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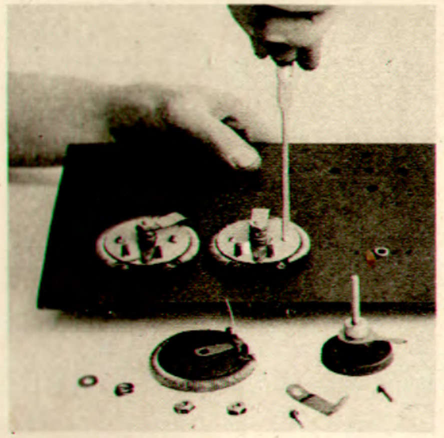


Fig. 14. Fitting filament resistances to panel. Rheostat parts in front

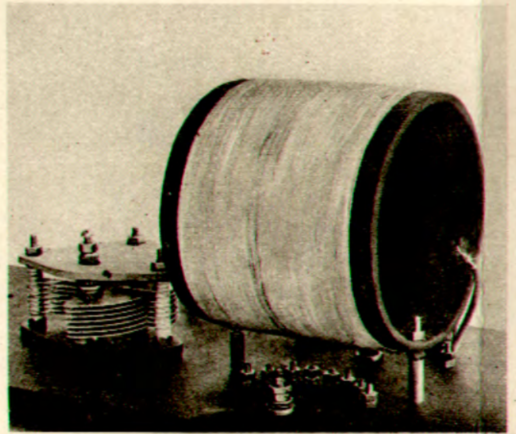


Fig. 15. Inductance secondary mounted clear of panel on valve legs and sockets

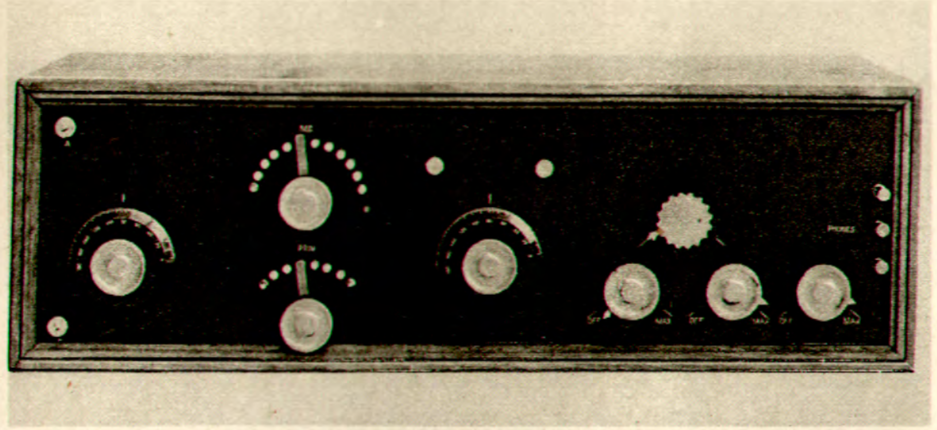


Fig. 16. Three-valve reflex set cabinet. The top stud switch is for inductance secondary and the lower switch for the primary

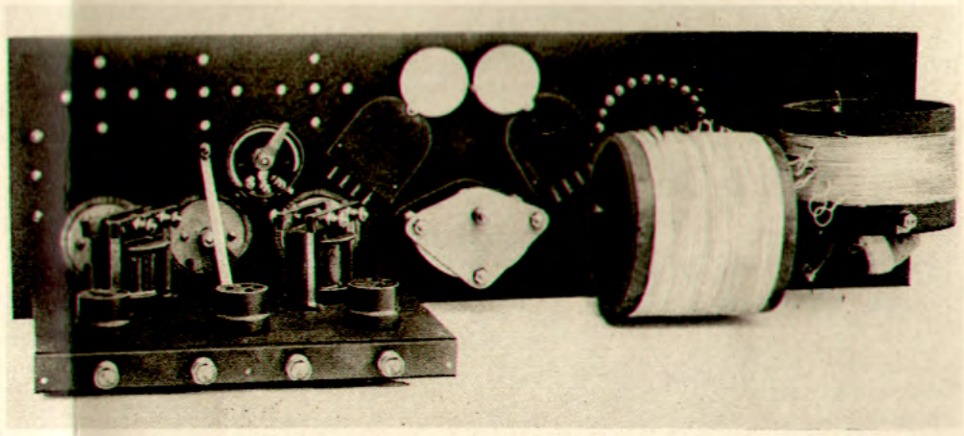


Fig. 17. General view of the back of the panel showing tuning coils, H.F. and L.F. transformers, condenser, potentiometer and valve panel

