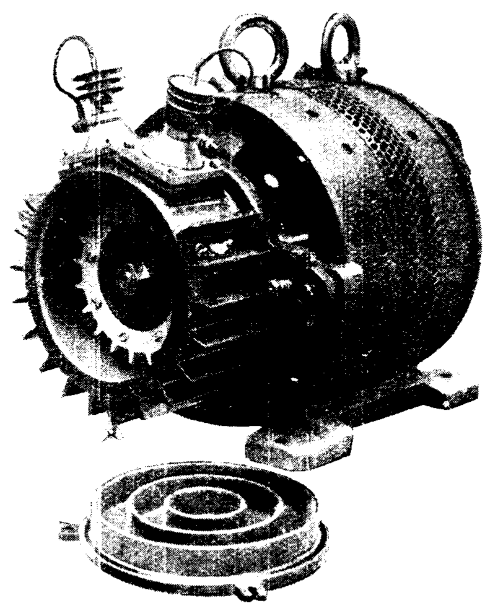
Fig. 2. Diagram to show the passage of the spark from disk 1 to 2, and from 2 to 3

The machine illustrated is interesting from another standpoint, for it has a further generator bolted to the top of the main alternator, which is used in case of the latter failing. The upper machine is a direct current generator, and is intended to be used in conjunction with an induction coil and a plain fixed gap. *See* Quenched Spark.

ROTARY SPARK GAP or Disk Discharger. A spark gap consisting of a toothed or studded cylinder or disk revolving at a high speed between two fixed electrodes.

The illustration shows a rotary spark gap attached to the spindle of a high-frequency alternator having a maximum output of one kilowatt and a half. The frequency of the alternator is 500 cycles. The principal feature of such an arrangement as this is that the sparks are always in phase with the alternator, which is the ideal position.

It will be seen that the rotor of the gap is a toothed ring of metal. It has the same number of teeth as there are poles in the machine. The fixed points in the gap are two in number, and are attached to rods projecting through the porcelain insulators shown at the top of the outer ribbed casing.



ROTARY SPARK GAP

The rotor of the gap may be seen; it is toothed to correspond with the poles of the machine. Two fixed electrodes project through porcelain insulators

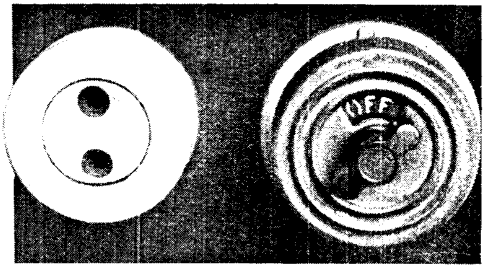
Courtesy Radio Communication Co., Ltd.

The whole of the outer casing of the gap is rotatable round the alternator body. The movement of this is accomplished by slackening the nut shown to the right of the casing. When this is done the knurled screw can be rotated by hand, which will cause a small gear to transfer motion to a curved rack attached to the gap cover. As the fixed discharger points are rigidly attached to this casing, it follows that they will move with it.

When the whole machine is first put into use at a station, the gap is correctly adjusted for phasal relationship with the alternator. A few months' working may necessitate a further adjustment, for the sparking will cause a removal of the sharp edges of the teeth on the rotor, altering the phasal relationship.

An interesting feature of this gap is that it is air-cooled, this being accomplished by the radiating fins on the outside of the case and the inside of the circular cover, which is shown lying in front of the machine. *See* Alternator; Quenched Spark Gap.

ROTARY SWITCH. A form of switch in which contact is made or broken by the rotary motion of the handle. While there are many forms of switch which could truly be described as rotary, the term is generally applied to the form shown in Fig. 1. This is a power switch having a safe capacity of five amperes. Contact is made or broken by turning always in a clockwise direction. This is important, for should it be turned anti-clockwise the handle will become unscrewed. As the rotation is always in the same direction, the relative position of the handle is no indication as to whether the switch is on or off. Therefore an indicator is fitted, which rotates with the handle and gives the requisite information.



ROTARY SWITCH

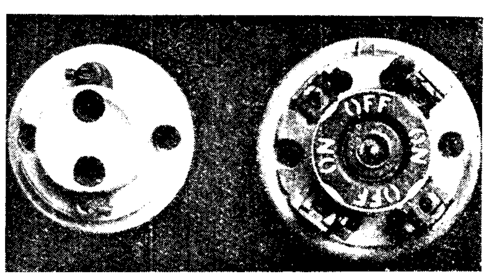
Fig. 1. Contact here is made or broken by always turning the switch knob in the same direction. An indicator is fitted

Fig. 2 is an interior view of the switch, and clearly shows the indicator dial with its on and off markings. There are two of each of these, because one quarter of a turn of the handle suffices to change over from one position to the other.

Switches such as this invariably have a quick break action, resulting in a freedom from arcing at the breaking points. This is accomplished by having a spring coupling between the handle and the moving contacts. The latter are made a tight fit into the fixed contacts, so that, due to the spring coupling, the moving contacts are gripped in the fixed ones for a considerable number of degrees of rotation of the handle. This grip is continued until the spring overcomes the resistance of the friction between the contacts. When this occurs the moving blades free themselves with a jerk, and no arcing can possibly form, for the movement is far too rapid.

In another type of rotary switch the circuit is made or broken by means of a revolving piece of metal, usually incorporated in a drum of ebonite or other insulating material. This type of switch is particularly useful where it is desired to operate a number of circuits simultaneously.

An easily constructed rotary switch of this kind is shown in Fig. 3. In this switch three contacts are arranged, two being in line with each other and the third set at right angles. This arrangement allows one circuit to be opened while the others are closed, or vice versa. A suitable application for a switch of this type in connexion with a receiving set is where the contacts in line are arranged to switch in or out the high- and low-tension batteries, while the single contact shorts the aerial and earth when the batteries are switched out of circuit. Many other uses of the rotary switch may suggest themselves to the experimenter, and if desired the switch described may be modified.



INTERIOR VIEW OF ROTARY SWITCH

Fig. 2. The dial is seen here with the two sets of "on" and "off" markings; a quarter of a turn makes or breaks contact

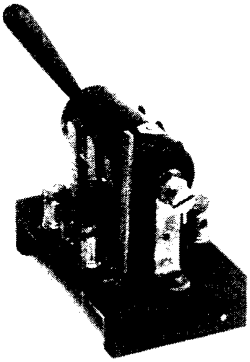


Fig. 3. The completed home-constructed rotary switch may be used in many different ways

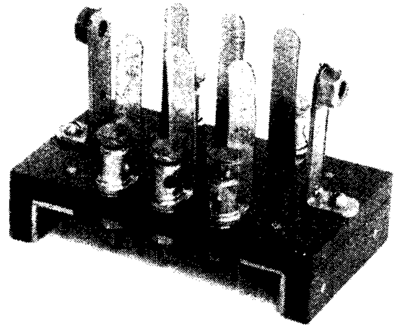


Fig. 4. Base with six contact strips and supporting brackets assembled. Telephone terminals are used for taking the necessary leads

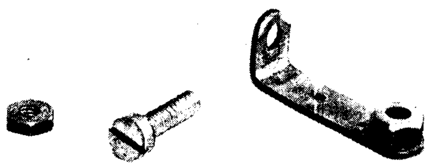


Fig. 5. Supporting bracket, with screw and lock nut, which is an end-bearing of the drum

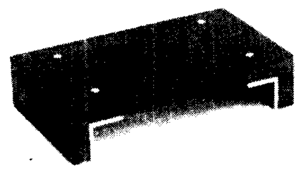
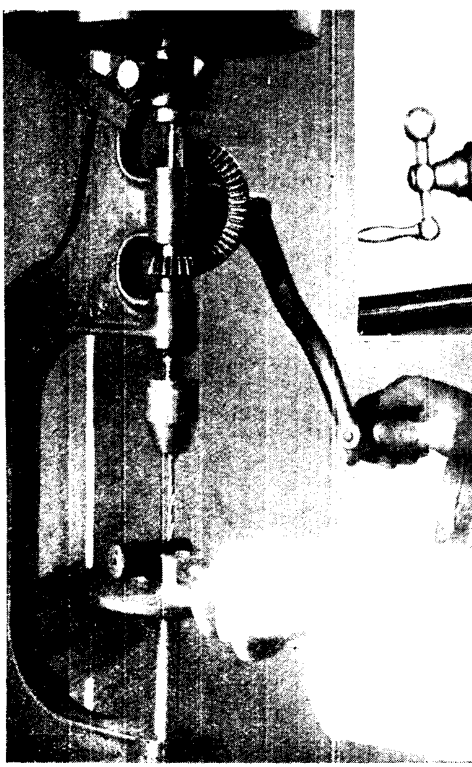


Fig. 6. Angle brackets of brass hold together the sides and base, made of ebonite



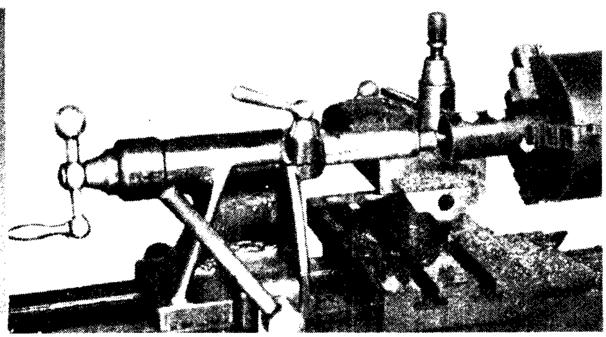


Fig. 8. The ends of the nuts forming the contacts are being turned flush; this could also be carried out with a file

Fig. 7. Drilling holes in the drum for contacts. A drill vice ensures their being vertical

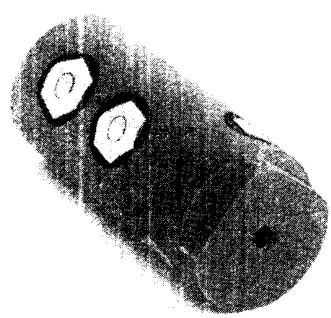


Fig. 9. Completed drum after the nuts forming the contacts have been turned down

HOW THE ROTARY SWITCH IS CONSTRUCTED

The base of the switch is cut from $\frac{1}{4}$ in. ebonite and measures $3\frac{1}{2}$ in by 2 in. Two strips of ebonite cut from the same material to a size of 2 in. by $\frac{1}{2}$ in. are secured by right-angle brass brackets at the ends of the base. The base is shown in Fig. 6 at this stage of the construction.

The switch drum, which is that part of the instrument carrying the movable contacts, is mounted on two brass brackets through holes at the top of which two 2 B.A. $\frac{3}{4}$ in. brass screws are passed. These screws are turned into tapped holes in the ends of the drum, and form the bearings on which the drum is rotated. A 2 B.A. standard nut is sweated over the bearing hole to the outside of the supporting brackets and is then drilled out 2 B.A. clearing size. The object of the nuts is to give a larger bearing surface to the screws forming the axles of the drum.

The supporting brackets are made from $\frac{3}{8}$ in. by $\frac{1}{16}$ in. brass strip, and are cut to a length of 2 in. each. At a distance of $\frac{1}{2}$ in. from one end each strip is bent at right angles, a 4 B.A. hole in the smaller part of the bracket taking a screw fitting into a tapped hole in the base. This screw holds the bracket rigidly in position. The appearance of the brackets is improved if the ends are rounded as shown in Fig. 5, which illustrates a completed bracket, and the bearing screw with a lock nut, by which the screw is rigidly attached to the drum of the switch.

Making the Contact Strips

The contact strips are made from springy brass, and are cut and bent to the same sizes as the supporting brackets. A hole at the top end is not required, but at the smaller ends of the strips suitable holes are drilled to fit over the stems of terminals by which the strips are secured to the base. Six strips are required, and are arranged as shown in Fig. 4. The central terminals on either side of the base are equidistant from each end, the outer terminals being placed $\frac{5}{8}$ in. on either side of the central one. The vertical sides of the contact strips are $\frac{1}{2}$ in. from the sides of the base.

The ebonite drum is of 1 in. diameter and $2\frac{1}{4}$ in. long. Central holes in the ends of the drum are tapped out 2 B.A. size. In these holes the bearing screws are fitted when the drum is assembled. Each contact in the drum consists of a 2 B.A. standard nut held in position and screwed to a short length of 2 B.A. screwed rod, which passes right through the drum. The holes are counterbored on either side of the drum, into which the nuts are sunk. Two holes are arranged in line with each other, while the third is drilled at right angles to the first two.

Drilling the Drum of the Switch

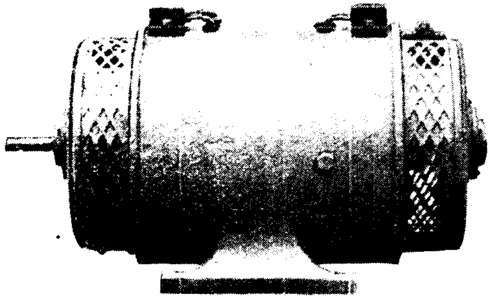
To ensure central drilling the drum is held in a drilling vice while the operation of drilling is in progress. Fig. 7 illustrates the drilling process. The two outer contacts are arranged $\frac{1}{2}$ in. from the edge of the drum and the centre one $\frac{5}{8}$ in. from either of the side holes, which position is also central in respect to the ends of the drum.

When the holes are drilled the screwed rod, with nuts attached, is fitted to the drum and tightened up securely. If a lathe is available the ends of the screwed rod and nuts are turned flush with the surface of the drum, as shown in Fig. 8. Alternatively the contacts may be filed up flush, taking care to avoid filing the metal lower than the drum. To obtain a positive movement, and to prevent overturning when operating the switch, two cam faces are cut at one end of the drum so that they are at right angles to the screwed rod holding the contact nuts. These cam faces extend $\frac{3}{16}$ in. from the edge of the drum and are $\frac{3}{16}$ in. deep. Their positions are shown in Fig. 9, which gives an illustration of the completed drum ready for assembly.

A spring arm is arranged to press against the cam faces, and may be made from a $2\frac{1}{2}$ in. length of $\frac{3}{16}$ in. by $\frac{1}{16}$ in. A right-angle bend is made $\frac{1}{2}$ in. from one end, a hole in this portion serving to screw the arm to the base. The position and purpose of the arm are shown in Fig. 3.

To one end of the drum an ebonite handle is fitted. This may be up to 2 in. in length, and is cut from $\frac{3}{8}$ in. diameter rod. It is fixed to the drum by means of a short length of 6 B.A. rod screwed to the handle and the drum itself. *See* Knife Switch ; Switch, etc.

ROTARY TRANSFORMER. A form of motor generator used in D.C. circuits for stepping the voltage up or down. As it is impossible to transform direct current by static transformers in the same way as alternating current, it is necessary to resort to the motor-generator method.



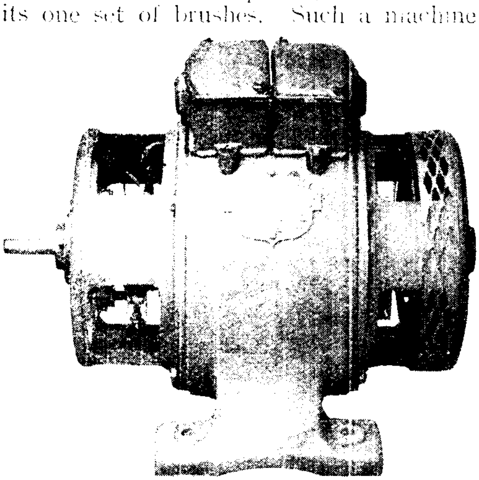
DIRECT CURRENT ROTARY TRANSFORMER

Fig. 1. This frame contains two armatures, one a motor and the other a dynamo. Direct current is stepped up or down by this machine in the same way that an ordinary stator transformer is used to step alternating current up or down

Courtesy Crypto Electrical Co., Ltd.

In this system a motor designed to be driven off the existing supply voltage is directly coupled to a dynamo of the voltage required. Such a scheme may be carried out by two separate machines, but it is more economical to employ a machine similar to that illustrated in Fig. 1. This, in reality, is two machines on the one shaft and within the one frame. The shaft, which is specially stout to prevent whip, carries two separate armatures. One is designed as a motor armature and the other as a dynamo. Two sets of field magnets are fitted opposite to the armatures.

The commutators are fitted at the extreme ends of the spindle, and each has its one set of brushes. Such a machine represents an enormous saving, both in first cost and running expenditure: in the former through economy of material and machining, and in the latter through a reduction of friction, for there are only two bearings. The latter is particularly apparent in the machine illustrated, for it runs on ball bearings.



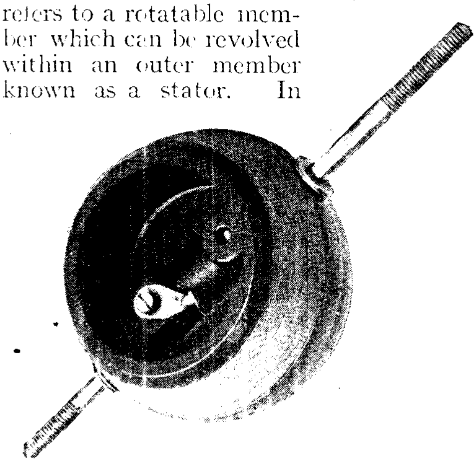
SMALL ROTARY TRANSFORMER

Fig. 2. Amateurs who want to charge their own accumulators off D.C. supply mains will find this rotary transformer very efficient

Courtesy Crypto Electrical Co., Ltd.

Fig. 2 shows another type of rotary transformer for transforming D.C. at ordinary house and power supply voltages to lower pressure suitable for accumulator charging. *See* Accumulator; Charging Board.

ROTOR. Expression used in several senses. In all cases, however, the word refers to a rotatable member which can be revolved within an outer member known as a stator. In wireless work two forms of rotor are chiefly employed. One is the large rotor which forms one of the moving members of an electrical generator, and the other, which is far more extensively used by the amateur experimenter, is the rotor which forms part of a variometer or vario-coupler, of which one example is illustrated in Fig. 1.



MOULDED EBONITE ROTOR

Fig. 1. Rotors wound on ebonite formers are among the most efficient rotors for variometers and vario-couplers

This shows the appliance complete, which in this case comprises a moulded ebonite part, approximately spherical in form, with cavities formed on either side of it. Within the cavity is a boss which provides a means of supporting the spindle. This spindle is either continuous or in two parts separated by a web of ebonite or other insulating material. The exterior of the ball has two grooves formed upon it, thus making a ridge in the centre and on the outer edge.

The depression between them provides a space wherein to wind a length of wire. This wire is commenced at one side of the former, as the ebonite block is called, and is continued to the central ridge, thence through a little slot cut in it, and so to the other side, where an equal number of turns of wire are taken in the same direction as the first, the resulting two ends of wire being attached to one of the supporting spindles.

A commonly used example of a rotor former is illustrated in Fig. 2. This is simply turned up from hardwood, and has the same general characteristics as the previous example, except that usually these formers are cheaper than those made of ebonite. They are obtainable in a variety of sizes, most commonly varying from 2 in. to 3½ in. in diameter.

The rotor provides a very convenient method of coupling a reaction coil to the inductance, and also as a means of coupling between primary and secondary inductances used for aerial tuning purposes. It is also employed in various regenerative circuits, as well as in a variometer.

The amateur experimenter often finds it difficult to obtain the exact size of former when making up some special piece of apparatus, and if unable to make a former from hardwood, a practicable plan is to construct the rotor from cardboard. A finished rotor made up in this way is illustrated in Fig. 3. The first step in such a construction is to take a piece of cardboard tube with a bore equal to the desired bore of the rotor, and of the proper width.

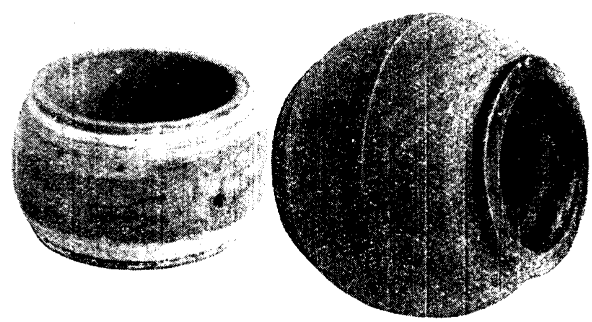
The next step is to cut a number of strips of brown paper sufficiently long to encircle the cardboard tube, and each strip slightly narrower than the one preceding.

A number of these strips, shown ready prepared, is illustrated in Fig. 4. The next step is to glue them, one at a time, around the cardboard tube, with ordinary Scotch glue, applied hot. The glue should be well dissolved in hot water, so that it will flow on to the cardboard freely. The paper strips are then wound around the cardboard tube, gluing thoroughly between each turn, as is illustrated in Fig. 5, which shows the application of the first strip of paper.

Sufficient strips of paper are then glued around the tube in the same way until the largest diameter is built up.

If the paper be wound on tightly, and well pressed on to the preceding turn, the result when the glue has set is to form a good rigid structure, the appearance of which is illustrated in Fig. 6. It should then be set aside until the glue has set thoroughly hard.

The next step, supposing that a turning lathe is available, is to chuck the ring in a three-jaw chuck and, with the aid of an ordinary wood-turning gouge, turn the outer face to the proper radius, the process being illustrated in Fig. 7. To obtain the exact curvature a full-size drawing of the rotor should be prepared, a template cut to the exact curvature of the face of the rotor, and this template should be applied to the work from time to time, as is illustrated in Fig. 8, to make sure that the shape is correct. The cardboard should be supported on the outer end by a disk of stout card, wood, or in any other convenient manner, so that the tailstock can be brought into use in the ordinary way.



HARDWOOD AND CARDBOARD ROTORS

Fig. 2 (right). Hardwood rotors of this kind are obtainable in various sizes, and are useful for the experimenter. Fig. 3 (left). Cardboard and laminae of paper are used as the basis of this rotor

The final finishing of the rotor is quickly accomplished with the aid of a rough file, applying this when the lathe is in motion in the manner illustrated in Fig. 9, at the same time passing the file across the moving face of the work in diagonal lines so as to preserve the proper contour. Any roughness can be quickly removed with the aid of very fine sandpaper.

The next step is to wind the rotor with the proper number of turns of wire of the correct gauge, according to the purpose for which it is required, these

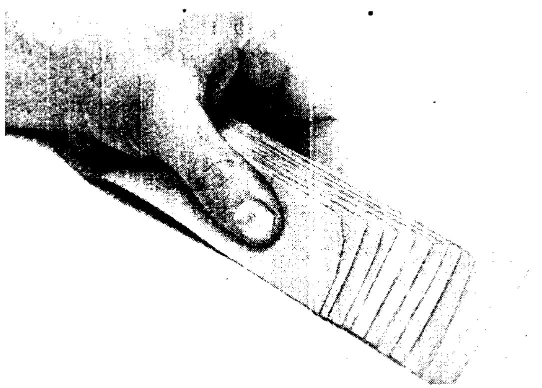


Fig. 4. Paper strips are cut into pieces of different widths and arranged in order, as illustrated

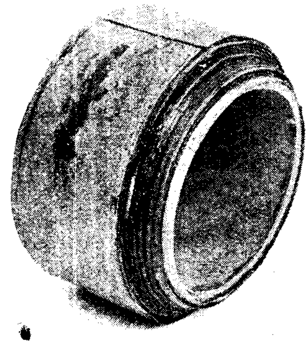


Fig. 6. Here the cardboard ring and laminae of paper are shown before shaping and smoothing

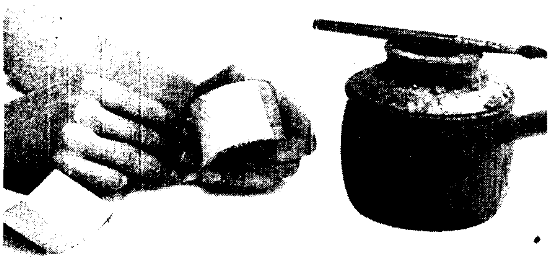


Fig. 5. Glue is applied thin and hot, and the strips of paper laid on, one after another, to form the shape shown in Fig. 6

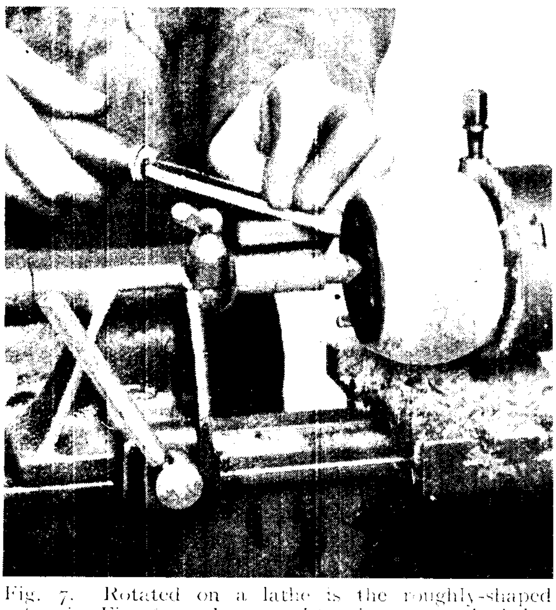
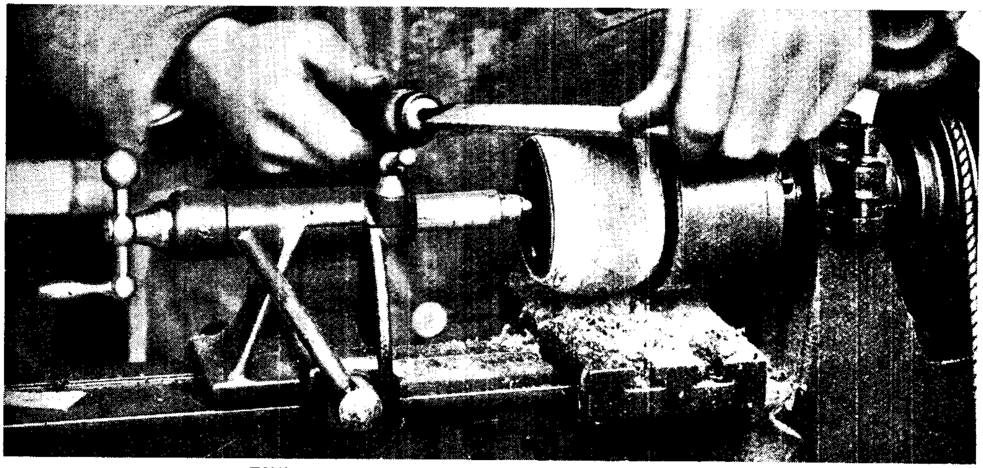


Fig. 7. Rotated on a lathe is the roughly-shaped rotor in Fig. 6, and a wood-turning gouge is being applied to make the desired shape

Fig. 8. Accuracy must be tested from time to time during the turning operation. In this photograph a template is being applied for this purpose

HOW TO MAKE A PAPER AND CARDBOARD ROTOR



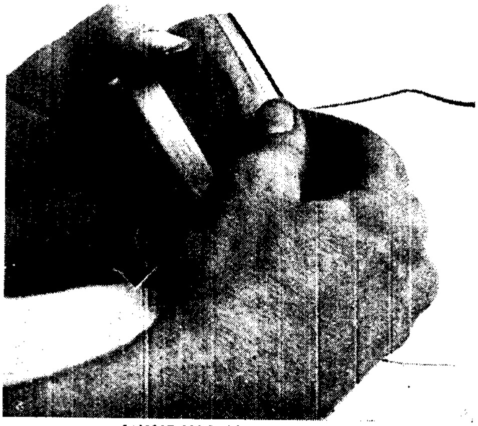
FINISHING THE ROTOR WITH A ROUGH FILE

Fig. 9. Final smoothing is carried out with sandpaper after the operation seen in progress in this photograph has been completed. This type of rotor is cheap to make and very effective

particulars being usually given in the various circuit diagrams and descriptions of the construction of receiving sets in this Encyclopedia. Briefly, the method is to commence on the outer edge by passing the ends of the wire through two small holes and making it secure in the ordinary way, as if winding an inductance, and then carefully to rotate the rotor with the left hand and guide the wire on to it with the right.

The requisite number of turns should be put on in this way, and the wire temporarily fastened off by securing it to the walls of the rotor and passing it through two small holes, leaving a short end free for connecting purposes. The other half of the rotor is wound in the same direction and with the same number of turns, finished in a similar manner, and the two finishing ends soldered together. There now remain the commencing ends of the first and second windings. These are connected either to the rotor spindle, which may simply be a piece of screwed brass rod passed through a hole drilled in the rotor and secured with lock nuts, or in any other convenient manner, according to the design of the apparatus and its purpose.

When two separate spindles are used the ends of the rotor winding are connected to them. When a continuous spindle is used, one winding may be connected to it, and the other is usually taken to the stator or fixed part of the apparatus by means of a brush contact or by leaving the wire sufficiently long to allow of the requisite degree of movement by the use



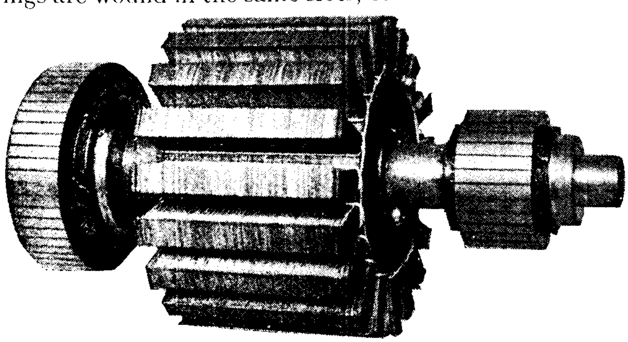
WINDING THE ROTOR

Fig. 10. Winding begins on the outer edge of the rotor and finishes on the inside

of a flexible wire soldered to the end of the wiring, or in any of the various other ways, several of which are described under the heading Connector (*q.v.*). To prevent the winding slipping off the rotor, little ridges are left at each end, and further to secure the wire it should be painted with shellac varnish or an insulating varnish, or brushed over with molten paraffin wax, the purpose being to unite the wires and keep them firm. *See* Coil; Loose Coupler; Stator; Variometer.

ROTOR SPINDLE. Shaft or spindle on which the rotating parts of an electric motor or generator turn. An excellent idea of the way in which a rotor spindle of a wireless generator is built up may be gathered from the figure. This armature shaft belongs to a form of direct current rotary transformer, *i.e.* it transforms direct current of a low or ordinary power voltage to a voltage sufficiently high to be applied direct to the anodes of low-power transmitting valves.

The low voltage input end is shown on the right. Comparing this with the high voltage output end on the left, it will be seen that the commutator at the former end is considerably smaller in diameter, and has a smaller number of segments. The spindle is of large diameter to prevent any possibility of whip, and is intended to be fitted with ball or roller bearings. Only one series of armature stampings is employed, as both high- and low-tension windings are wound in the same slots, one above



ROTARY TRANSFORMER SPINDLE

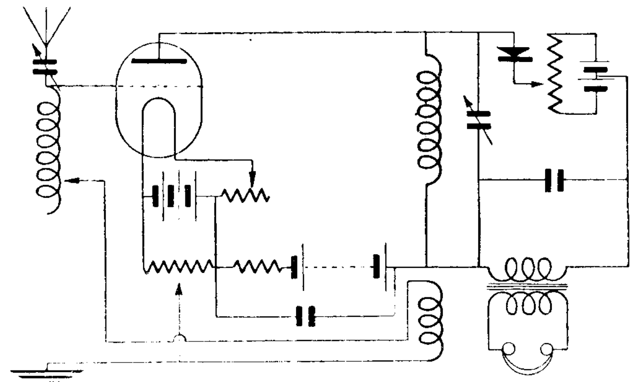
How the rotor spindle of a generator such as is used in wireless is built up may be seen in this photograph

Courtesy S. W. Woods, Ltd.

the other. A point of note is the thickness of the end laminations in each case. These are made of insulating material, and this ensures that if the insulation of the wire should accidentally become damaged at this point in winding, no current shall leak to the core. *See* Dynamo; Generator; Rotor.

ROUND CIRCUITS. Name given to a number of wireless receiving circuits invented by H. J. Round, of the Marconi Company, and largely used by the latter in its receiving sets.

Fig. 1 shows the well-known No. 16 circuit used by Round with his soft valve. The valve is used as a high-frequency



ROUND CIRCUIT

Fig. 1. Carborundum is used for rectification in the No. 16 circuit invented by H. J. Round and used by the Marconi Company. The circuit is represented in the above diagram

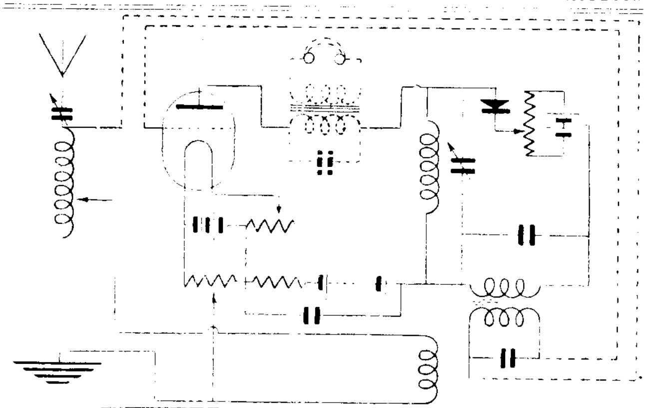
amplifier, and a carborundum crystal with battery and potentiometer is used for rectifying purposes. There are several unusual features about this circuit. The filament battery is also used to vary the potential of the grid through a potentiometer, a coupling coil and the aerial tuning inductance.

The anode filament circuit includes an inductance coil in series with the high-tension battery and a high resistance of about two to four thousand ohms. This is a necessary resistance with such valves. Its function is to limit the value of the anode current, which would otherwise become too great when the vacuum became too soft. An impedance for small high-frequency oscillations of current in the anode circuit is supplied by a fixed condenser.

Oscillations in the aerial circuit induce oscillating potentials in the aerial tuning inductance, and so vary the potential of the grid. Corresponding oscillations are set up in the anode filament current, which flows through the inductance coil in this circuit. These in turn induce oscillating potentials in the coupling coil which feed back into the aerial circuit and amplify the original oscillations. This has a greater effect on the grid potential, and magnifies the incoming signals far more than is the case with the straightforward detecting valve circuit. This circuit is sometimes known as a single magnification circuit.

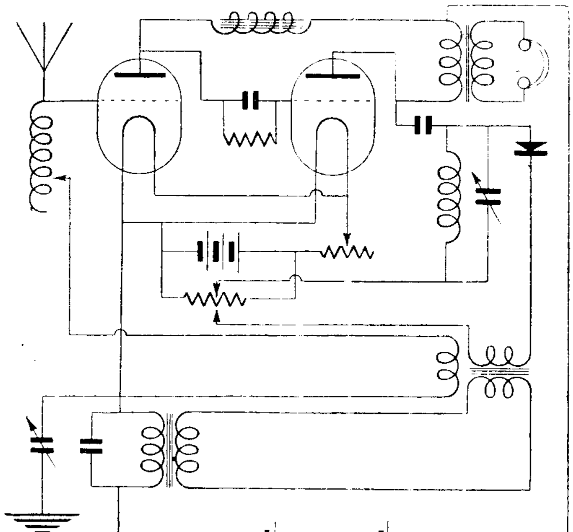
Fig. 2 shows the modification of this Round circuit which is in effect a dual amplification circuit. A second telephone transformer has been placed in the circuit, and the secondary of the original telephone transformer is connected to the grid circuit, the telephones being joined to the anode circuit through the telephone transformer. The valve now acts both as a high-frequency and as a low-frequency amplifier, the crystal, as before, acting as a rectifier. This circuit works better with a soft valve of the Round type than with a hard valve.

Fig. 3 shows another high-frequency amplification circuit due to Round. Here two amplifying valves are used, and an iron core coil is used in the plate circuit of the two valves. This circuit gives very good results. The Q valve and V24 type of valve were designed by Round for H.F. amplification, their capacity effects being much smaller than with the usual valve. Fig. 4 shows a five-valve amplifier designed by Round.