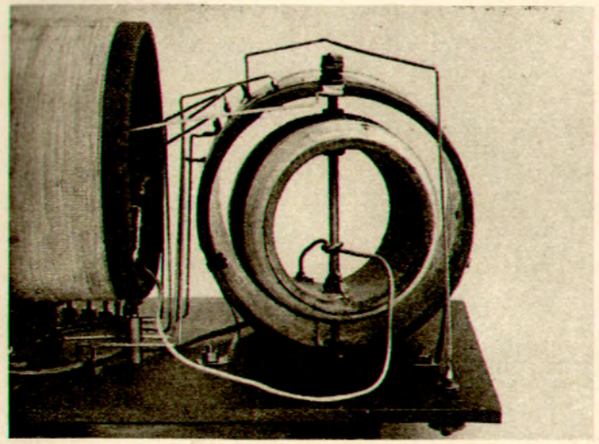


Fig. 18. Close-up view of rotor showing connexion with secondary coil

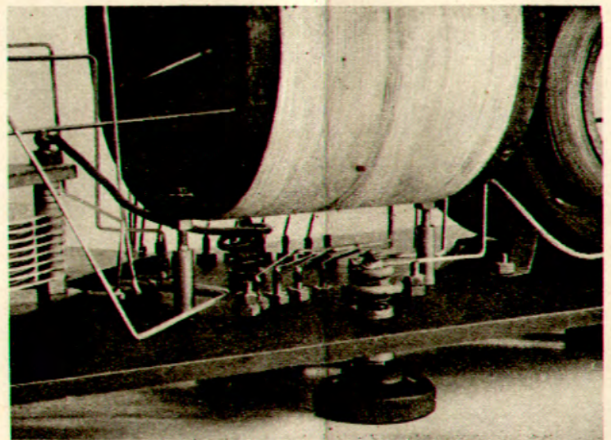


Fig. 19. Method of connecting flex wires to switch spindles to avoid fraying

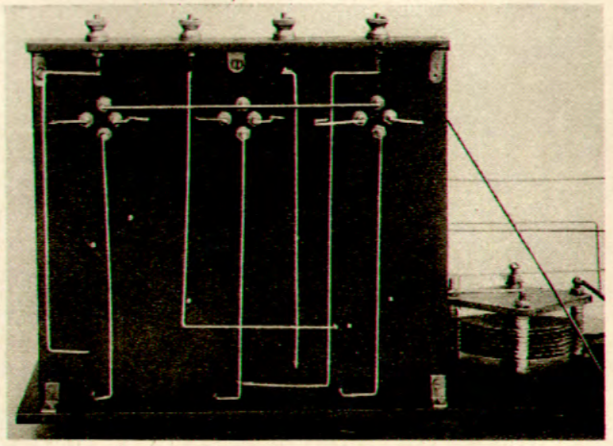


Fig. 20. Under view of platform showing wiring of low-tension circuit

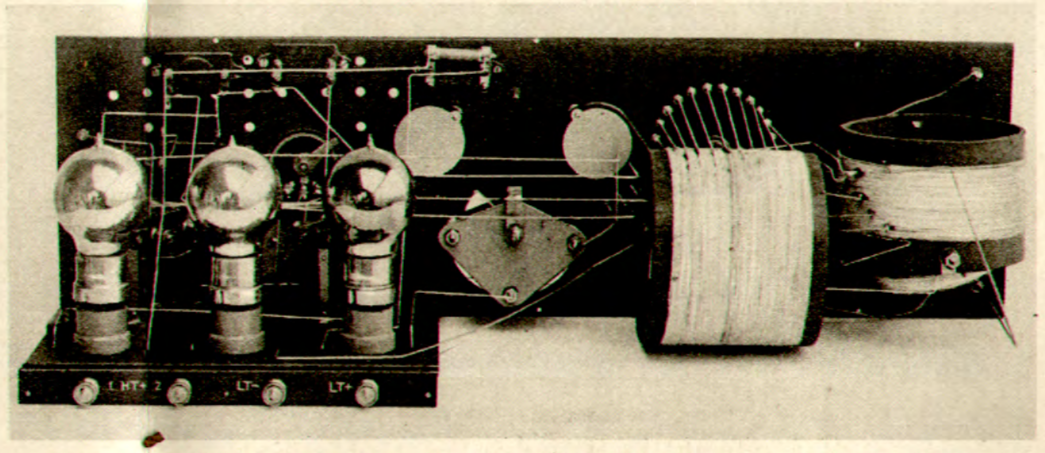


Fig. 21. Back view of set with valves in position. The wiring is completed and the whole of it can be seen by studying this and other views

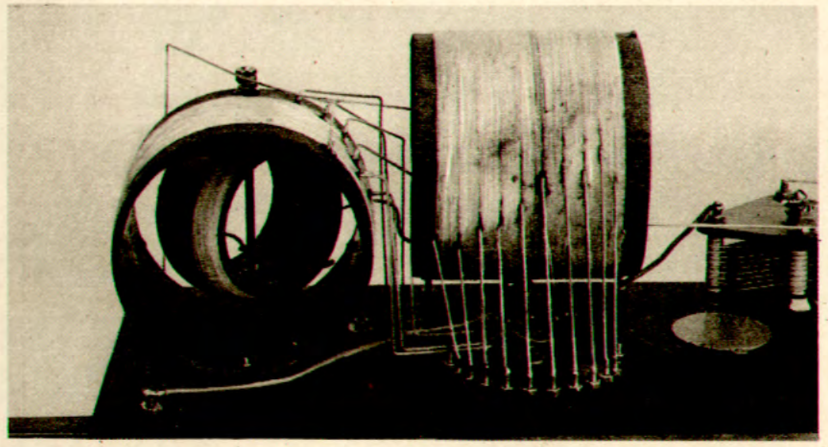


Fig. 22. Tappings of secondary coil shown connected to the studs of the switch. Note how the primary coil wires are connected

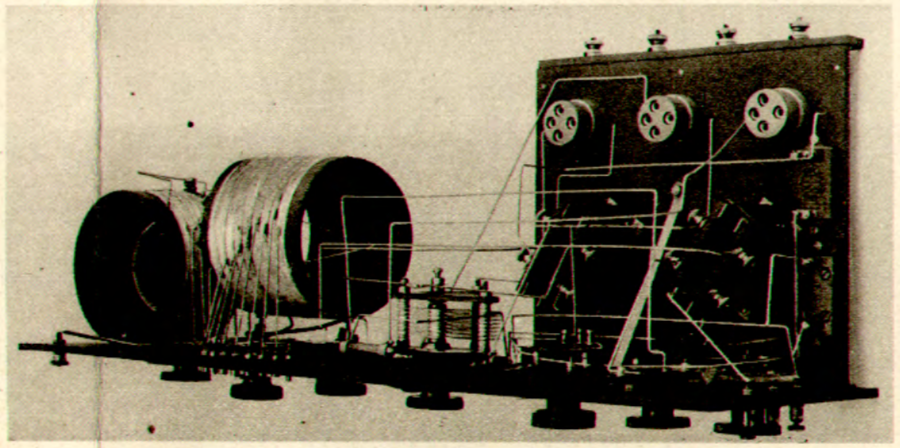


Fig. 23. Slanting plan view seen from the right of the apparatus. Many of the connecting wires may be followed in this photograph

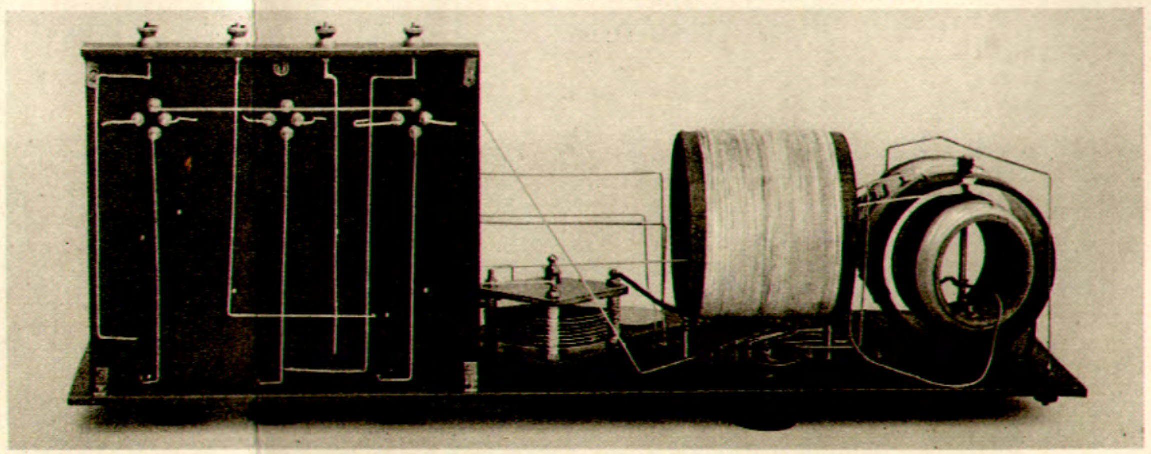


Fig. 24. In this photograph the panel and platform are complete and the wiring of the underside of the platform as well as of the coils is seen

REFLEX SET: A THREE-VALVE RECEIVER, ECONOMICAL IN COST & UPKEEP, WITH VALVES SERVING THE DUAL PURPOSE OF HIGH & LOW FREQUENCY AMPLIFICATION

To face page 1676

From photographs of a set specially constructed for HARMSWORTH'S WIRELESS ENCYCLOPEDIA

POWER AMPLIFIERS FOR LOUD SPEAKERS

Standard and Home-made Instruments for Great Amplification

Here is outlined the making of a power amplifier which enables a loud speaker to be used on a crystal set with only one valve. Various interesting commercial instruments designed for similar purposes are also described. The reader should consult such cognate articles as Amplifier ; High-frequency Amplifier ; Loud Speaker ; Transformer, etc. See also Power Valve ; Valve, etc.

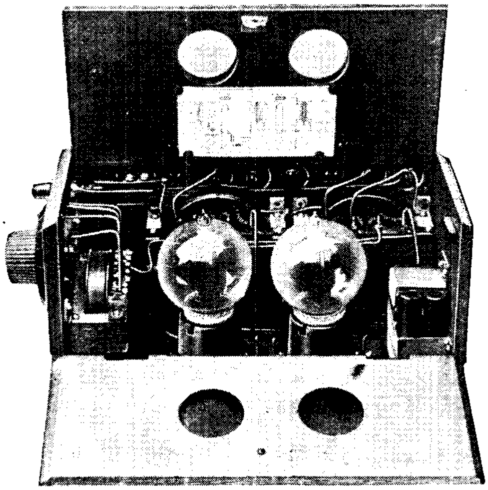
"Power amplifier" is a term which may be applied to any device for amplifying electro-magnetic waves either before or after rectification. It may thus be used to describe either radio- or audio-frequency amplifiers for reception, the construction and working of which are fully dealt with in a number of other articles under separate headings, notably in that on Amplifiers.

Power amplifiers are used in transmission (*q.v.*), a special application being that resorted to in the case of the Glasgow Broadcasting Station, where the studio is situated about a mile from the transmitting station. The variations of current produced in the microphone by speech or music are first amplified by a special amplifier with dull-emitter valves, and then, after passage over the cable leading to the station proper, they are further amplified by a two-valve power amplifier, the plate of the last valve of which is connected through a radio-frequency choke to the anode of the power valve.

Power amplification as commonly understood is usually associated with the employment of power valves.