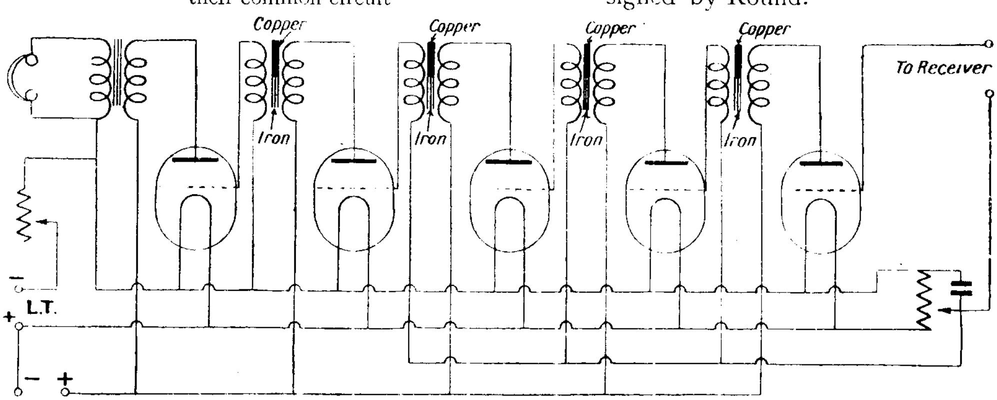
MODIFICATION OF NO. 16 CIRCUIT

Fig. 2. In effect this is a dual amplification circuit. The valve acts both as an H.F. and a L.F. amplifier. Dotted lines show the modification



TWO-VALVE HIGH-FREQUENCY CIRCUIT

Fig. 3. Here the two H.F. valves are used with a crystal detector. The anodes have an iron-core choke coil in their common circuit



FIVE-VALVE ROUND CIRCUIT EMPLOYING SPECIAL TRANSFORMERS

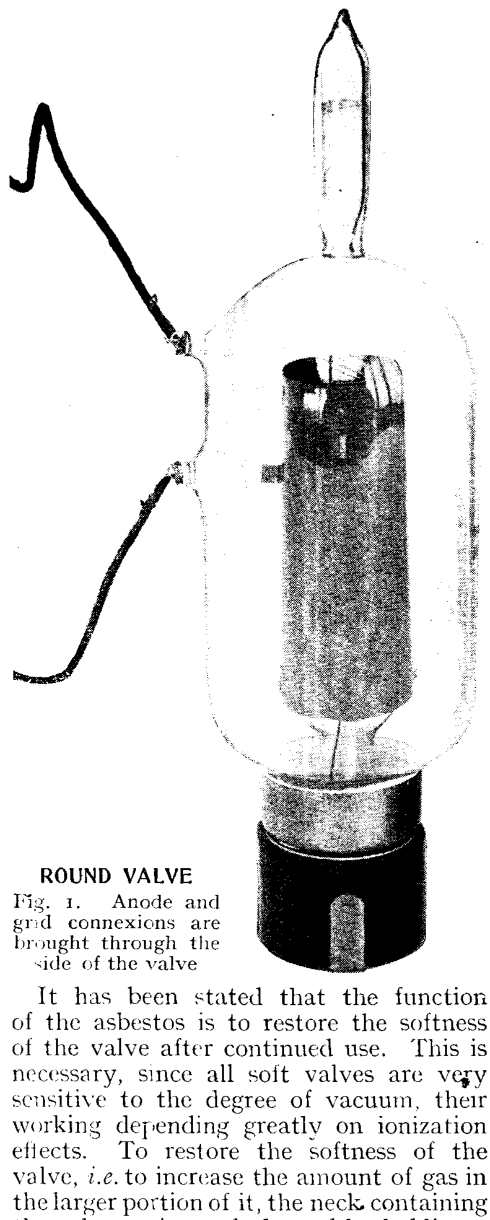
Fig. 4. Four high-frequency valves are used in this circuit, and the last valve is a rectifier. Special transformers are used, fitted with adjustable nuts and having iron and copper cores, and these are shown in use in this circuit between the valves

The first four valves are for high-frequency, and the last one acts as a rectifier. The high-frequency valves were V24's and the rectifying valve of the Q type. The anodes and grids of the valves were interconnected by special transformers, which had adjustable cores partly of iron and partly of copper. The inductance effects were increased by inserting the iron cores and the capacity effects by inserting the copper cores, an ingenious tuning device. The grid potentials of the amplifying valves were controlled by means of a potentiometer. The iron and copper cores have presented certain difficulties in actual working and have now been discarded. *See* Marconiphone.

ROUND VALVE. Type of soft valve invented by H. J. Round, of the Marconi Company. As will be seen from the photograph, Fig. 1, the Round valve differs from the ordinary three-electrode valve in a number of ways. In the first place it is considerably larger, measuring some seven inches in total length. The base of the valve has not got the usual four legs or prongs of the ordinary three-electrode valve. Instead of this, it is fitted with four metal strips, one of which is visible in the photograph. Two of these strips are dummy and two are connected to the ends of the filament. The two active strips are usually marked by a lead pencil mark across the white cement with which the bottom of the base is filled.

The anode and grid leads, instead of coming to the base in the ordinary way, are brought out through the sides of the valve as shown. These leads are separately coloured to distinguish them, red for the anode lead and black or green for the grid lead, though it is easy to see where the wires connect inside the valve.

A remarkable feature of the valve is the thin tubular projection on the top of the valve. This contains a quantity of asbestos, and is used to counteract the tendency of the valve to harden after continued use. The filament is of platinum coated with a mixture of barium and calcium oxides. The grid is a long cylinder of fine mesh nickel wire, and outside is the anode cylinder, also made of nickel. The grid potential is regulated by means of a potentiometer, and the adjustment of the grid potential is very sensitive to get the best results, a characteristic of soft valves.

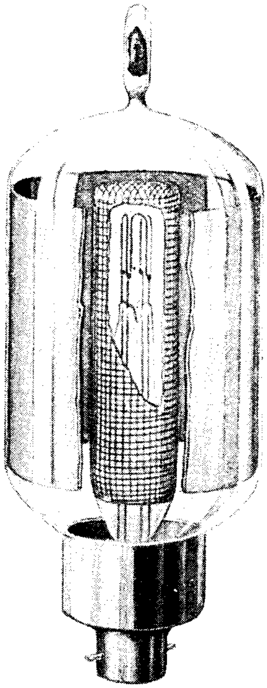


ROUND VALVE

Fig. 1. Anode and grid connexions are brought through the side of the valve

It has been stated that the function of the asbestos is to restore the softness of the valve after continued use. This is necessary, since all soft valves are very sensitive to the degree of vacuum, their working depending greatly on ionization effects. To restore the softness of the valve, *i.e.* to increase the amount of gas in the larger portion of it, the neck containing the asbestos is gently heated by holding a lighted match about an eighth of an inch away from the tube. This causes the asbestos to throw off or emit gas molecules and so increase the softness of the valve.

This unusual method of regulating the sensitiveness of the valve is one of its disadvantages, and another is that it takes an appreciable time after the filament has been lighted before it comes into operation. The filament requires very careful heating, too, and is easily



ROUND TRANSMISSION VALVE

Fig. 2. Three filaments are used in this valve, and the anode is close to the glass to facilitate heat radiation

burnt out. It had the advantage at the time of its appearance, however, of being a greatly superior valve to any other when properly used. The filament current is 6 volts and the plate current of the order of 60 to 200 volts.

Fig. 2 shows the Round transmission valve. The outstanding feature of this valve is the three lime-coated filaments, so that as one burnt out others could immediately be brought into use. These filaments are thicker than the ordinary filaments, and take 6 volts with a current of 4 amperes. The filaments are strongly made, so that they can withstand comparatively severe mechanical shocks, and in consequence this design of valve has a long life. The grid is similar to that of the grid of the Round valve in Fig. 1, but the anode is placed close to the glass tube to enable the heat generated to radiate away quickly.

The valve is immersed in oil to keep it cool. The distance of the anode from the filament necessitates a very high voltage on the anode of the order of 15,000 volts. The valve could be used to induce as much as 5 amperes of oscillating current in the aerial without overheating. *See* Valves for Reception ; Valves for Transmission.

R.P.M. This is the standard abbreviation for revolutions per minute. The speed of many machines or parts of machines with rotating parts is generally stated in revolutions per minute or revolutions per second. Thus in alternators we get the statement that the speed of the rotor is 20,000 r.p.m. in an Alexanderson alternator. Or in the Peukert discharger the revolving disk is said to be driven from a small electric motor at a belt speed of 2,000 r.p.m. The revolutions per minute or per second at which a rotating part of some machine is to be run is of great importance when it is required to calculate the strength of the revolving parts. It is impossible to run flywheels beyond a certain speed unless they are specially designed, or they would burst. The stresses set up at high speeds of revolution are sometimes so severe that the greatest care has to be taken in the design to prevent a mechanical breakdown. *See* Alternator ; Dynamo ; Generator.

R.P.S. This is the usual abbreviation for revolutions per second, generally used in connexion with the speed of revolving parts of any machine. *See* R.P.M.

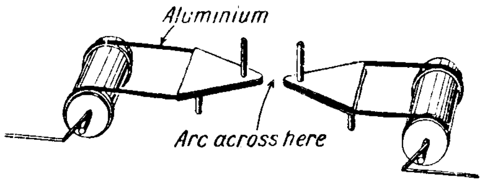
RUBBER. Term used generally as an abbreviation for indiarubber or caoutchouc. Rubber is a natural material obtained largely from a certain tree, *Hevea brasiliensis*, found in Central and South America, India and the East. Rubber plays an important part in wireless work in the form of a manufactured material. For example, small rubber tubes are used as a sheathing or case for conductors to improve the insulation qualities. It forms one of the most important constituents in the insulating covering for all manner of conductors of electricity, such as cables and the like.

When suitably associated with other constituents, including particularly the addition of sulphur, rubber can be subjected to a heat treatment which converts it into a hard, generally black-coloured, material variously known as hard rubber, vulcanite, ebonite or other proprietary names. This makes an admirable insulating material and is extensively used for panels, bases and other parts of wireless apparatus.

Flat sheet rubber is used to some extent underneath valve holders, on receiving and other sets, as a means of minimizing the effects of vibration. Rubber gloves are also used by electricians for protection against electric shocks. Rubber can be used in a liquid state, when treated with a special solvent, and is then considerably used as a solution for uniting parts made of sheet rubber. It is also, to some extent, used in waterproofing and insulating compounds. *See* Indiarubber ; Sleeving.

RUBIDIUM. One of the rare elementary metals. Its chemical symbol is Rb, and its atomic weight, 84·78. It is a silvery-white metal, waxlike and soft, and oxidizes rapidly in air.

Rubidium is interesting to the wireless experimenter, as its hydride, when enclosed in neon gas, forms a cell which is very sensitive to light, and may be used in exactly the same way as a selenium cell. Such a cell has the property that a current passing through it is proportional to the incident energy in the light beam thrown upon it. *See* Selenium.



PRINCIPLE OF RUHMER ARC

Two moving aluminium wires form the electrodes of the Ruhmer arc, and these are arranged so that they move in opposite directions, keeping the arc length constant

RUHMER ARC. Form of arc invented by E. Ruhmer. The arc was devised with the object of overcoming the difficulties caused by the irregular burning away of the electrodes in the ordinary form of arc oscillation generator. The illustration shows the principle of the arc. The chief point of difference from other arcs consists in the moving electrodes, which constantly present fresh surfaces at the point where the arc is struck.

The electrodes consist of two moving wires of aluminium kept in uniform motion by an electric motor, the wire being constantly wound off fresh reels. The movement is slow, and a new cool surface is regularly presented for the arc to strike upon, thereby doing away with irregularities, the arc length keeping constant. The wires move in opposite directions, or otherwise the arc might be drawn out to one side and its length increased. The distance between the wires may be varied to increase or decrease the length of the gap. The wires are passed over insulated supports of slate or marble, or metal supports which are water-cooled.

RUHMKORFF COIL. Another name for induction or spark coil. The Ruhmkorff coil usually refers to the type of induction coil having a secondary coil consisting of a number of layers of wire wound over each other in distinction to the coil whose secondary has a number of flat coils arranged side by side.

The primary is alternately made and broken by means of the interrupter or trembler placed at one end of the coils. This primary coil has an iron core composed of a number of fine soft iron wires. The base of the instrument is of box construction and carries a fixed condenser of large capacity, designed to absorb the spark when the primary circuit is broken. *See* Induction Coil.

RUTHERFORD, SIR ERNEST. British physicist. Born at Nelson, New Zealand, August 30th, 1871, he was educated at Canterbury College, Christchurch, New Zealand University, and Trinity College, Cambridge. From 1898 to 1907 he held the position of MacDonald professor of physics at McGill University, and from 1907 to 1919 he was Langworthy professor of physics at Manchester University. In the latter year he was appointed Cavendish professor of physics and director of the Cavendish laboratory at Cambridge.

Rutherford is one of our most brilliant living physicists and has carried out a series of researches on the ultimate composition of matter which has placed him in the front rank of the world's scientists. To him is largely due the many experiments which have confirmed the researches of J. J. Thomson and others and which have revolutionized the theories of matter and introduced the

SIR ERNEST RUTHERFORD

One of the best-known professors of physics, this noted Colonial has done much to promote important advances in scientific research. His experiments have considerably aided the investigations which revealed the possibilities of wireless as a universal means of communication

Photo, Elliott & Fry

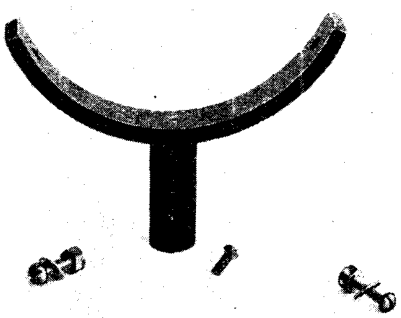
conception of the electron and the positive nucleus.

Sir Ernest Rutherford has received many honours for his brilliant researches, including the Nobel prize for chemistry awarded to him in 1908. He has written widely on the subjects of radioactivity, his books including "Radioactivity," 1904; "Radioactive Transformations," 1906; Radioactive Substances and Their Radiations," 1913; as well as many papers for technical journals. Sir Ernest was knighted in 1914.

S

S. This is the chemical symbol for the non-metallic element sulphur (*q.v.*).

SADDLE. Supporting device designed to conform to the shape of the object seated upon it at the part where the two are attached. The saddle forms a convenient



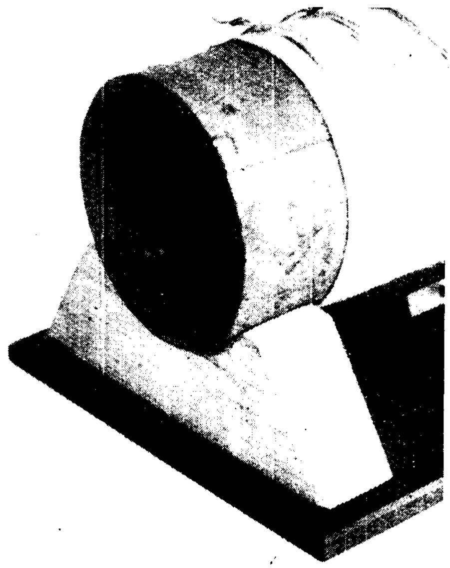
SADDLE FOR INDUCTANCE COIL

Fig. 1. An ebonite strip and rod are used in making the saddle here shown, which is designed to support an inductance coil

method of mounting a tubular inductance or other wireless component. It may be made of any suitable material, dependent on the weight of the object being supported, and the position and distance of the latter from the panel or other object to which the saddle is attached.

The saddle method of mounting an inductance has the advantage of allowing more space on the panel, as the inductance may be raised above it, thus allowing the space underneath the inductance to be used for mounting filament resistances or other shallow fitments.

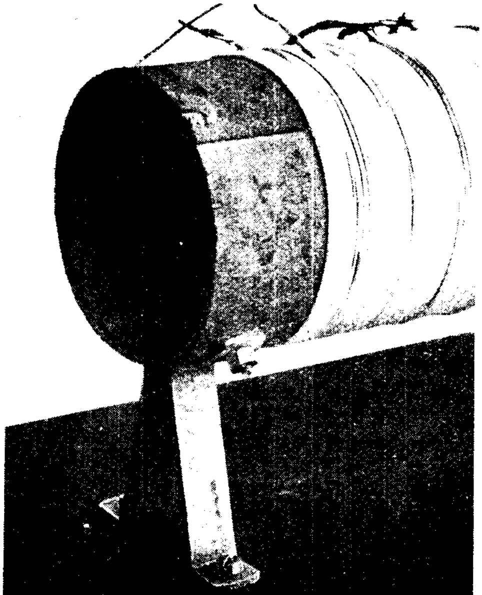
A very neat form of saddle is shown in Fig. 1, and consists of a curved strip of ebonite screwed to a short length of ebonite rod. At either end of the strip



WOODEN SADDLE FOR COIL SUPPORT

Fig. 2. One of the quickest and easiest made saddles is composed of a shaped wood block

holes are drilled through which small brass bolts secure the inductance. The ebonite rod or pillar is drilled and tapped at its lower end, and permits a screw to secure it rigidly to the panel, the screw being fitted from the outside of the panel.



METAL SADDLE FOR A COIL

Fig. 3. Brass strips are bent to shape to make this saddle, which has both strength and rigidity

CONDUIT PIPING SADDLES

Fig. 4. Curved metal saddle fittings as shown are used for securing the electric conduit tubing to a wall or other support

The screw and bolt used for fixing the saddle and the inductance are shown in the foreground.

Fig. 2 shows a saddle of wood which is cut or filed to the shape of the inductance on its top side, the inductance being fixed thereto with small wood screws inserted from the inside of its end. The saddle is similarly attached to the panel by means of wood screws inserted from the outside of the panel.

Another form of saddle is shown in Fig. 3, and consists of two brass brackets shaped at their top ends to the contour of the inductance, the lower ends being bent round to form feet. This saddle does not require holes drilled right through the panel, as blind holes will suffice for fixing the screws for attachment of the saddle. The inductance is held by means of a small bolt at either end of the top or curved parts of the saddle.

Saddles are largely used for fixing conduit piping to a wall or other support, examples of which are shown in Fig. 4, and take the form of arch-shaped strips of metal drilled at either end to allow for fixing nails or screws. *See* Insulating; Staple.

SAFETY GAP. Term applied to a device incorporating a discontinuity in a circuit normally carrying an electric current. There are numerous applications, varying in form, but in essence a safety gap consists of a device capable of carrying the normal full voltage. There is shunted across such device a pair of electrodes separated by a small space which is known as the safety gap. The gap is of such dimensions that the current normally flows through the conductor formed within the device, but when the voltage rises to a dangerous amount, the pressure is sufficient to cause the current to jump the gap, usually in the form of an electric spark. This has the effect of shorting the device by means of the conductive spark.

An example of the application of the principle is the use of a spark gap across two sets of plates of a condenser.

Usually the dielectric of a condenser is reduced to a minimum, and to protect it from damage by a sudden strain, such as that from bad atmospherics, a safety gap is provided comprising two fixed or adjustable metal points separated by a half millimetre or so. This is sufficient to provide a path for the excess high tension discharge, and thus avoid puncturing the dielectric and ruining the condenser. *See* Earth Arrester.

SAL-AMMONIAC. Common name for ammonium chloride. Its chemical formula is NH_4Cl. It occurs naturally in volcanic regions, but is more generally obtained as a product of the ammoniacal liquor of gas works. It is employed in wireless work, when dissolved in water, in many forms of primary battery, particularly that known as Leclanché. It is also employed to some extent in the so-called dry batteries, in which case the material is used in a paste form, or dissolved in water, as a means of keeping the elements of the cell moist.