Standard Power Amplifier. The Gecophone power amplifier is a two-valve instrument arranged within a flat cabinet. The latter is made this shape in order that the standard two-valve Gecophone receiver may be conveniently placed on top of it. Figs. 2 and 3 are photographs of the front and rear respectively. From Fig. 2 it will be seen that the controls are three in number. The knobs on the left and right-hand side of the ebonite panel are for the filament resistances.

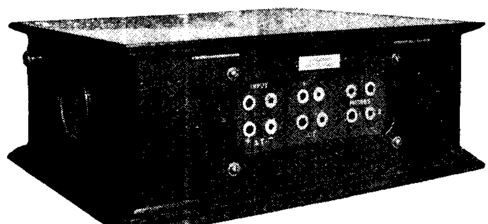
The central knob is a control switch, and enables one or two valves to be used at will, as well as providing an off position. All the connexions to and from the instrument are made by means of plug-in connectors. This is clearly shown in Fig. 3, where will be seen all the sockets for making the connexions. An interesting feature



INTERIOR OF LOUD-SPEAKER AMPLIFIER

Fig. 1. Top and front of the cabinet are open and the very compact arrangement of components revealed. This is a two-valve power amplifier

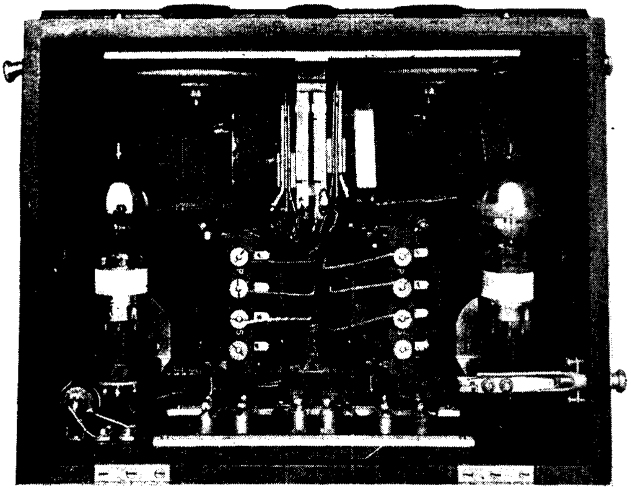
Courtesy Western Electric Co., Ltd.



FRONT AND REAR ASPECTS OF THE GECOPHONE POWER AMPLIFIER

Fig. 2 (left). Two valves are used in this instrument, and the control knobs are mounted on a small inserted panel. Fig. 3 (right). On the rear side may be seen the sockets for the plug-in connectors. These sockets are of different sizes to prevent mistakes in plugging in. The cabinet is shaped so that the Gecophone standard two-valve receiver may conveniently be placed on the top

Courtesy General Electric Co., Ltd.



INTERIOR OF GECOPHONE POWER AMPLIFIER

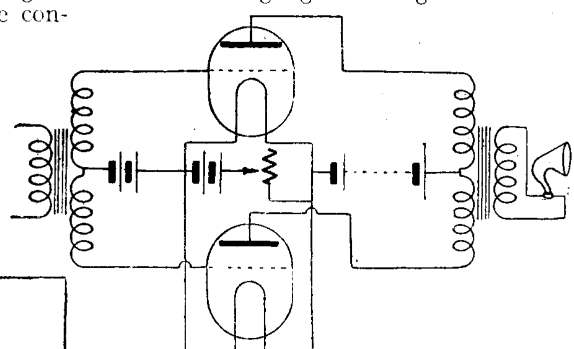
Fig. 4. The high-voltage transformers are placed side by side. The switch between the two rheostats consists mainly of jack parts. When the valves have been inserted their filaments are in the vertical position

Courtesy General Electric Co., Ltd.

of the plug and socket system in use in these instruments is that all the holes are of different sizes, thus rendering it impossible to make a mistake while connecting up.

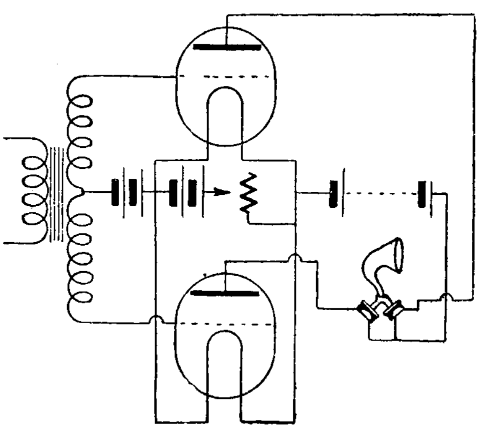
A view of the internal arrangements is given in Fig. 4. From this it will be seen that the valves are placed on either side of the cabinet, the holders being arranged so that the filaments naturally assume a vertical position. The transformers, which are side by side, in the centre, are designed to take a high voltage without fear of breakdown. The switch may be seen behind the panel, and it will be noted that it consists chiefly of standard telephone jack parts. Beneath this is a large fixed condenser, in a metal case. This amplifier is fitted with grid cells, one of which may be seen in the near left-hand corner of the cabinet.

The majority of power or multi-stage amplifier circuits have a series arrangement of valves, in which the output from one valve is handed on to the next. A somewhat different method of audio-frequency amplification is given in the circuit diagrams shown in Figs. 5 and 6. These circuits demand the use of a special transformer or one tapped exactly at a central point on the finer gauge winding. In other respects these transformers are similar to the ordinary iron-core inter-valve transformers. They are known as push-pull transformers, and permit a parallel wiring of the amplifying valves.