It is conveniently obtainable in two forms. In one case it is purchasable in the form of small cylinders or pellets, and in others, in a dry, powdery state. It is also obtainable in a flaky form, often known as crystal, but in any case it is imperative to obtain nothing but the best quality, free from dirt and foreign matter. *See* Leclanché Cell.

SANDPAPER. A prepared sheet of paper used for the smoothing of wood and other materials. Sandpaper is a commercially produced article, obtainable in conveniently sized sheets, and usually purchased by the dozen or ream.

SANDPAPER RUBBER BLOCK

Sandpaper should be held round a block of soft wood or cork and used as a rubber in the manner shown in this illustration

There are many grades of sandpaper, and these range from the very finest to the very coarsest grades. The grading is carried out in the process of manufacture. This process, as a whole, consists essentially of coating one side of the paper with an adhesive and then sprinkling it with sand. The grading is done to separate the variously sized particles of sand into a number of different grades.

Various kinds of sand and other abrasives are used to get the desired effect. The very finest paper in general use is sometimes known as superfine, or No. 000, and the coarsest commonly employed is known as coarse or rough, No. 2½ or No 3.

Sandpaper is used generally by folding it up, thus making a pad, and rubbing it on the wood to be smoothed. Actually, it is an abrasive process, each particle of sand being hard and sharp, with a number of facets, which as it were, scratch or scrape off very minute amounts of wood. Consequently it is important to use the proper grade of paper, and also to keep the paper clean and free from dust or grit, as if there be one or two large pieces of grit or sand embedded in the paper, they will make deep scratches on the work.

A better way to use sandpaper when finishing a flat surface is to take a piece of cork about 2 in. or 3 in. in width, 4 in. to 6 in. in length, and 2 in. or 3 in. in thickness; or a block of soft wood, as in the illustration, can be used. The sheet of sandpaper is most conveniently cut into four pieces of uniform size and one of them wrapped around the block and grasped between the fingers and thumb of the right hand. The block is then applied to the wood to be cleaned or smoothed, and by pressing the sandpaper flat upon it the smoothing is carried out by quick, light strokes. On the roughest work this may be of a circular character, but on finished work all the rubbing should be strictly in the same direction as the grain of the wood. If the wood is practically smooth at the start, the fine grade paper should be used at the commencement, and should be finished off with the very finest grade or with a worn piece.

If the work be curved or uneven, and it is desired to shape or smooth it, the first paper should be the coarsest available, and should be worked in all directions so as to shape the wood neatly to the desired curvature. This should then be followed by rubbing in the direction of the grain with a medium grade paper, following this with a fine grade, and finishing it with the superfine or No. 000.

Another use for sandpaper is for imparting a fine point to a lead pencil, a method that is often adopted by draughtsmen and artists.

It consists merely in holding the piece of sandpaper on the bench and revolving the pencil between the finger and thumb, at the same time moving it bodily to and fro over the surface of the paper, thus very quickly bringing the lead to a fine point. A medium and fine grade of sandpaper is very useful for smoothing the ends of cardboard tubes used as formers for inductance coils. *See* Emery Paper.

SATURATION. Word used in a number of connexions in electrical and scientific work. In dealing with primary cells, for example, as the Daniell cell or the Leclanché cell, some such expression as a saturated solution of copper sulphate or a saturated solution of ammonium chloride is used. A solution is said to be saturated or to have reached its saturation point when the liquid solvent contains as much of the substance as it is possible to dissolve in it.

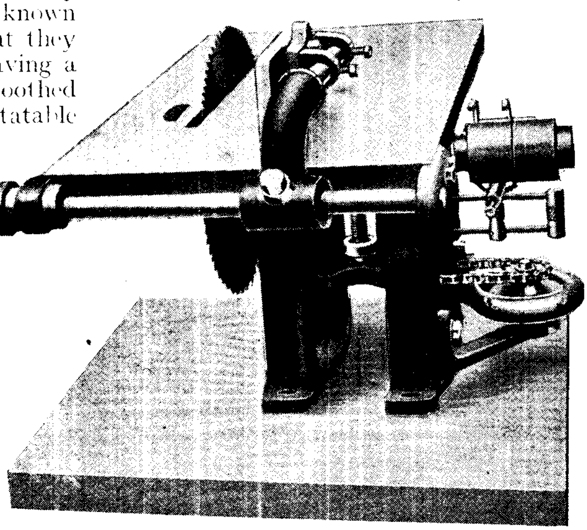
In the case of an ordinary three-electrode valve, the number of electrons emitted from the filament depends upon its temperature, and increases as the temperature is raised. There comes a time, however, when the plate will be taking the maximum amount of electrons it can from the filament, and by suitably arranging the positive potential of the plate with reference to the filament it is taking all the electrons emitted by the filament and passing through the electric field surrounding it. This is called the saturation point.

A magnet is said to have reached the saturation point when it is not possible to increase its magnetism. *See* Space Charge.

SATURATION CURRENT. Of a thermionic valve. The more or less clearly defined maximum value which can be reached by the feed current of a valve for a given condition of filament temperature under non-oscillating conditions. *See* Saturation; Space Charge; Valve.

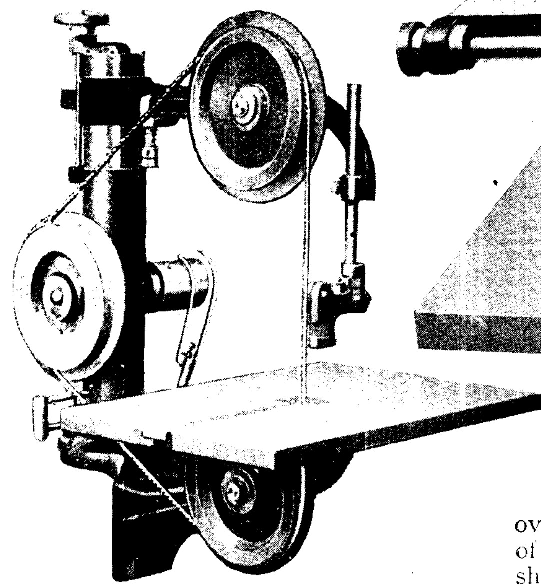
SAWS AND SAWING. A saw is a cutting tool used for the severing of wood, metal and other materials. It takes several characteristically different forms. As most commonly used by the amateur experimenter, the saw is a hand tool comprising essentially a flat, thin blade of steel with a serrated or toothed edge, one end of the blade being provided with a wooden or other handle so that it can be conveniently grasped by the hand.

This class of saw is generally known as a hand saw, although that expression is particularly applied to one type. The next class of saw comes into the general heading of machine tools, as it is adapted to be rotated either by foot power or by an engine. These saws are usually known as circular saws, from the fact that they are composed of a disk of steel having a hole in its centre and a serrated or toothed edge. The disk is mounted on a rotatable



SMALL POWER CIRCULAR SAW

Fig. 1. Experimenters who do their own wood and ebonite cutting can save considerable time and labour by using a small power circular saw driven by motor or gas



SMALL POWER BAND SAW

Fig. 2. This type of small power band saw is very useful to the wireless constructor, and can be driven by foot power or by a small engine

Courtesy Buck & Hickman, Ltd.

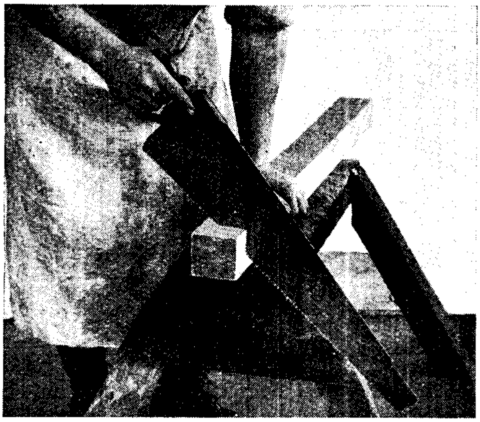
spindle which turns in suitable bearings attached to the framework.

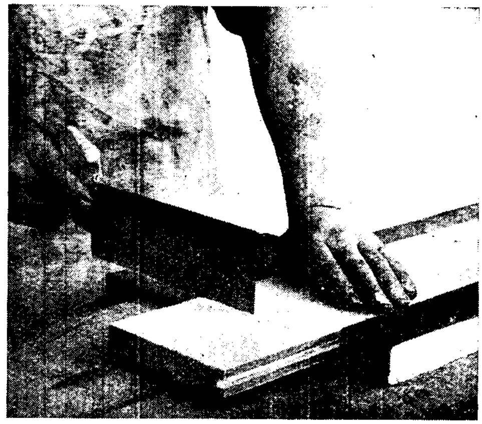
This framework supports an adjustable horizontal surface, known as the table, which is usually provided with an adjustable guide piece known as a fence, and also with a safety device or guard. An example of a small circular saw, by G. F. Young, Ltd., is illustrated in Fig. 2. This pattern is particularly useful to the experimenter with a small electric motor or gas engine, or some other source of power available for driving it. The same general type of saw is made from 6 in. or so in diameter upwards. Useful sizes for the amateur are from 6 in. to 9 in. in diameter.

The third class of saw, extensively used for shaping curved work, consists of a long narrow strip of steel, usually of the order of $\frac{3}{8}$ in. wide or thereabouts, rising to 1 in. or more in large sizes of saw. These are known as band saws, as the ends of the strip are united by brazing, and the saw is set in motion by placing it over comparatively large-sized wheels of equal diameter, as is visible in Fig. 1, showing a typical small power band saw suitable for wireless work. These saws are driven by power, but the smaller patterns can be driven by the foot.

The work to be sawn is rested upon the work-table, and when the saw is in motion is moved carefully so that the saw follows and cuts out the desired curved shape.

By far the greatest amount of sawing is done by the amateur with an ordinary hand saw, of which a common example is illustrated in Fig. 3. This contains a tapered steel blade with a wooden handle. A convenient length for the blade is from 30 in. to 36 in. The number of teeth to the inch and their shape vary according to the nature of the work which it is desired the saw should perform. For a hand saw which is to be used for cutting across the grain, the teeth are comparatively fine. In a rip saw, which is used for sawing with





HOW TO USE HAND AND TENON SAWS

Fig. 3 (left). Probably the most useful general saw for wireless work is the hand saw, which is here shown in use. Note the position of the worker. Fig. 4 (right). Tenon saws are also very useful for the wireless constructor. The blade is backed, for rigidity

the grain and is similar in appearance to the hand saw, the teeth are coarser, and the saw should be restricted to the cutting of wood in the direction of the grain.

In the use of such hand saws the right hand should grip the handle firmly; the right forefinger should be extended along one side of the handle, and the thumb be extended and grasp the opposite side of the handle. In use the saw should be moved so that the whole of the teeth pass across the wood to be sawn with a regular, steady notion, working from the shoulder and elbow. The novice should imagine that the right forefinger is pointing constantly down the line to be sawn.

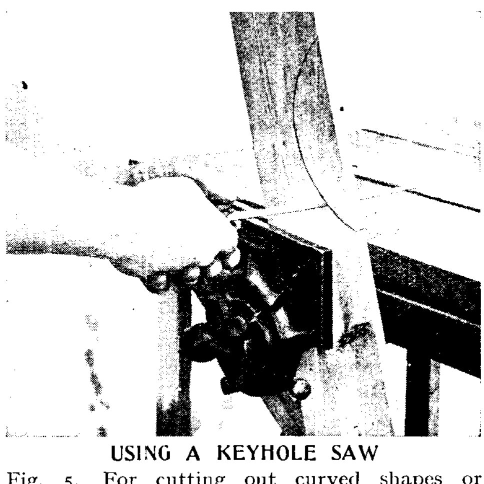
To start the saw, the thumb is rested against the side of the blade with the teeth resting on the mark where the cut is to be made. The saw is drawn backwards a few inches to make a slight indentation, after which the whole of the cutting is accomplished on the forward stroke. The pressure should only be sufficient to enable the saw to cut.

When working properly there should be a clean, crisp, ripping sound. The saw should cut freely and fairly quickly. If it does not, it is an indication that the teeth require sharpening and setting.

Another type of hand saw, known as the tenon saw, has a brass or steel back to stiffen the blade. This saw is grasped in very much the same way, with the right forefinger extended along the side of the handle, as is shown in Fig. 4. The tenon saw should be used for cutting wood particularly across the grain.

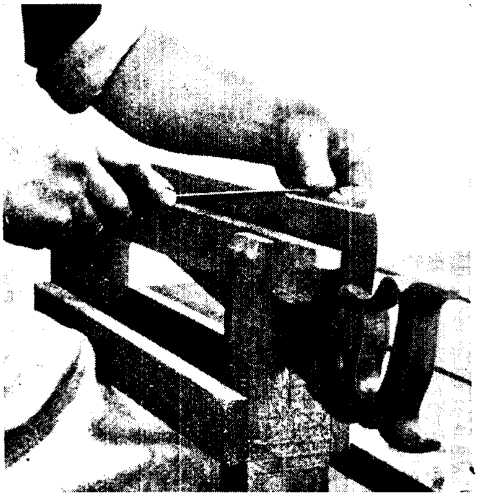
The work to be sawn is practically always employed in conjunction with a bench hook, which comprises a flat piece of wood having a batten nailed to the top outer end and the bottom inner end. The work is held by the left hand by pressing it downwards and forwards, thus holding it firmly. The tenon saw can then be used in a horizontal position, so that the whole of the teeth cut all the fibres of the wood from side to side of the work, instead of working in an inclined position as is necessary with a hand saw.

For working on curved surfaces, or those entirely within a board, the keyhole saw, or pad saw, can be used, such as that illustrated in Fig. 5. This is a very narrow



USING A KEYHOLE SAW

Fig. 5. For cutting out curved shapes or working interior cuts a keyhole saw is an indispensable tool



SHARPENING A SAW

Fig. 6. How the teeth of a hand saw are sharpened by means of a saw file; the saw is grasped in a vice or clamp, as illustrated

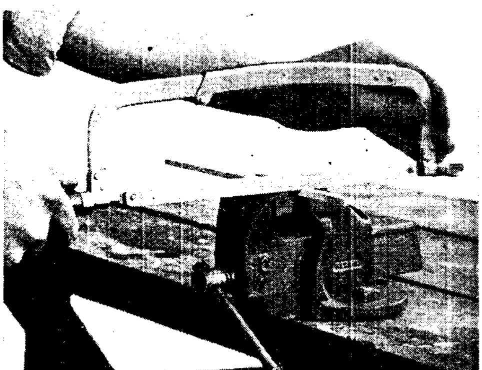
saw about 10 in. in length and provided with a wood or metal handle like an ordinary chisel handle. The saw is grasped by both hands, and used in a similar manner, with a straight, forward thrust. At the same time the narrowness of the blade allows the saw to follow a curved line. Its general purpose and application are clearly shown in the illustration, Fig. 5.

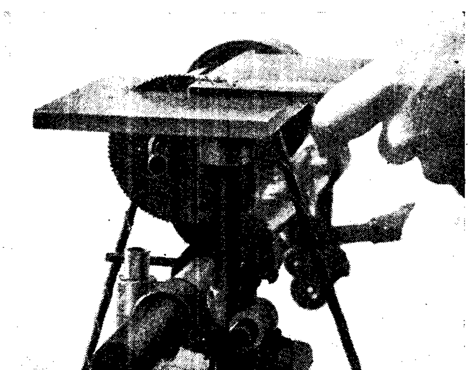
There are numerous other types of saw, but the foregoing will be found the most useful for wireless purposes, with the addition perhaps of an ordinary treadle fret saw, a machine driven by foot power and comprising a movable frame with a very narrow saw blade. It can be used for cutting thin wood, ebonite or metal into curved shapes. All woodworking saws require frequent sharpening, an operation that is carried out by holding the saw in a long clamp, such as that illustrated in Fig. 6, or between two long pieces of wood held in a vice.

A three-cornered saw file is then used to file the back of the teeth so as to produce a sharp point upon them. The file is used at a slight angle to the line of the saw, filing first one side of the teeth then reversing the saw in the clamp and filing the other side of the teeth. It will be seen by inspection that the teeth are tilted over to the right and left, so that the breadth across the teeth is considerably greater than the thickness of the saw blade, this breadth being known as the set, and necessary to allow the blade of the saw to move freely in the saw cut.

On wet or soft wood, or when cutting with the grain, a saw with greater set is needed than with the dry, hard woods, or when sawing across the grain. The teeth are set with the aid of a small appliance known as a saw set, which has a kind of lever which is clamped over the teeth, thus bending them. It is seldom, however, needed by the amateur.

For the cutting of metal, a hack saw, such as that illustrated in Fig. 7, is an indispensable tool. It consists of an adjustable frame with clamps at each end for holding a hard steel saw, which usually measures from 8 in. to 12 in. in length and from $\frac{3}{8}$ in. to $\frac{1}{2}$ in. in breadth. These saws are made with teeth of varying degrees of fineness. The finest toothed blades should be used for cutting tubes and hard metals,





METHODS OF SAWING METAL AND EBONITE

Fig. 7 (left). Metal can be sawn by the method here shown. A hack saw is being used. This is an inexpensive and practical instrument for this work. Fig. 8 (right). A simple arrangement of a saw table and circular saw is very suitable for cutting ebonite, metal or wood rapidly and the coarser blades for cutting brass, ebonite and other materials.

The saw is used by simultaneously moving the right and left hands, wrists and arms. It is imperative to push the saw in a perfectly straight line, and also to keep it horizontal when sawing. It is only useful for cutting straight lines.

When sawing ebonite into panels, nothing is more useful than a small circular saw, which can often be adapted for use in conjunction with a small lathe or polishing head. One such arrangement is shown in Fig. 8. The saw, which should measure about 3 in. to 4 in. in diameter, is mounted on a spindle or on the lathe mandrel. A cast-iron table with a slit in it through which the saw protrudes is clamped to the table or bed, and the saw revolved by treadling the lathe or machine in a forward direction in the usual way. The work to be cut is held firmly on the table and pressed against the saw, which will rapidly cut it. A safety device should be added if much work is done with the circular saw.