POWER AMPLIFIER WITH TWO TRANSFORMERS

Fig. 6. Two specially made transformers are used. The exact centres are tapped and wired to the batteries. The second transformer couples the loud speaker to the circuit



CIRCUIT WITH ONE TRANSFORMER

Fig. 5. A special push-pull transformer is used in this arrangement for a power amplifier. Note how the two earpieces of the loud speaker are wired

In the circuit arrangement shown in Fig. 5 only one tapped transformer is required, the anodes being connected to the loud speaker terminals. The other two terminals are connected to the positive side of the high-tension battery.

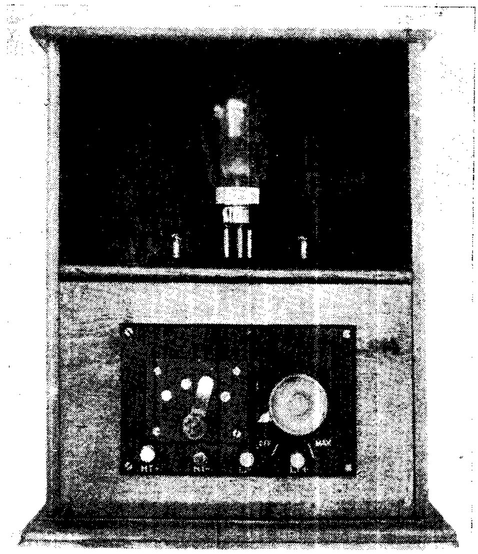


Fig. 7. Inside the upper part of the cabinet is an ebonite base on which is mounted the power valve. The amplifier here is complete

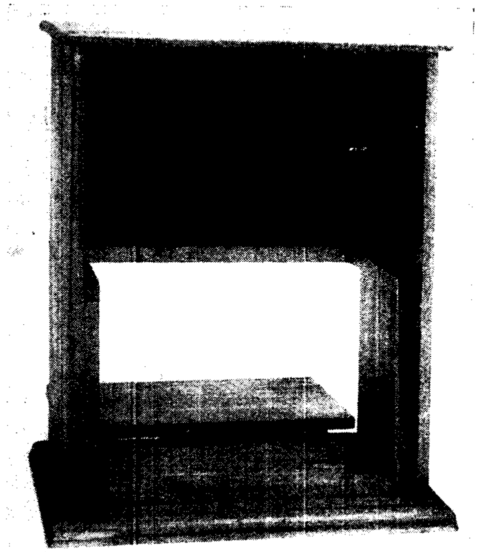


Fig. 8. Before the front section and the horizontal section are fitted, the cabinet for housing the power amplifier appears as in this photograph

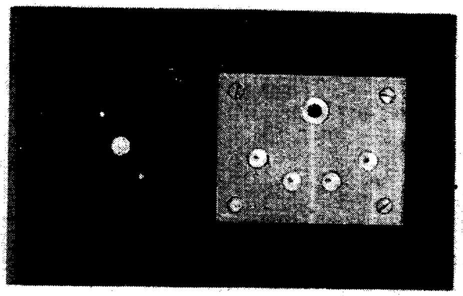


Fig. 9. Cup-like depressions are made in the contact studs of the switch before assembling the contact arms

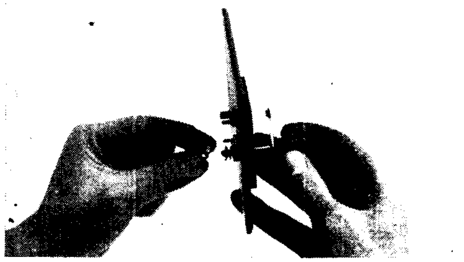


Fig. 10. How the contact arm and spindle are fixed. The method adopted is to use a spring washer and lock nut

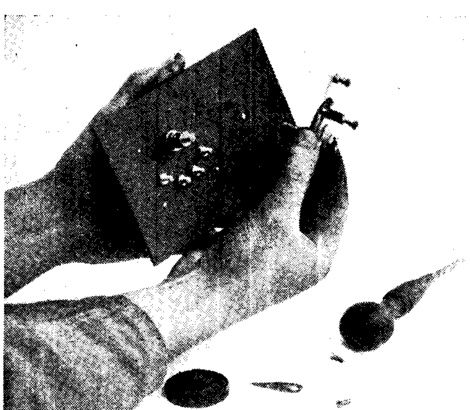


Fig. 11. Three small holes are drilled in the panel for the accommodation of the rheostat, which is here being fitted in place

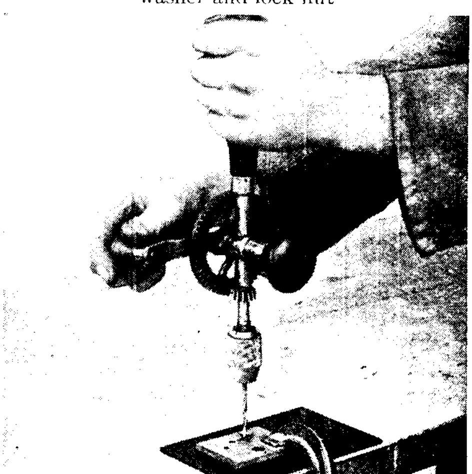


Fig. 12. Clamped together, the stud switch base and the panel are being drilled while thus held to ensure the stud holes registering exactly

Fig. 6 is a similar circuit, but requires an additional tapped transformer. The ends of the finer windings are connected to both anodes, while the central tapping is joined to high-tension positive.