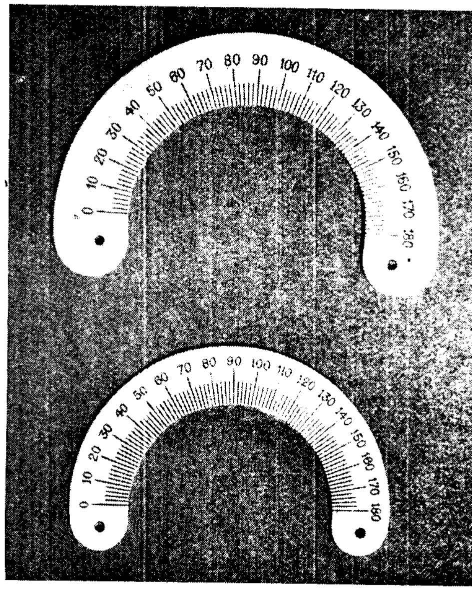
When cutting brass it is not necessary to lubricate the teeth of the hack saw, nor is it necessary when cutting cast iron. Steel and wrought iron should be lubricated with soapy water or with a light machine oil. Copper may be lubricated with turpentine or water. Aluminium can generally be sawn without a lubricant, otherwise it is best to use paraffin or soap and water. Ebonite is best lubricated with water, the purpose in this case being to keep the material cool.

A somewhat similar type of saw, generally known as the slitting saw, can be used for cutting metals. The saws are small in diameter, but are very efficient. They will quickly saw tubes, strips, etc., and should be lubricated according to the material to be sawn. A variation of the tenon saw, used for sawing brass and copper, is a small variety of the tenon saw and known as the brass-back saw. It measures about 6 in. to 8 in. in length, and is very handy for cutting off screwed rods, surplus ends of screws and bolts, and other small brass fittings. It is not necessary to lubricate it. This pattern of saw is not, as a rule, satisfactory for cutting iron or steel. *See* under the heads of various saws, as Hand Saw.

Sb. This is the chemical symbol for antimony. It is a contraction of the Latin name, stibium, for the metal. *See* Antimony.

SCALES. Term applied to a number of differently shaped dials or calibrated tablets. Their essential purpose is to indicate the relative adjustment of a piece of apparatus.

Scales are only a small item on a wireless receiving set, but are nevertheless a matter of some importance, as by their aid any particular setting of the controls can be noted for future use, and the same adjustments arrived at by merely setting the pointers to the original settings as indicated by the calibrations on the scales. Commercially made scales are usually of ivorine

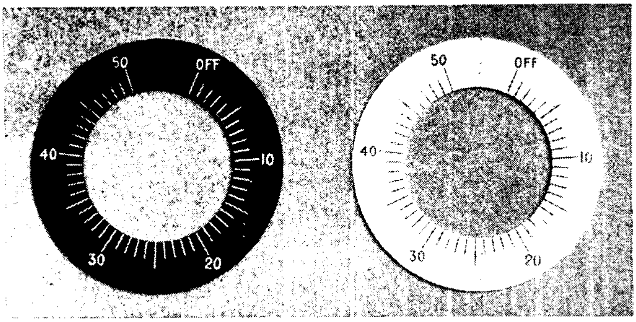


IVORINE CONDENSER SCALES

Fig. 1. Two examples of ivorine scales, suitable for use with variable condensers to determine relative positions for tuning, are shown here

or similar material of half-moon shape, as illustrated in Fig. 1. These are intended for use with a variable condenser, and are marked in degrees from 0 to 180. When such are used the centre of the condenser spindle should be located and the scale set so that the arc is concentric with the spindle hole. Set in this way the pointer will move regularly around the scale and give accurate readings.

Another type of scale made from similar materials is shown in Fig. 2, and is appropriate for use with a potentiometer or a filament rheostat. In this example there are 50 divisions distributed over about 300 degrees of arc. The commencement is designated " off," and the scale of calibrations read from that end. This type of scale



POTENTIOMETER OR RHEOSTAT SCALES

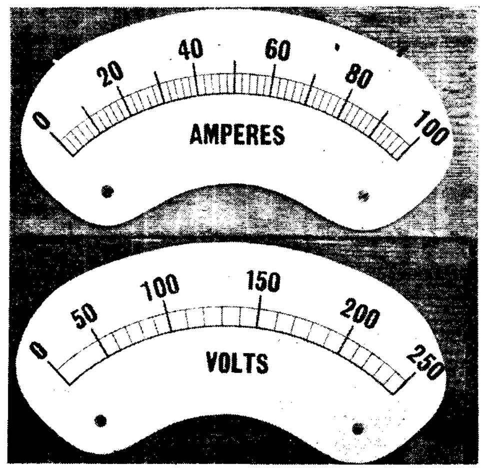
Fig. 2. Circular scales of this kind, with gradations from the off position to 50, are used for potentiometers or rheostats

is available in black with white lines or white with black lines, while other varieties are also made on dull plated metal and have a very handsome appearance.

A variety of the same type of scale, shown in Fig. 3, is marked "off" and "strengthen," and has an arrow to indicate the direction of rotation of the pointer to increase the current. On certain instruments the scales are not calibrated regularly, but on an ascending or irregular grade of divisions, such, for instance, as those used on some voltmeters.

Fig. 4 shows the difference between the divisioning of the scales for a moving coil and a moving iron type of instrument as made by the General Electric Co. The differences are necessitated by the unequal amount of movement of the pointer.

The experimenter who makes special apparatus is often in need of special scales, and will often find that the appearance of a set is greatly enhanced by the use of those scales which are just right for size and shape. These can be made from thin sheet ivorine, white celluloid and other materials, as well as from good quality white cardboard. The card known as Bristol board is the best, as this has a nice surface and takes the ink lines well. The first step in making a scale is to pin the card to the drawing-board and then draw two lines on it at right angles to each other. Then, from the point of intersection of these lines, strike an arc with a pair of compasses, as shown in Fig. 5. This

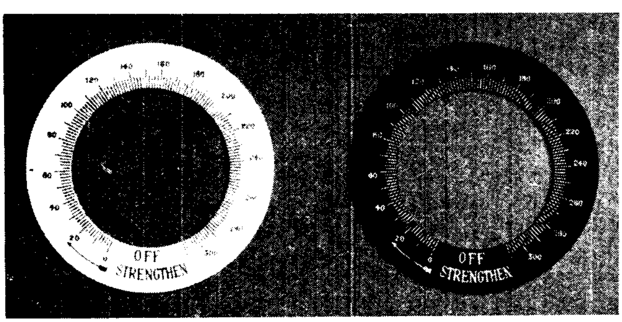


MOVING COIL SCALES

Fig. 4. These scales, with differently spaced divisions, are used for moving coil and moving iron instruments

should be the inner part of the scale, and a similar line, but at the proper distance from the first, has then to be drawn to represent the width of the scale. The next step is to divide the arc into the required number of divisions with a protractor. Otherwise a pair of dividers can be set to the correct spacing and the distance set off along the inner line, as shown in Fig. 6.

Radial lines have then to be drawn from a centre to the outer part of the scale, as shown in Fig. 7. The ends are rounded, and all the lines inked in with waterproof indian ink, using a ruling



CALIBRATED SCALES FOR FINE ADJUSTMENT

Fig. 3. From the off position to the maximum point 310 degrees are shown on these scales. The arrow indicates the direction of rotation of the turning knob to strengthen the current or potential according to the use of the scale

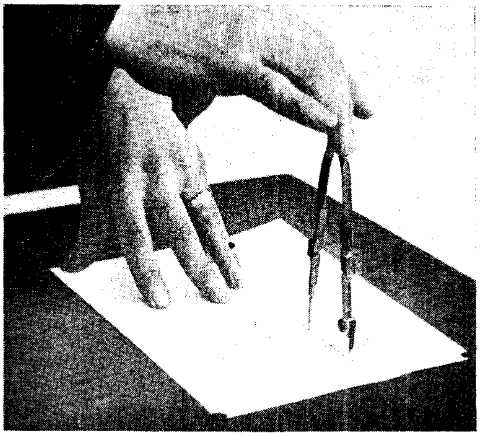


Fig. 5. Bristol board is used, and on this two concentric half circles are drawn

Fig. 6. With the aid of dividers the degrees are marked off at intervals round the crescent

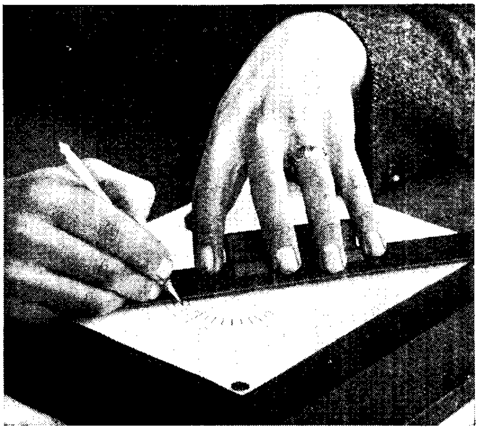


Fig. 7. Projection of the radial lines is here shown being carried out with the aid of a ruler

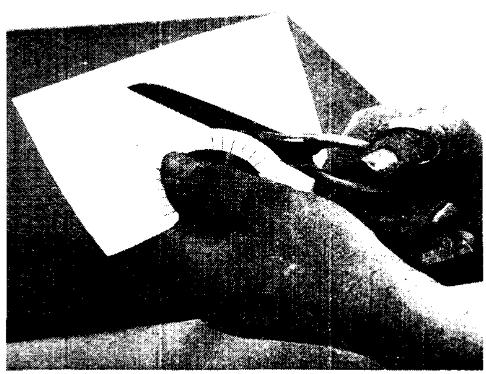


Fig. 8. After the scale is completely drawn the card is cut to shape with a pair of scissors

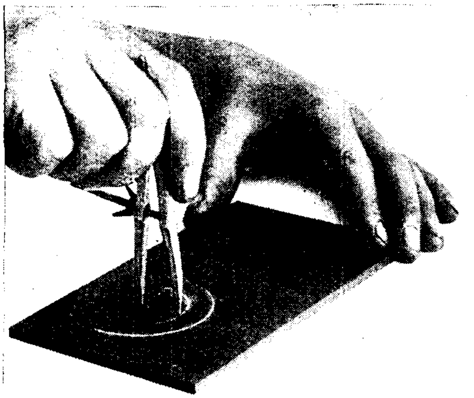
STAGES IN THE MAKING OF A DIVIDED SCALE

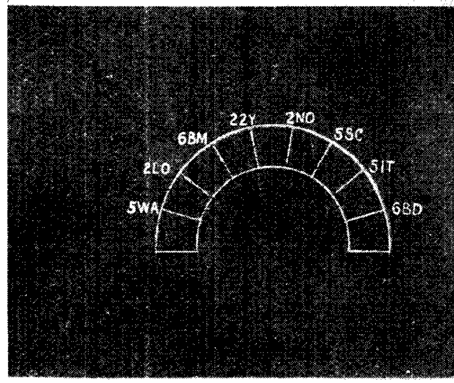
pen for this work. The scale is then cut to shape with a pair of scissors, as shown in Fig. 8, thus completing the work.

These scales can be stuck on a panel with adhesive such as seccotine or thin shellac varnish, and if desired the surface can be finished and protected with a coat of paper varnish.

One other method of making scales is to draw them directly on the ebonite panel, a method that usually results in accuracy and a very neat finish. It also avoids the necessity of fixing a separate scale with an adhesive or with a couple of small screws.

In this case the centres for the spindles are first marked on the panel and the arcs struck out from them with the aid of sharp-pointed dividers, as shown in Fig. 9. The lines are thereby incised somewhat into the material and can subsequently be filled with white or other coloured paint. It is often a convenience to calibrate directly the scale, when drawn in this way, by first tuning the set very carefully to the desired stations or wavelengths that are of most interest, and to mark these positions on the scale, omitting all other calibrations than the signal signs of the particular stations concerned, somewhat as shown in Fig. 10. This enables a novice to tune the set readily to any particular station by turning all the controls to the same designations on the scales. The exact positions for these markings can only be determined, practically, by tuning the set and marking the whereabouts of the pointers on the scale





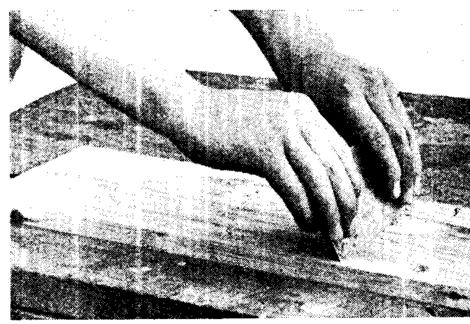
ENGRAVING A SCALE ON AN EBONITE PANEL

Fig. 9 (left). Sharp-pointed dividers are used for marking the half-circle lines directly on to a panel. Fig. 10 (right). This scale is now complete and the markings show tuning points of various stations

and then permanently incising lines at those points and filling the lines with white paint in the usual way. *See* Dial.

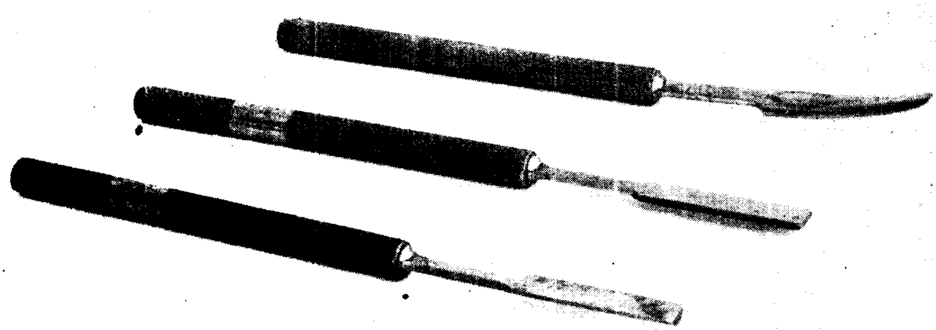
SCRAPER. Name given to a form of cutting tool used for removing small quantities of material. The wireless experimenter will probably only need two kinds of scrapers. Those known as the engineer's, and illustrated in Fig. 2, are generally of three types. One has a triangular blade, the other a rectangular-sectioned blade, and the third a D-shaped blade which is bent upwards slightly.

The length of these scrapers is about 6 in., the major portion of which is occupied with a handle made of metal, knurled on the outside to provide a firm grip. They are used on metal by propelling them with both hands across the surface in such a way as to scrape off a very small amount of the material.



FLAT STEEL SCRAPER IN USE

Fig. 1. Steel scrapers of the kind here shown in use are invaluable for working up a fine finish in all classes of woodwork



SCRAPERS AS USED BY WIRELESS CONSTRUCTORS

Fig. 2. Three examples of metal scrapers are illustrated. These are used for removing small quantities of material, as in smoothing the edges of ebonite panels, or for work on metal surfaces. The one in the foreground is triangular in section, the middle one is rectangular in section and the third is known as a D-shaped scraper

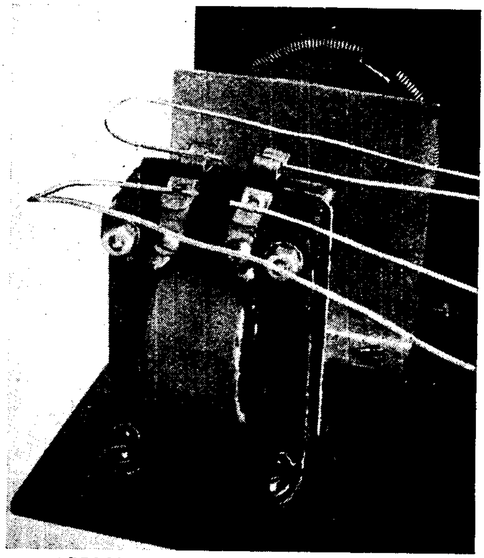
Another form of scraper of service to the wireless experimenter is known as the joiner's, and shown in Fig. 1. It comprises a rectangular blade of hard steel. The cutting edge is formed by grinding and sharpening on an oilstone in such a way that a fine burr or lip is turned up on the edge, this lip acting as the cutting edge. The method of use is to grasp the scraper in both hands with the fingers in front of the tool, and the thumbs on the back or inside. The tool is then drawn along the work in the direction of the grain so as to scrape off a small amount of wood, doing this with a regular, even movement. Some amount of knack is needed to do this properly, but once this has been gained the tool can be used easily, and will give very satisfactory results. Care should be taken always to work the tool in the direction of the grain, downwards.

SCREENING. Screening is used in wireless in two senses. In one application it refers to the detrimental effect of trees, buildings or other large objects which hamper reception of signals. It is often found that signal strength is poor with apparatus of known efficiency, and in many cases the trouble may be found in the screened position of the aerial. A town situated in a valley or beyond a range of high hills often suffers from the screening effects of the local geographical conditions. Where screening is caused by trees or buildings, a rearrangement of the aerial should be tried. It should be made higher, if possible, and placed at right angles to the object obstructing it. In cases where the trouble cannot be eliminated, the power of the receiving station must be increased if louder signal strength is required.

Screening applied to a receiving set refers to the placing of a metallic plate or object between parts of the apparatus under magnetic or other influence to each other to avoid the effects of interaction.

An illustration of this principle is shown in Fig. 1, where a thin iron plate is secured to the back of a low-frequency transformer to intercept the magnetic lines of force which surround the transformer.

Where a receiving set is susceptible to body capacities, that is, when the presence of the hand near the controls affects the tuning of the set, the interior may be screened by covering the inside of the panel with tin or lead foil. A light varnish may be used to stick the foil to the panel.



APPLICATION OF SCREENING PLATE

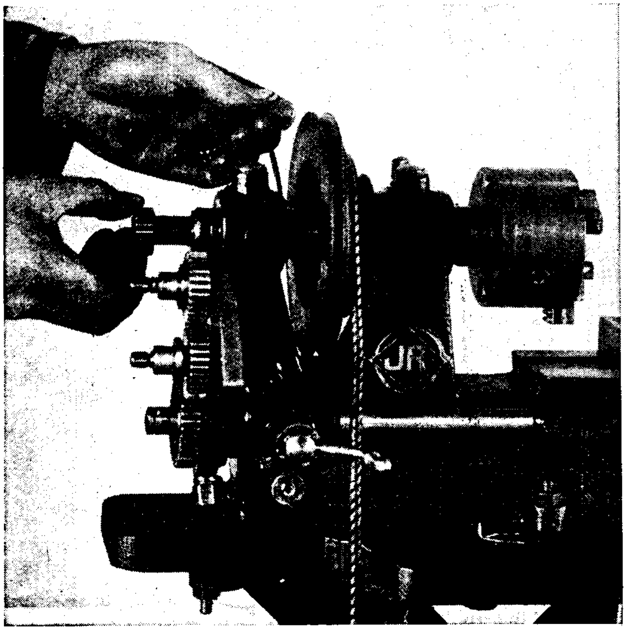
Fig. 1. In order to avoid the effect of the magnetic field set up by a L.F. transformer, a metal plate is used as a screen

The operation is shown in Fig. 2, where the varnish is being applied with a small brush. Care must be taken to ensure that the foil does not touch any conductor likely to short circuit the current. *See* Fading.