How to Make a One-valve Power Amplifier. A single-valve power amplifier is shown completed in Fig. 7. This will be found to be a useful piece of apparatus; it is capable of amplifying crystal set reception to sufficient strength for connexion to a loud speaker.

The instrument shown in Fig. 7 has a tapped switch mounted to the front of the panel. The studs of the switch connect to a set of small dry cells, by which means a varying potential is obtainable on the grid of the valve. As the grid is made more negative, a greater anode current may be used, with resulting increase of amplification. The inclusion of a battery of grid cells in a power amplifier is therefore a desirable feature, although adding considerably to the construction.

Cabinet Dimensions and Constructional Detail

The cabinet is open at the top half and allows good protection to the valve. A box-like construction is built into the lower half of the cabinet, and houses the grid-biasing batteries, transformers and other components of the power amplifier. The lower half of the back is hinged and allows inspection of the wiring and interior of the set. Fig. 8 gives a good idea of the method of constructing the cabinet, and shows a fillet at the back and a shelf at either side of the cabinet, to which a horizontal wooden panel, with a small panel of ebonite in its centre, is attached. The sides of the vertical shelves support the front partition, and are assisted in this direction by a false base or lining, to the back of which the hinged section of the back is fitted.

The base is of solid construction, having an ornamental moulding around it. The base measures 10$\frac{3}{4}$ in. by 7$\frac{1}{4}$ in. by $\frac{3}{4}$ in. The sides of the cabinet are 12 in. high and 5$\frac{3}{4}$ in. wide. These may be cut from $\frac{1}{2}$ in. timber, which must be chosen to the experimenter's inclination. Oak or mahogany, suitably stained, gives a very fine appearance, but quite a well-made cabinet can be constructed from pine or deal. If stained dark with old oak stain, the effect is quite good. Whichever wood is chosen, it should be well seasoned and free from knots or flaws. The distance between the sides of the cabinet permits a sliding fit of the horizontal platform and the front section, which measure respectively 9 in. by 6 in. by $\frac{3}{8}$ in., and 9 in. by 5$\frac{3}{4}$ in. by $\frac{3}{8}$ in.

The height of the vertical shelves attached to each of the sides is 5$\frac{3}{4}$ in. to the top of the base, while their width allows the hinged back and front section to fit flush with the edges of the sides. The fillet on the inside of the fixed back is $\frac{1}{2}$ in. square. From Fig. 8, which shows the completed cabinet without the front and horizontal panels, it will be seen that the top of the cabinet overlaps a little on all four sides, and is also slightly round. Although the cabinet is constructed throughout in wood, the insulation of the electrical conductors is by ebonite, and care must be taken to maintain this degree of insulation in every part. To this end, no loose wires should be allowed to touch the wood.

The filament resistance and grid battery switch are mounted on an ebonite panel, which is in turn screwed to the front section of the cabinet. The front section is cut away to within $\frac{3}{8}$ in. of the side of the ebonite panel, to allow the fittings to project into the interior. For the ebonite panel an oblong of $\frac{3}{16}$ in. ebonite is cut, measuring 6 in. by 3$\frac{3}{4}$ in. The outer edge is then bevelled to half the thickness of the panel. The filament resistance occupies the right half, while the switch is to the left.

Special Switch Features

A feature of the switch is that an oblong of ebonite is laid over the studs so that their faces come flush with the smaller panel. This feature is made clear in Fig. 9, which shows the smaller switch panel screwed at each corner to the main panel. It will be seen that the faces of the contact studs come flush with the smaller panel. The method of proceeding with this part of the construction is shown in Fig. 12.

The stud positions are marked out on the smaller base, using the spindle holes as a centre. The smaller panel is then placed over the large one, and both are clamped to a bench. The stud holes are then drilled through both panels. While still clamped up, the correct position of the bush hole is also drilled. The holes for the contact studs in the smaller panel are

Fig. 13. When the stud switch and filament resistance have been mounted the panel is secured to the wood front

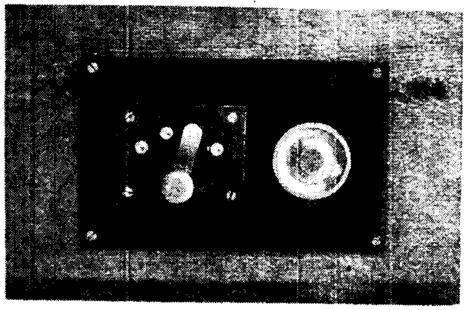


Fig. 14. Details of the front section of the cabinet panel are seen in this view. The panel is ready for assembly

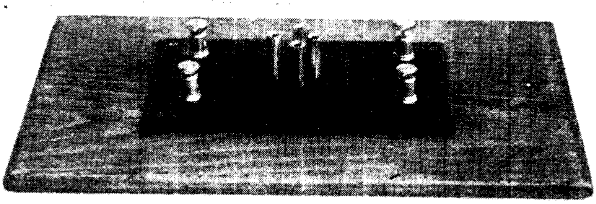


Fig. 15. Before the fixed condenser is attached, the horizontal section or valve shelf of the cabinet, with holder and terminals, appears as in this photograph

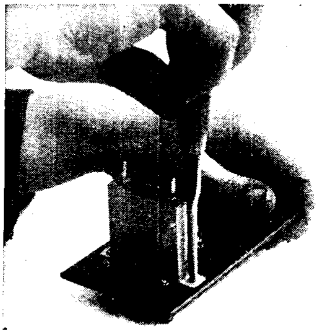


Fig. 16. The fixed condenser is secured to the underside of the panel by screws through the lugs