SCREW CUTTING. Term used to describe a mechanical process of making a screw thread within or upon a cylindrical surface. In a general sense the term may be applied to all forms and processes whereby the metal or other material is severed during the screwing operation. In actual practice the expression "screw cutting" is limited to the processes carried out on the lathe.

MINIMIZING CAPACITY EFFECT

Fig. 2. Capacity effect may be effectually screened out by the application of a metal plate or thin foil. Varnish is the adhesive used



PREPARING LATHE FOR SCREW CUTTING

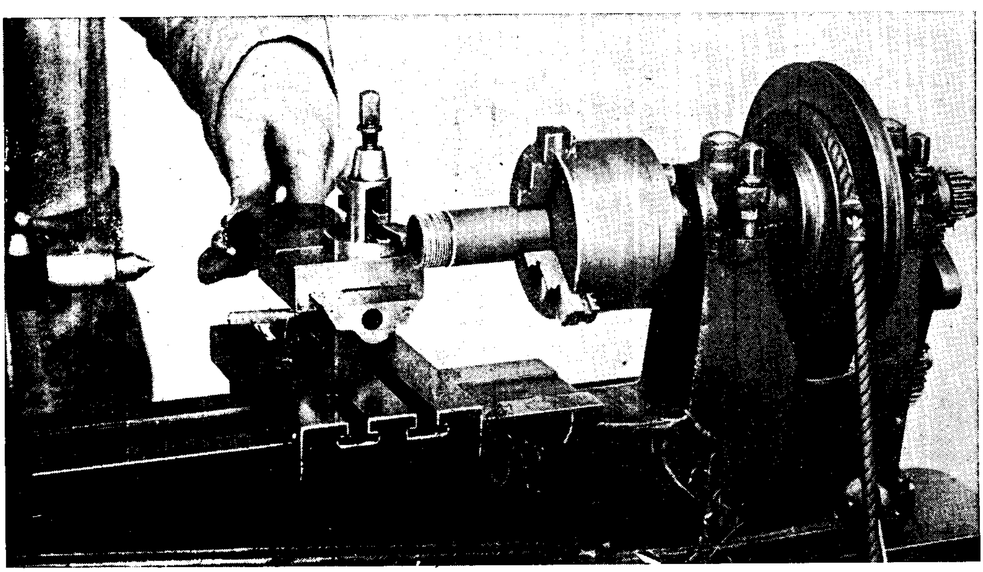
Fig. 1. Change wheels of a lathe are being set up preparatory to the cutting of a screw thread

details of these processes are extensively dealt with in this Encyclopedia under the heading Dies and Taps.

To cut a screw thread in a lathe practically necessitates the use of a tool known as a screw-cutting lathe, the elements of which are dealt with under the heading Lathe.

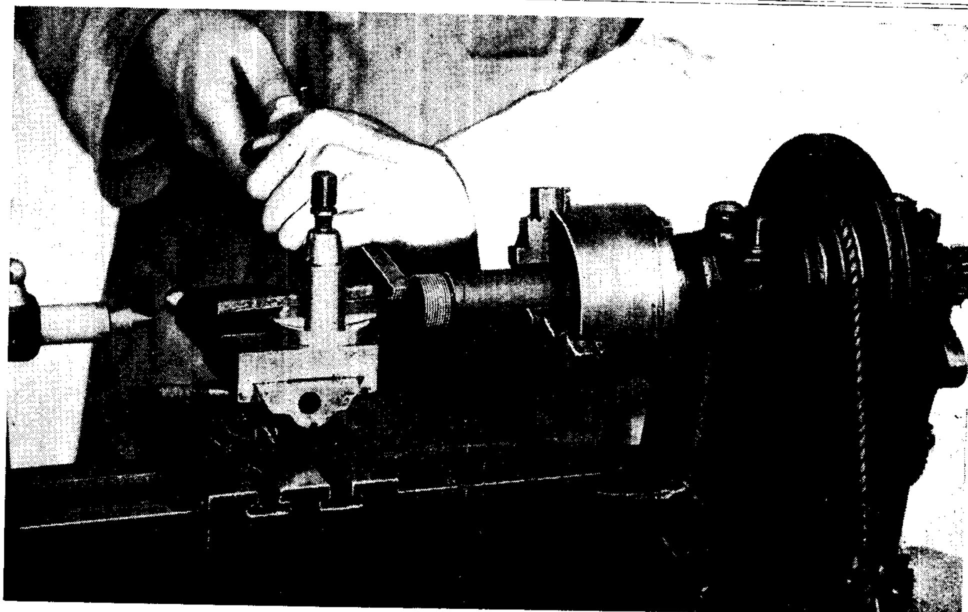
The first operation in screw cutting is to place the proper change wheels on the mandrel and lead screw and on the quadrant and intermediate spindles, as shown in Fig. 1, the purpose being to cause the saddle and tool holder ultimately to travel along the bed of the lathe at a predetermined rate of motion relative to the number of turns of the mandrel. The correct change wheels are indicated on a table attached to the lathe. The next steps are to chuck the work firmly on the mandrel in the usual way and to turn the surface to the correct diameter. This in the case of external threads is the diameter to the tops of the threads. The screwing tool has then to be fixed in the

The wireless experimenter will find that the bulk of the screws that have to be cut are of small diameter, and therefore can be done with a die on external work and with a tap on internal work. The



CUTTING A SCREW THREAD ON A LATHE

Fig. 2. Fixed in the tool holder is a screw-cutting tool, which is held in such a way that it can move in a transverse direction along the work, but without receding from it. When the lathe is set in motion the spiral cut is made at the requisite depth



REDUCING A SCREW THREAD TO ITS EXACT SIZE

Fig. 3. Should the screw thread not be smoothly finished, it is turned up by means of a tool known as a chaser, which has in it a set of teeth corresponding to the thread that has been cut

tool post of the lathe at the correct angle and the top slide rest adjusted until the tool will cut to the correct depth, provided the thread is only a shallow one, such as is found on most scientific instrument work and on screws as used in making wireless sets.

The lathe is then set in motion and the tool is thereby traversed along the work, and in its passage cuts a thread, the pitch of which is determined by the change wheels and the shape of the thread by the screwing tool. When it is not possible to cut a full thread at once over, that is, at one cut, the tool has to be brought back to the exact starting point, adjusted a little to cut slightly deeper, and the same operations repeated, somewhat as illustrated in Fig. 2.

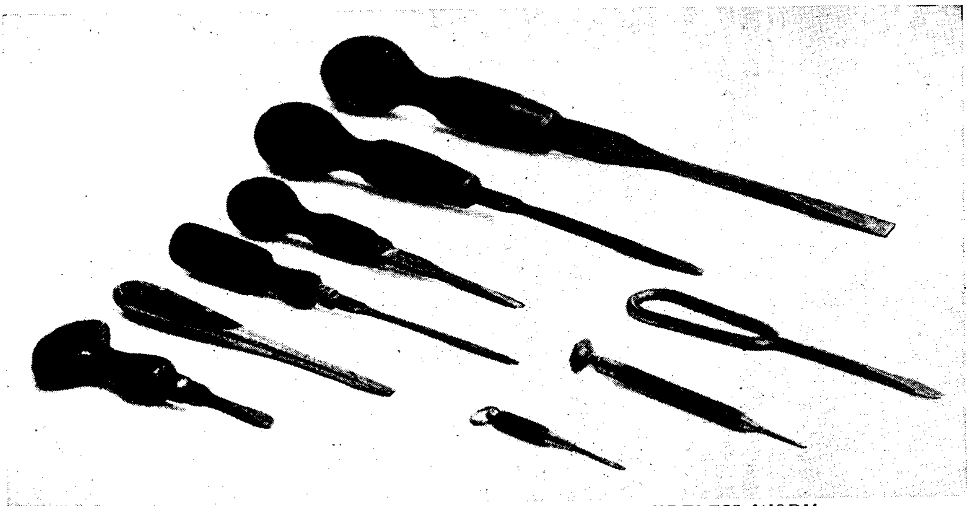
When cutting a thread in this way, the result is not always a perfectly smooth thread, and to remedy this a good plan for the novice is to use an ordinary hand chaser. This is a tool having a series of teeth, of the correct form for the particular thread, formed at the cutting end, and this is run over the work as shown in Fig. 3, thereby imparting a finish to the threads.

The hand chaser is employed in the same way as a hand tool, but is fed along the work at the correct speed corresponding to that of the pitch of the screw. It is a useful instrument to employ when the screw is just a trifle too large and has to be reduced to fit properly into a nut or a tapped hole. Internal threads are cut in a similar way, but the screwing tool is shaped like a boring tool, but with the proper-shaped cutting edge corresponding to the desired screw thread.

When cutting screw threads on metals they should be lubricated according to the nature of the material, a matter dealt with under the headings Lathes and Lathe Work (*q.v.*).

Screw cutting is an operation which calls for care and a fair amount of skill, but it is quite within the capability of the average painstaking amateur; proficiency is only obtained by practice. *See* Dies and Taps; Lathe.

SCREWDRIVER. An appliance for fixing or removing wood or metal screws, sometimes called a turnscrew. The screwdriver is probably the most common and the most useful tool to the experimenter, and a selection for the different purposes required should always be to hand. A collection of screwdrivers suitable for most purposes the wireless experimenter is likely to require is shown in Fig. 1. The crutch handle screwdriver is a well-finished tool having a short boxwood



SELECTION OF SCREWDRIVERS USEFUL IN WIRELESS WORK

Fig. 1. One of the most useful tools on the wireless experimenter's bench is a screwdriver. This tool cannot be adapted for all screwdriving jobs, and special designs of screwdriver are necessary for particular circumstances. Here are a number of screwdrivers, covering a wide range of requirements; these are described in the text

handle, the massiveness of which, combined with the shortness of the blade, enables considerable pressure to bear on the screw that it is desired to turn.

The Perfect pattern screwdriver is also an extremely robust tool and suitable for general workshop requirements. In this pattern the handle is partly of steel and is made with the blade, a wooden covering being riveted to each side to form a convenient gripping surface. Probably the most useful tool for set construction is the electrician's screwdriver, which has a thin blade and is sometimes known as the octagon-handled screwdriver, on account of its shape.

The registered screwdriver is also a useful tool for set construction and is somewhat shorter than the previous one and has an oval handle. The two larger screwdrivers of the cabinet type, the name of which suggests their application, are of similar design to the registered variety, but of larger size. For small work the pocket and the Starrett watch screwdrivers are useful. The former has a blade which when required for use fits into a slot cut at the top end of the handle.

When not in use the blade may be pulled out and reversed, enabling it to be inserted into the handle, which is made hollow to accommodate it. The watch screwdriver, which has a knurled handle to provide a good grip, is provided with a flat-ended top on which the first finger of the right hand presses when the tool is in use. The method of using the watch screwdriver is shown in Fig. 2. Another small screwdriver of the wire type is also suitable for small work.

WATCH SCREWDRIVER IN USE

Fig. 2. An illustration showing how a watch screwdriver should be held. This tool is suitable for driving very small worm screws as used in wireless construction

Fig. 3 shows the correct method of holding the screwdriver where considerable force in turning is required, and is applicable to the larger sizes. Where extra turning power is demanded, as in the removal of an obdurate screw, a spanner may be applied to the flat of the screwdriver, and in this manner considerable leverage is obtained. This operation is shown in Fig. 4.

The screwdriver is regarded by many as a rough and general tool equally suitable for mixing paint and functioning as a cold chisel. If screws are to preserve their appearance and their slots are not to be damaged, care should be periodically given to the screwdriver. It should have a flat end, the width of which is dependent on the size of the tool. As a guide, however, the end of the blade should be a good fit in the slot of the screw for which the size of the screwdriver is designed. The

CABINET SCREWDRIVER IN USE

Fig. 3. In this photograph is shown the correct method of holding the cabinet screwdriver

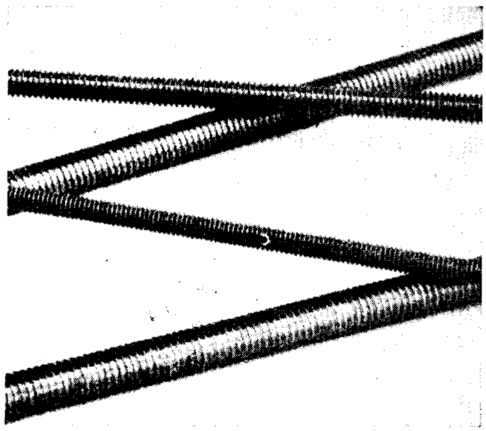
AIDING SCREWDRIVER WITH A SPANNER

Fig. 4. Increased leverage may be obtained when a screw is long and difficult to drive home by employing a spanner in this way

sides of the implement should be ground flat towards the ends. A worn screwdriver with curved sides will turn itself out of the screw slot, damaging the latter as it comes out and failing to turn the screw. This trouble may be avoided if the tool is properly ground.

Where difficulty is experienced in putting a screw into the hole where it is intended to go, owing to its inaccessible position, the slot of the screw may be filled in with a sticky substance. When the end of the screwdriver is now applied to the screw slot, the screw may be made to stick on the end of the tool and carried in this way into position.

SCREWED ROD. Screwed rod, often known as stemming, consists of rod, usually of brass and sold in 12 in. lengths, screwed on the outside for the full length. The rods are usually screwed in British Association threads, the most common



SPECIMENS OF SCREWED ROD

Screwed rod is used for many purposes in wireless. It is made in many sizes and is useful for spindles and the like

sizes being 6, 4 and 2 B.A. The largest size, which has a diameter of approximately $\frac{3}{16}$ in., is very largely used for spindles of filament resistances and for the supporting pillars of variable condensers. For this reason a hard brass is used in the construction of screwed rod.

It is important in using screwed rod for spindles to see that it is quite straight. Sizes up to 2 B.A. may be cut with sharp cutting pliers or nippers, a method which enables the rod to be cut when in position on a panel. Cutting screwed rod, especially if the tool is at all blunt, very often spoils the thread at the end, which prevents a nut from being screwed on. If trouble is experienced from this source, a die should be run over the end. A better plan is to screw an extra nut on the rod before cutting. When this nut is removed it will clear the thread as it is turned off. Several different sizes of screwed rod are shown.

SCREW. A cylindrical object with an external helicoidal rib. Screws used for constructional purposes in wireless are more or less limited to the short threaded rods having a head at one end and a slot for the application of a screwdriver in the head.

Screws are divided into two main classes: those for insertion into wood and those used with metal or other material of a similar nature. Owing to the comparative softness of wood, a wood screw may be turned straight in without the necessity of cutting a thread in the material. For this purpose a wood screw has a pointed end and the thread has a quick pitch, and is extremely coarse compared with a metal thread screw. In referring to a wood or a metal screw, the association of the screw with the material with which it is used is inferred, and not the composition of the screw itself, which in the great majority of cases is of metal. The shank of the wood screw is usually threaded only two-thirds of its length, the unthreaded portion giving a jamming effect which increases the hold in the wood.

Metal screws are threaded throughout their length, and are parallel-sided in distinction to wood screws, which are tapered. Great similarity exists in the heads of the two types of screw, the heads taking the form of round, countersunk or cheese shapes. These three patterns of heads on metal screws are shown in Fig. 1, and in Fig. 2 are seen three types of wood screws. The cheese-headed wood screw is the least used. The turning motion of the screwdriver is usually imparted by a slot cut across the centre of the screw head in both wood and metal screws. An exception, however, is shown in the upper screw in Fig. 2. The head of this screw,

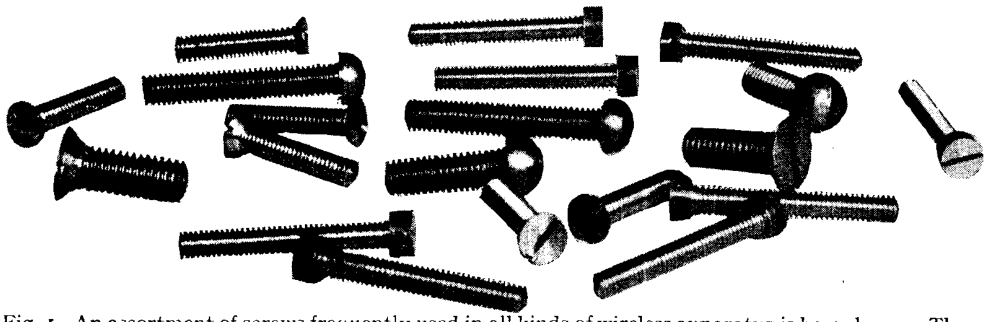
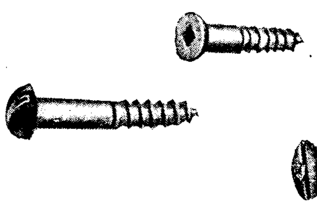


Fig. 1. An assortment of screws frequently used in all kinds of wireless apparatus is here shown. These are known as cheese-head, round-head and countersunk screws, and are made in standard sizes

SCREWS COMMONLY EMPLOYED IN WIRELESS CONSTRUCTION



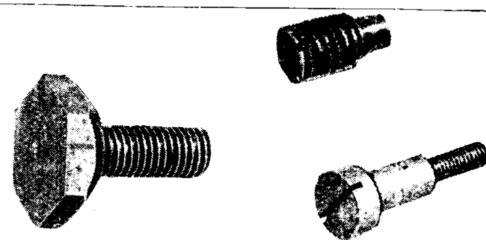


Fig. 2 (left). Above the round-head and countersunk pattern wood screws is a special type with a square hole for turning. Fig. 3 (right). These screws are designed for particular purposes. One has a large hexagonal head and is turned like a nut, that on the right has a shoulder to fill a space without a worm; the top example is a grub screw

SCREWS FOR SPECIAL PURPOSES IN WIRELESS

which is known as a recess screw, has a square hole, a special square key being used for turning it.

The small metal screws used in wireless constructional work are limited largely to the British Association sizes, commonly abbreviated to the letters B.A. These screws range in eleven sizes from 0 to 10 B.A., the largest size, No. 0, being about $\frac{1}{4}$ in. in diameter. The largest of these screws meets the majority of cases where fairly large screws are required. If bigger screws are needed, however, Whitworth screws are generally used. The most useful sizes in screws for ordinary wireless constructional work are the 2, 4 and 6 B.A.

For screwing into ebonite, metal screws are generally used, the ebonite being suitably drilled and tapped to receive the screw. It is not commonly known that a wood screw will often answer the purpose, and has the advantage of saving the time of the tapping process. Tapping blind holes for screw accommodation in ebonite is a somewhat difficult process, as if care is not taken the tap is overturned and the threads spoiled.