DETAILS IN THE CONSTRUCTION OF A POWER AMPLIFIER

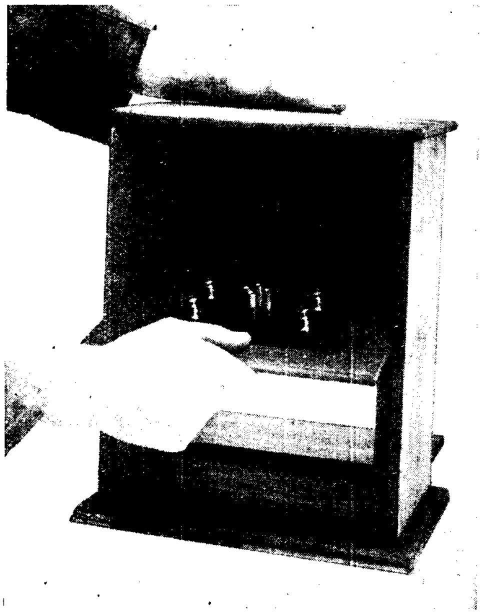
now enlarged to $\frac{1}{4}$ in. diameter, which is the diameter of the contact studs. The latter are now inserted and the smaller panel permanently secured to the larger one by four countersunk screws, arranged one at each corner.

A brass bush for the contact arm spindle is now driven in from the inside. This method of switch construction has the advantage of keeping out dust which accumulates between the contact studs, very often giving rise to parasitic noises through insulation breakages. Care must be taken that no open joint is allowed between the panels, as the object of the additional panel would be defeated.

The interior of the faces of the contact studs is cupped, or concaved, slightly. A round-headed screw on the contact arm coincides with these cup-like depressions, and gives a positive lock when the contact arm registers with one of the cupped studs. The contact arm is cut from a piece of springy brass, and is sweated or otherwise attached to the condenser spindle and ebonite knob, the latter having a brass bush for this purpose.

An alternative plan, and one that permits the knob to be home-made, is to drill and tap a home-constructed knob of ebonite so that a length of 2 B.A. screwed rod may be screwed into it. The contact arm is now slipped over and tightened with a lock nut. Fig. 10 shows the operation of fitting the contact arm, where a spring washer and flat washer are slipped over the end of the spindle after it has passed through its bush. Two locking nuts are tightened against each other and secure the arm in position.

The filament resistance is mounted to the panel according to its type. In the illustration, Fig. 11, the resistance is fixed by two screws inserted in holes for the purpose on either side of the spindle. Excepting the four battery terminals, which are added later, the panel is now ready for fixing to the wood front, which



FITTING THE VALVE SHELF

Fig. 17. Before the wiring and condenser fitting on the panel is started the valve shelf is tried for fit, to ensure that it slides in smoothly and will not require adjusting

operation is shown in Fig. 13, a $\frac{1}{2}$ in. wood screw at each corner being used.

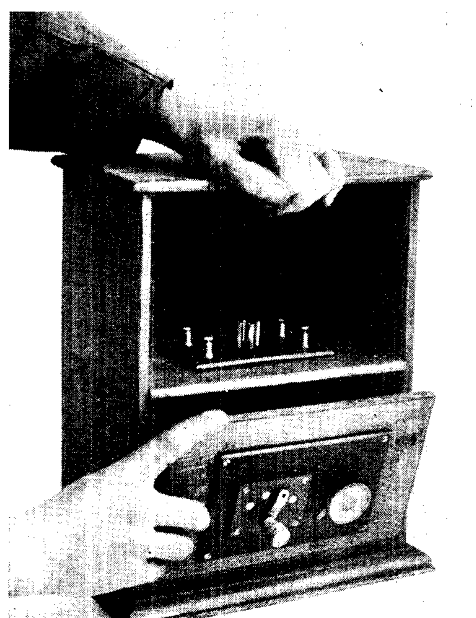
Fig. 14 shows the front portion of the apparatus before the battery terminals are fixed. Four terminals are required, and are spaced in a line to the bottom of the panel. A very similar panel operation is carried out for the horizontal part of the woodwork. A panel, measuring 5 in. by 3 in. is cut and bevelled. In the centre of the panel four valve sockets are arranged, into which the power valve is eventually fitted. Two terminals are arranged, as shown in Fig. 15, on either side of the valve sockets, and form the input and output terminals. The wood is cut away from underneath the panel, leaving a margin of $\frac{3}{8}$ in., in which the panel is screwed. Fig. 17 shows the horizontal section being offered up to the cabinet to ensure that it will fit before the panel is completed.

At this point the front of the panel may be offered up to the horizontal shelf to ensure a good fit before proceeding with the mounting of the components. This is illustrated in Fig. 18. A fixed condenser of 2 mfd. capacity is shunted across the output terminals. The fixing of the condenser is shown in Fig. 16.

Owing to the somewhat inaccessible position of this panel the connexions to terminals and valve sockets should be soldered before final assembly. Fig. 19, where one of the valve leg connexions is being soldered, shows this feature. The next point in the construction of the amplifier lies in the assembly of the battery and grid cells. Four of these are joined up in series, and a tapping is taken from each negative element.

The cells used for pocket lamp batteries will be found useful, but, if required, single cells of larger capacity may be purchased. In any case the centre contact is the positive side of the battery and the zinc casing the negative side. In connecting in series the carbon of one cell is joined to the zinc element of the adjoining cell. The operation of soldering up the grid cells is shown in Fig. 20. The soldering iron must not be allowed to get too hot when soldering to the zinc element, as it will melt a hole in it.