In employing a wood screw for use with ebonite, a hole should first be drilled rather smaller than the diameter of the threaded portion of the screw and to the whole of the depth of the screw. Where screws are fitted to the outside of a panel, countersunk screws should be used and the heads carefully blackened to match the ebonite. If carefully countersunk into the panel, a screw fixed in this manner shows but very little, and if seen at all does not present an unsightly appearance.

Cheese- and round-headed metal screws are used largely for bolting together two surfaces or pieces of metal. The upper piece, against which the screw head is pressed, is drilled a clearance size, while the lower piece is drilled and tapped to receive the stem of the screw. For the experimenter the most useful lengths of screws of either the wood or metal variety are from $\frac{3}{8}$ in. to 1 in.

In cabinet making, screws should be used in preference to nails, and the heads carefully sunk flush with the sides of the cabinet. The smallest screw consistent with strength should be used. As far as possible the wood screw should be screwed in at right angles to the grain, as it affords a stronger hold than when inserted with the grain. It is important when joining two pieces of either wood or metal to arrange for the screw portion of the screw to bite into the thicker of the two pieces.

Special forms of screw are shown in Fig. 3. The screw to the left in this illustration has a large hexagonal head, while the right-hand one has a shoulder capable of forming a pivot on which a moving arm or similar object may rotate. A grub screw is shown to the top right, and this is largely used in fixing control knobs to spindles. One end is turned down where the screw grips the shaft or spindle, and does not prevent the extraction of the screw if it should burr by contact with the spindle. The other end is slotted in the usual manner. *See* Dies and Taps; Ebonite.

SCRIBER. A scriber is a steel-pointed instrument used for marking out work. Of two general forms of scriber one is used by wood workers, this having a sharp point at one end and a broad cutting blade at the other end. The engineer's type of scriber usually has a fine sharp point at one end and a more or less increased diameter in the middle of its length, this part being knurled to provide a secure grip, and the other end bent over at right angles.

For ordinary work a 6 in. to 8 in. length of $\frac{1}{8}$ in. diameter silver steel wire with one end bent over at right angles and both

HOW A SCRIBER IS USED

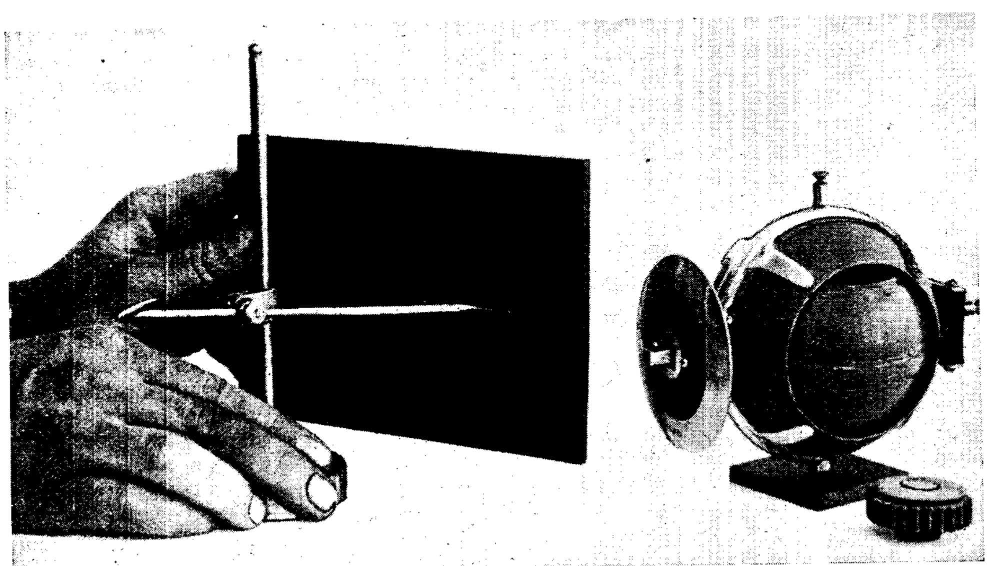
Ebonite panels are usually marked out with a scriber, which cuts a line in the same way that a pencil is used for drawing a line. The marks are made on the back of the panel

ends ground to a point makes a serviceable instrument for the experimenter. It is used for marking out ebonite panels and metal work generally. The method is to hold a steel rule or set square on the face of the work with one of its edges in register with the position where the line is to be scribed. The scriber is then held in the right hand and manipulated as if it were a pencil.

The depth of the lines should be sufficient to avoid any chance of their being obliterated while the panel is being worked upon, but should not be deeper than is necessary. When using a scriber, the best practice is to mark out the back of the panel, so that the appearance of the scribing will not be visible when the work is completed. The only attention needed with a scriber is to keep the point sharp by grinding or sharpening on an oilstone. *See* Marking Gauge ; Scales.

SCRIBING BLOCK. Term given to a marking out or measuring tool largely used by machinists but of considerable utility to the wireless experimenter. The instrument comprises a circular or other shaped base with a vertical central rod attached to it, and a universal clamp, which may be adjusted up or down on a rod, rotated upon it, and which also supports a thin cast steel rod known as a scriber. One end of this scriber is tapered to a sharp cutting point and the other end is bent over at right angles and similarly pointed.

In use the instrument operates on a perfectly flat surface, such as a piece of plate glass. One valuable use for a scribing block is in the setting out of a panel for a receiving set. In the example illustrated a variometer has to be fixed to the panel, and it is desired to know the exact distance from the base of the former to the centre of



MARKING A PANEL WITH A SCRIBING BLOCK

At the side of the panel is a variometer, the spindle of which is to be fitted at a point equal to its height from the bottom of the base. A scribing block is used for marking the panel where the spindle is to be fitted, by setting the point at the exact height of the spindle and holding the panel with its edge on the same surface as the base of the variometer the variometer spindle, and to transfer this distance to the panel, so that the hole for the spindle can be accurately drilled.

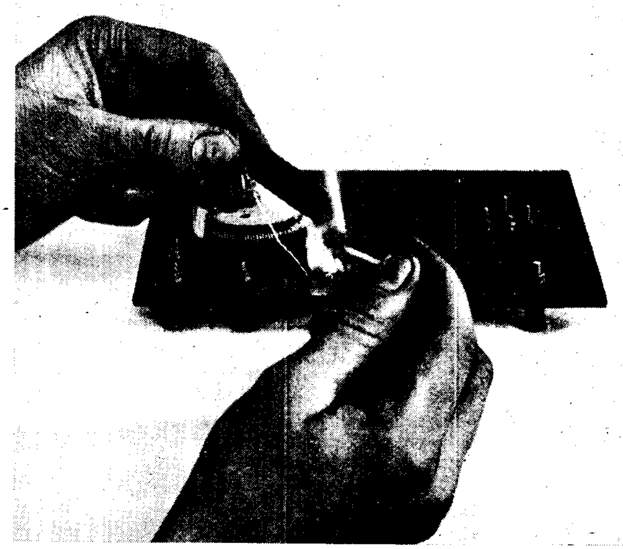
This is accomplished by standing the variometer and the scribing block on a flat surface. The point of the scriber is adjusted so that it is exactly on the centre of the variometer spindle. The scriber is then secured to the block by tightening the universal clamp. The panel is set in a vertical position and held in the left hand. The scribing block is then moved across the level surface until the cutting point is in engagement with the panel, when a short line can be scribed upon it. As one edge of the panel is resting on the flat surface and the variometer is also resting on the same flat surface, it follows that the exact height of the variometer spindle has been transferred to the panel.

In this case it is presupposed that the edge of the panel resting on the flat surface will ultimately rest upon the base of the receiving set, and that the variometer is to stand on that base. Should there be any difference in these dimensions, either the variometer or the panel can be rested upon packing blocks to compensate for the difference: as, for instance, if the base were 1 in. in thickness, the variometer should rest upon a block of this thickness before adjusting the height of the cutter. The instrument is used on the same principle for many other marking-out operations. *See* Marking Gauge.

Se. This is the chemical symbol for the metallic element selenium (*q.v.*).

SEALING WAX. Varieties of hard wax, usually consisting of a mixture of shellac, Venice turpentine and vermilion, possessing the property of becoming fluid or plastic when heated to a low temperature. Sealing wax is used for fixing the string on parcels and in other domestic work of a like character, but can also be applied in wireless work to a variety of other uses. One application is as a filling for unwanted holes in an ebonite panel.

In this case the process, which is illustrated, is to hold the stick of sealing wax in the left hand with its end immediately over the hole to be filled and then with a lighted match held in the right hand apply the flame to the end of the sealing wax. The wax is thus melted and drops into the hole, which it will speedily fill. Both sides of the hole in the plate may have to be filled in this way. To produce a smooth surface, any surplus wax may be cut off with a knife or smoothed off with a file, the final smoothing being



FILLING HOLES IN EBONITE WITH SEALING WAX

Sealing wax is very useful for filling holes in ebonite panels. It may also be used in a variety of other ways in wireless as a means of insulating

accomplished with a warm knife blade. Other uses for sealing wax include the filling of holes in plugs and making a firm connexion between them and the insulated wire which passes through them.

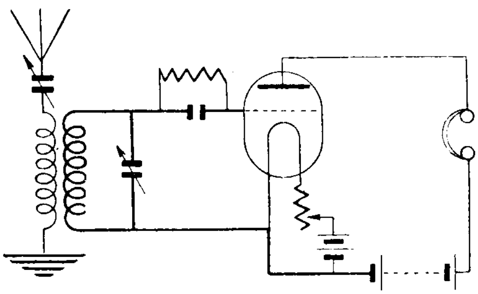
Another use for sealing wax is as a temporary means of fixing small parts, such as a grid condenser, to an ebonite plate. Other small parts can be moulded with sealing wax by melting the wax and running it into a cavity cut in a piece of wood or hollowed in a plate. *See* Insulating Material; Paraffin Wax.

SEARCH COIL. Name given to the rotating coil which moves between the fixed coils of a radiogoniometer. *See* Bellini-Tosi Aerial; Goniometer; Radiogoniometer; Robinson Direction Finder.

SECOHM. Name formerly given to the unit of self-induction, the henry. *See* Henry.

SECOHMETER. Name given occasionally to those instruments used for the measurement of self-inductance. They are so called from the former name of secohm once used in place of the henry as the unit of self-inductance.

SECONDARY CIRCUIT. Circuit which depends for the current passing through it upon another circuit known as the primary circuit. In a receiving set where the detecting circuit is inductively coupled to the aerial circuit, the latter is the primary circuit and the former the secondary circuit. This secondary circuit is tuned to have the same value of the product of the



SECONDARY CIRCUIT OF RECEIVING SET

Fig. 1. In the above diagram, which shows the circuit of a receiving set, the secondary circuit is shown in heavy lines

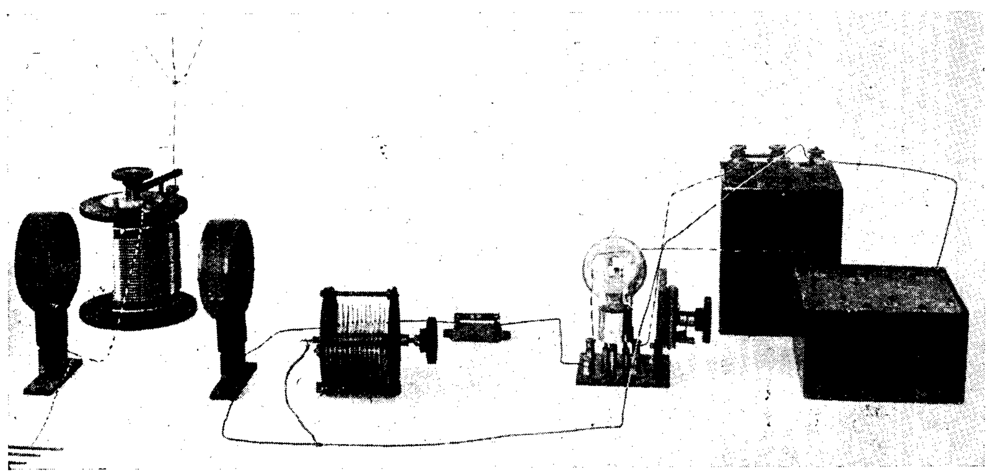
inductance and capacity, *i.e.* the same oscillation constant, as the aerial or primary circuit.

A common secondary circuit is illustrated in the form of a theoretical circuit diagram in Fig. 1, the secondary circuit being shown in heavy lines. Commencing from the grid of the valve, the circuit includes the grid leak and condenser, the secondary coil with the tuning condenser shunted across it, and the connexion from the latter to the low-tension negative side of the filament-lighting battery. A pictorial lay-out of the same components is illustrated in Fig. 2, from which the relative positions of the various parts can be judged. *See* Circuits; Inductance; Reaction; Transformers.

SECONDARY COIL. General term applied to any coil which relies for its current supply upon another coil called the primary. This arrangement is found very frequently in wireless transmitters and receivers, notably in tuners and transformers.

An elementary example of a secondary coil is illustrated, and shows a primary coil in an aerial circuit, represented in this case by the customary aerial and earth symbols. Adjacent to it is the secondary coil with the connecting wires from it leading to the right, where they may take their place in the circuit. For instance, they may be connected to the terminals of a variable condenser, and to the remainder of the circuit. The coils shown are Igranic honeycomb in ordinary coil holders.

In the case of tuners, it is general practice to have two or more separate circuits, each separately tuned, and



LAY-OUT OF RECEIVING SET WITH SECONDARY CIRCUIT

Fig. 2. Components of a receiving set are laid out and wired to show the two distinct circuits. On the left is the aerial and earth shown symbolically, with a coil and condenser between, and on the right of them is the entire secondary circuit, comprising coil, condenser, grid leak and condenser, valve unit and batteries

inductively coupled. The most common form of tuner for receiving work is the two-circuit type, in which the first circuit consists of a coil and condenser connected to aerial and earth, and the second, consisting of another coil and condenser, connected to grid and filament of the first valve. The first circuit is known as the primary, and the second as the secondary.

Generally speaking there is no metallic connexion between the two circuits, but the coils are placed in such a manner in relation to one another that they are inductively coupled. It is general practice to have the coils placed in a suitable mechanical device which allows of the space or angle between the coils to be conveniently adjusted at will. By this means a considerable degree of selectivity (*q.v.*) may be obtained.

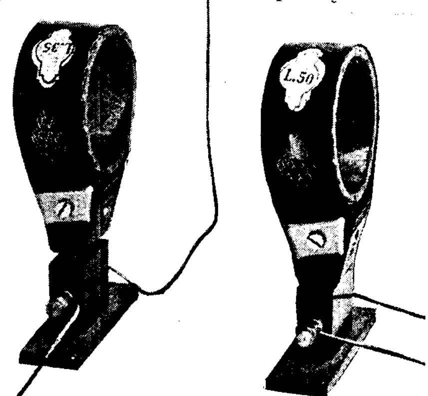
Transformers for receiving sets, whether high- or low-frequency, invariably have two windings. In the case of high-frequency transformers the ratio of the windings (*i.e.* the number of turns in each winding) is 1 : 1. On the other hand, the general rule in the case of low-frequency transformers is to have a voltage step-up effect between the windings. This is accomplished by having the primary of a small number of turns of comparatively thick wire, while the secondary has many turns of thinner wire. In all cases the coupling between the windings is purely inductive, there being no metallic connexion.

Telephone transformers are the reverse of inter-valve low-frequency transformers, in that the secondary winding is thick and has few turns, while the primary is thin and has many turns. By this means a voltage step-down is obtained. *See* Loose Coupler; Transformer.

SEDIMENT. Name applied to a deposit found at the bottom of accumulator cases. It is caused by the active material of the plates of an accumulator slowly disintegrating and settling at the bottom of the case. Great care must be exercised to see that this sediment never reaches a sufficient height to touch the bottom of the plates, or they will thereby be short-circuited. Sediment is largely caused by discharging too low.

The colour of the sediment is to some extent an indication of the health of the battery or cell. If a pale brown colour it indicates insufficient charging, if deep brown it shows normal treatment. Greyish sediment indicates overcharging; but a very white sediment is an indication of insufficient charging, or that the cell has been standing for a lengthy period and not sufficiently charged. Any excess of sediment can be removed by a thorough washing out of the cell accompanied by the proper refilling and recharging. *See* Accumulator; Storage Battery.

SEIBT AIR CONDENSER. Well-known form of air condenser. The construction of the Seibt type of air condenser may be gathered from Fig. 1. It will be seen that the tiers of vanes are made in each case out of solid material. Thus the warping of plates and the bad contact between plates and spacer washers is eliminated. The air gap, which is illustrated better in Fig. 2, is very minute, not exceeding, in fact, a few thousandths of an inch. So long as the bearings, which are of very large size, remain perfect there is little chance of any variation in capacity. Contact to the moving vanes is effected by a thin ligament wound round the lower end of the central spindle. The bearings are insulated from the metal end plates by large ebonite bushes, which are clearly seen in both illustrations. A stop is provided on the left-hand side of the condenser for preventing the vanes from rotating more than 180°. *See* Air Condenser; Condenser.



AERIAL AND SECONDARY COILS
On the left is an aerial coil, and on the right, loosely coupled to it, is a secondary coil. Either or both coils could be tuned by a variable condenser

SEIZING. Term used in various senses. In one case it refers to a condition of

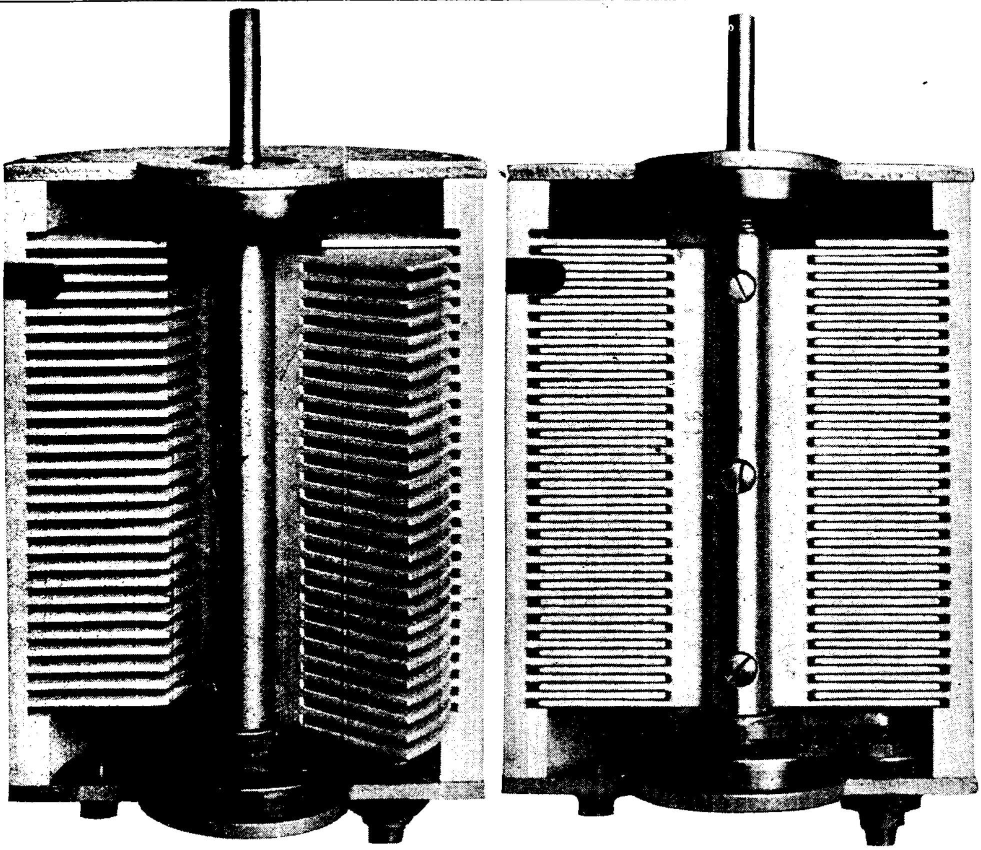


Fig. 1 (left). Seibt air condensers differ from the ordinary air condenser in the way the two sets of vanes, fixed and movable, are constructed out of solid material. Fig. 2 (right). The moving vanes of the condenser are shown here well engaged and the solid construction is clearly seen

Courtesy E. E. Rosen & Co.

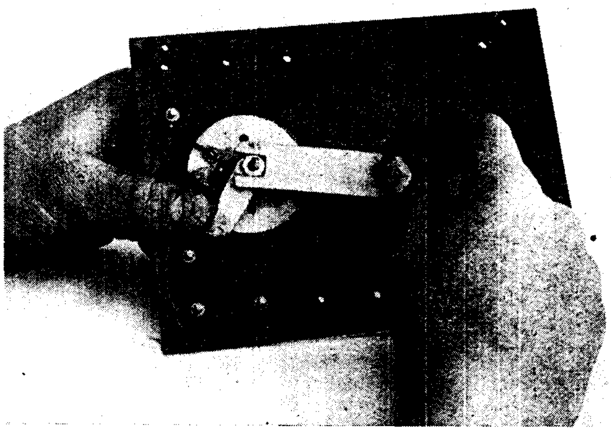
SEIBT AIR CONDENSERS, SHOWING THEIR CONSTRUCTION

affairs between a spindle and a bearing which are normally rotatable, and is used to define that condition when the two surfaces become scored and thereby prevent, or seriously impede, the movement of the spindle in the bearing. This form of seizing is occasionally met with in the running bearings of various machines, and is generally traceable either to bad design, absence of lubrication, or the ingress of dirt or foreign matter. Remedies are to take the bearing apart, clean it and resurface the bearings and shaft by suitable means according to their size and nature.

Another form of seizing which is prevalent on many types of wireless receiving sets is that due to the jamming of, for example, the filament resistance. In a commonly used construction the contact arm of the filament resistance is attached to a screwed rod and secured by means of two lock nuts. A spring washer and one or more plain washers are introduced between one of the lock nuts and the fixed bearing of the spindle, the other end of the spindle being provided with a knob.

Unless these parts are properly assembled the contact arm is liable either to work loose, or, more frequently, to tighten up until movement becomes impossible. In other words, the spindle has seized. This is frequently due to the knob not being properly fixed to the spindle, but more generally to the improper tightening of the lock nuts securing the contact arm.

The proper way to avoid this trouble, or to remedy it, should it arise, is first to disassemble the spindle, knob and contact arm; secondly, to attach the knob securely to the outer end of the spindle; and, thirdly, to pass it through the bush in the usual way, slip the plain and spring washers over the spindle, and screw down the lock nut until sufficient pressure has been brought to bear upon the spring to effect a firm contact. The contact arm is then placed in position, and should be prevented from rotating by means of the left thumb, as shown in Fig. 1. The second nut is then screwed on to the spindle and tightened up on to the contact arm, holding the latter by pressing upon it with the thumb while the nut is tightened with a small spanner, as illustrated in Fig. 1. If the nuts be tightened in this way, there is very little risk of their moving.



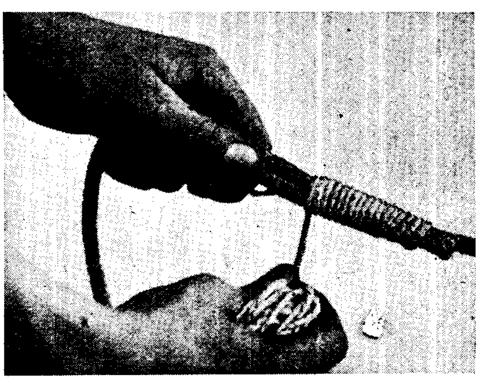
PREVENTING SEIZURE OF CONTACT ARM

Fig. 1. The panel is held and the knob steadied in the left hand, while the right tightens the nut firmly on the end of the spindle

Another application of the word seizing, as found in wireless work, is that illustrated in Fig. 2, and is the method of uniting the two ends of a rope. It consists essentially of binding them together with thinner cord, turning it round and round the two ends of the rope, thereby securing them very firmly together. This method of seizing, or, as it is sometimes called, whipping, can be carried out with thread, thin cord, or with copper or other binding wire, and is an effective and quick way of securing the ends of rope.

SELECTANCE. This is another name for selectivity. It is a name suggested in analogy with capacitance, inductance, resistance, etc.

SELECTIVITY. In wireless the power of selecting any particular wave-length from a number to the exclusion of others. It is in practice the same as tuning. In this Encyclopedia the subject is dealt with in its various aspects under such headings as Atmospherics; Direction Finder; Frame Aerial; Interference Eliminator; Wave Trap, etc. *See* also under the titles of the various sets whose construction has been described in this Encyclopedia, *e.g.* Amplifiers; Crystal Sets; Hanging Sets; Tuned Anode, etc.



SEIZING APPLIED TO ROPES

Fig. 2. How the ends of a rope are united by binding them with cord

SELECTOR SWITCH. A form of switch used in a variety of ways by which one of any number of circuits may be chosen at will. A common use for the selector switch is found in connexion with the employment of valves having different voltages. A two-, four- or six-volt battery may be wired up to the switch and selection of voltage taken according to the type of valve in use.

A useful type of selector switch is shown in Fig. 6, and is of the double-pole variety, being fitted with a pair of contact arms. A selector switch for home construction is shown in Fig. 1. This consists of an ebonite plate into which are secured four pairs of contact studs. To prevent the contact arms from falling down between the studs, they are sunk into an ebonite ring so that the tops of the studs come flush with the upper side of the ring.

Detailed measurements are avoided, as the switch may easily be made up to the requirements of the experimenter. The ring should be turned up in a lathe and marked out for the positions of the studs.

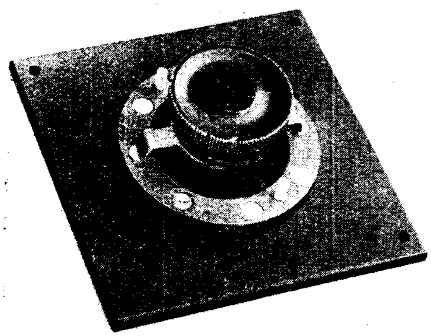


Fig. 1. Four circuits can be used with this simply constructed contact switch used for switching in different circuits

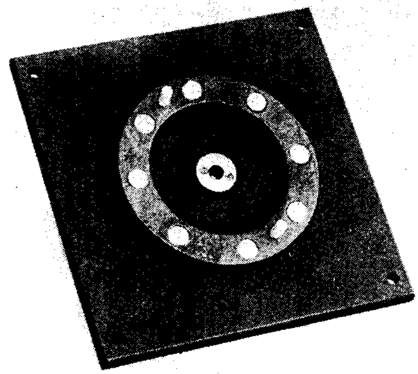


Fig. 2. The central bush, contact studs and stop pegs are shown. The pegs prevent the switch arm from moving right round

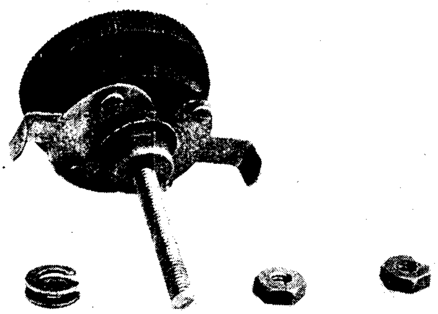


Fig. 3. Moving parts—double switch arm, spindle and control knobs—are illustrated here, ready for assembly upon the switch panel shown in Fig. 2

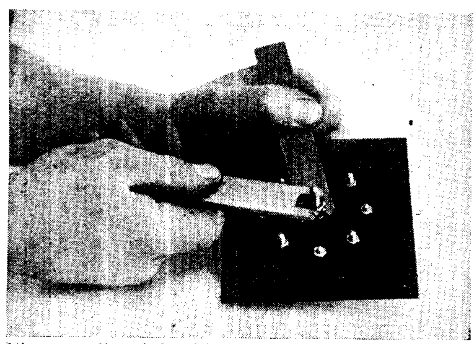


Fig. 4. Special thin spanners are used to tighten the two lock nuts which secure the spindle, so that each nut is tightened independently

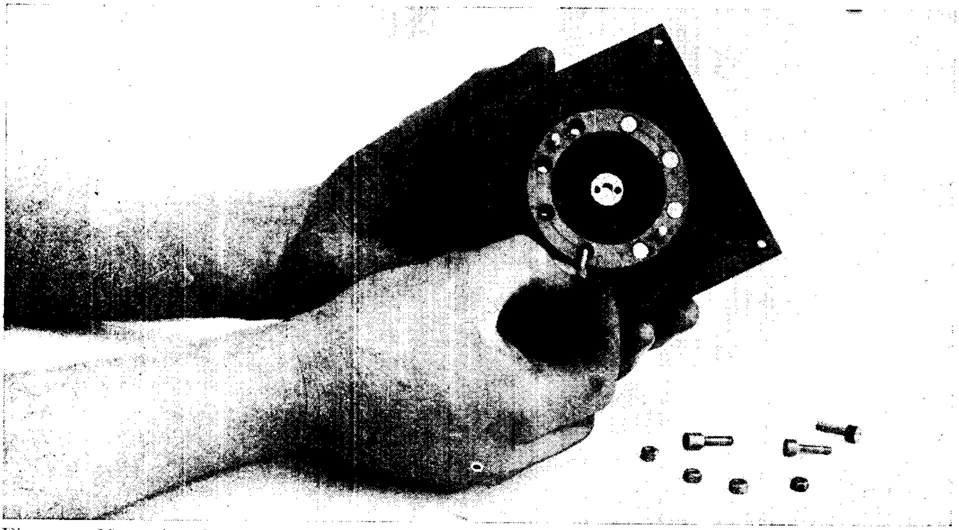


Fig. 5. Here is shown in close detail the assembly of the contact studs, the faces of which come flush with the top side of the ring

ASSEMBLING THE AMATEUR-CONSTRUCTED SELECTOR SWITCH

Care must be taken in fitting the ring to the panel to ensure that it comes concentric with the spindle hole drilled in the centre of the panel. It is important also to see that the stud holes in the panel register with the holes in the ring.

Fig. 5 shows the operation of fitting the studs to the switch panel. Two stop pegs are fitted between the studs on the opposite sides of the switch arm. These are shown fitted in Fig. 2. A central bush is secured to the panel in which the spindle of the switch arm rotates. The switch arm consists of two metallic parts, which are screwed to the underside of an ebonite knob. Each half arm is insulated from the other, one forming contact with any of the four studs on one side of the stop pegs, and the other performing the same function on the other side.

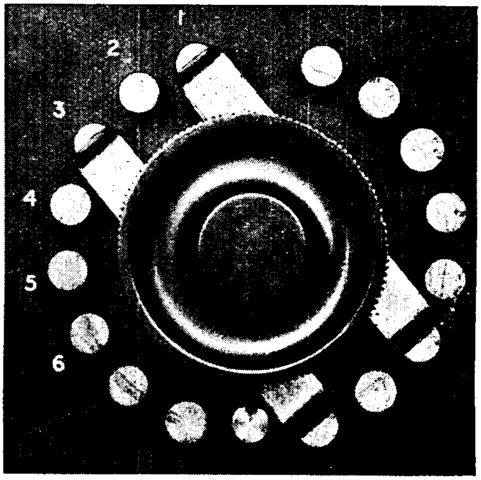
One half arm is electrically connected with the centre spindle, while contact with the other half arm is made by a fine flexible wire passed through a hole in the panel and soldered to the underside of the arm. An insulated washer is slipped over the spindle before a lock nut tightening the knob to the spindle is fitted.

Details of the switch arm and spindle are shown in Fig. 3, the spring washer and lock nuts securing the whole to the panel being shown in the foreground. These are fitted to the spindle at the back of the panel, the spring washer being fitted first. The method of locking the nuts is shown in Fig. 4, where two specially made thin spanners are used. A trace of oil at the bearing surfaces will allow the switch to move, with a sweeter action if it is found to be at all harsh. *See* Knife Switch; Switch.

SELENIUM. One of the metallic chemical elements. Its symbol is Se and atomic weight 79·2. Selenium is similar in crystalline structure to sulphur, and exists in several allotropic forms, the most important being the amorphous and the metallic. In the amorphous form selenium is a brick-red powder, and the metallic form may be obtained from it by melting and allowing it to cool under certain conditions. It is then a grey, crystalline metal. The element was discovered in 1817 by Berzelius.

Selenium is important in wireless because of its extreme sensitivity to light. The crystalline form of selenium is a conductor of electricity, and its conductivity varies with the light that is allowed to fall on it. It is clear, therefore, that if a beam of light can be controlled, say by the voice, a corresponding control of an electric current may be obtained by means of selenium. This is the principle of the photophone (*q.v.*).

Alexander Graham Bell, the inventor of the telephone, was the first to make use of selenium. He used flat selenium cells, which consisted of two copper or brass plates separated by a dielectric of mica. In these plates a large number of holes were bored, and in the holes of one



PETO-SCOTT SELECTOR SWITCH

Fig. 6. Double arms which make contact on alternate studs are found in this very useful type of selector switch

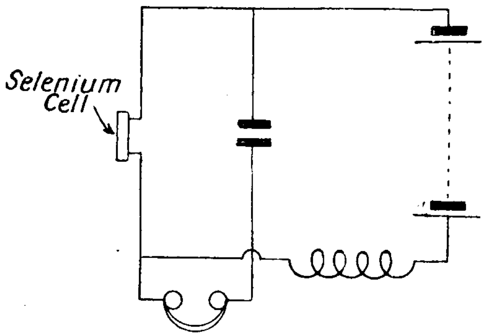
Courtesy Peto-Scott Co., Ltd.

plate were fixed cone-shaped brass strips which entered the holes of the other plate but did not touch it, leaving a series of annular spaces.

These spaces were filled in with melted black glassy selenium, and the cell was then heated until the selenium began to melt and turn into the grey crystalline state. The amount of selenium exposed to the light in this form of cell was only about one-tenth of the whole, and Bell, with Sumner Tainter, produced a cylindrical cell in which as much as 60 per cent of the selenium could be exposed to the light.

In this type of cell a series of brass and mica disks were piled alternately on each other. The mica disks were of smaller diameter than the brass ones, and in the intervening spaces round the edges melted selenium was run. Alternate brass disks were connected to one terminal of the cell and the others to the other terminal, and each layer of selenium was in contact with two brass disks. The selenium was afterwards melted and converted into the usual grey crystalline formation, and was then ready for use. The resistance of such a cell was about 1,200 ohms in darkness and about half that amount when the light shone on it.

Since then many types of selenium cells have been brought out. Ruhmer used cells with unglazed porcelain and soapstone cores, selenium adhering firmly to



SIMON'S CIRCUIT

Fig. 1. A telephone and condenser are connected in parallel, the battery circuit being directed off the telephone. Speech was thus received over a distance of one kilometre

either material. The surface of the core is cut in a double-threaded screw, round which are wound two wires while hot. These wires are the electrodes of the cell. The pitch of the double screw is small, so that the unlike electrodes of the cell are near to each other. The selenium in its melted state is put on the screw to cover all the space between the wires, and then converted as usual into the grey crystalline form sensitive to light. The current flows from one wire to the other through the selenium. These cells were made both flat and cylindrical. The cylindrical cells were enclosed in a vacuum bulb fitted with contacts, and the battery actuating them was about 100–150 volts.

The light on these cells should fall as nearly perpendicular to the surface as possible, to increase its sensitivity. Any part of the cell left unilluminated naturally increases the resistance and decreases the change in the fluctuations of current through the cell. The resistance of Ruhmer's cells had an upper limit of 25,000 ohms. The cylindrical cells were 25 mm. in length and 12·5 mm. in diameter, and the diameter of the flat type of cell 25 to 30 mm.

A selenium cell must not only be sensitive to light, but must be sensitive to changes in light. That is, it must have little inertia to light changes, and for this reason the selenium layer should be as thin as possible, so that as much as possible is affected by the light. A thick layer of selenium means that all the selenium below the surface is unacted upon, adding to the resistance of the cell. Some cells are more sensitive when faintly illuminated, and others when strongly illuminated, and the former type is usually more sensitive than the latter.

The type of light used is important, selenium cells being most affected by red rays.

The methods of modulating the light which falls on the selenium cell, by means of speech, is described in this Encyclopedia under the heading Photophone.

Fig. 1 shows diagrammatically the receiving arrangement, using a selenium cell, as used by Simon in 1901 for transmitting speech by a beam of light. The telephone and a condenser are connected in parallel with the selenium cell, so that the battery current through the cell does not pass through the telephone. Speech by this arrangement was received over a distance of 1 kilometre.

The selenium cell has been used in wireless as a sensitive relay. The selenium relay due to G. Allström is probably the most sensitive relay in existence, and is stated to respond to a current of less than one hundred-billionth of an ampere. Fig. 2 shows the circuit for such a relay.

A very light small piece of iron foil is hung between two platinum wires whose diameter is of the order of a thousandth of an inch. In the centre of the iron foil is fixed a small light mirror. Behind the iron foil is an electro-magnet, its core almost touching the iron.

In front of the iron foil, and some distance away, is the selenium cell enclosed in a box with a narrow slot in it. A source of light is placed behind the cell, and the light is concentrated on the mirror on the iron foil by means of a reflector. This latter mirror reflects light towards the selenium cell. When the mirror is motionless the beam does not fall through the slot of the box in which the cell is placed. The slightest vibration, however, carries the beam across the slot so that it impinges on the selenium cell.