It should be remembered after joining up the cells that the zinc elements must not be allowed to touch, as this would result in running down the battery. It is as well at this stage to finish the construction of the grid battery, and thus avoid



TRYING THE FIT OF THE FRONT PANEL

Fig. 18. After the valve shelf has been fixed the front panel is placed temporarily in position to ensure that it will fit

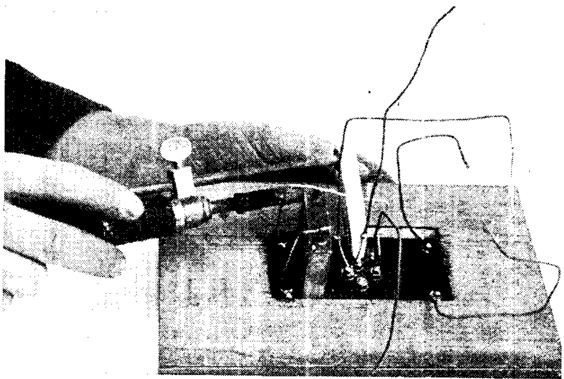


Fig. 19. Wiring is carried out as far as possible on the valve shelf before it is fitted to the cabinet. Soldering to one of the valve terminals is shown

Fig. 20. Four small cells for grid-biasing are connected up in series by soldering short wire connectors from the carbons to zincs

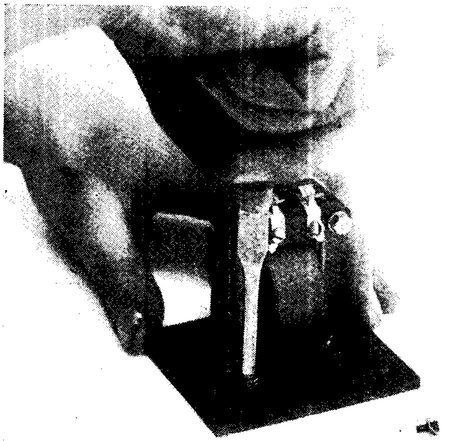


Fig. 21. Screws are used to secure the transformer to a small ebonite base. One of the screws is here being attached

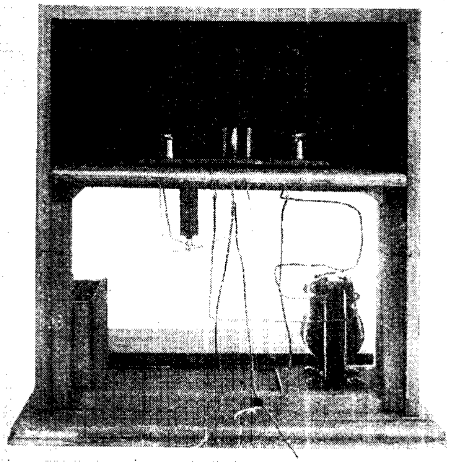
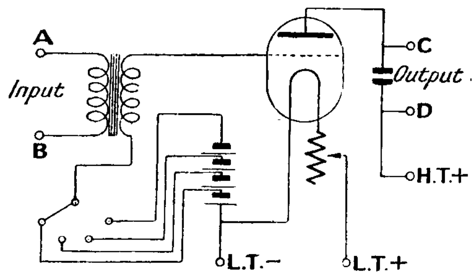


Fig. 22. Relative positions of the grid battery, transformer and valve shelf, with its condenser, are shown in the interior view

Fig. 23. The ebonite transformer base is screwed on the wood base. The transformer is placed on the right-hand side of the cabinet

FITTING TOGETHER THE POWER AMPLIFIER COMPONENTS



HOW THE WIRING IS CARRIED OUT

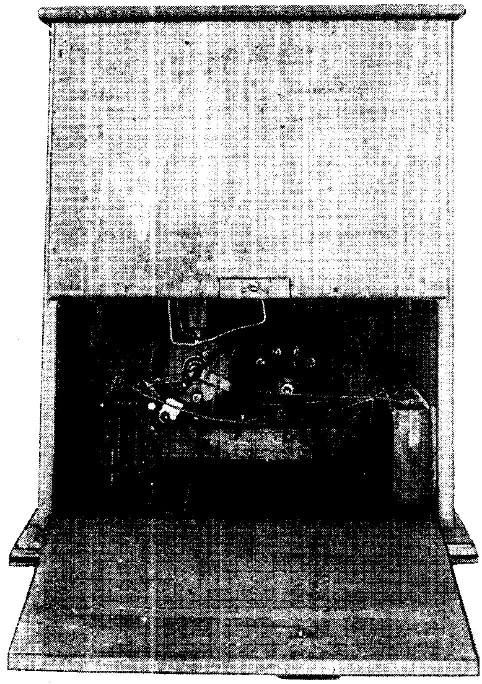
Fig. 24. How the grid-biasing battery is tapped and wired to a stud switch is seen in the wiring diagram of the power amplifier

the possibility of a short circuit while the battery is lying about. Three partitions of $\frac{1}{16}$ in. ebonite are cut and placed between the adjoining cells.

To the left of the cabinet and in the lower or closed section a small box is made from three-ply wood into which the four cells may be lowered. Sufficient room should be left in making this box to allow for its being lined on all sides and bottom with the thin ebonite sheet used for the partition strips between the cells.

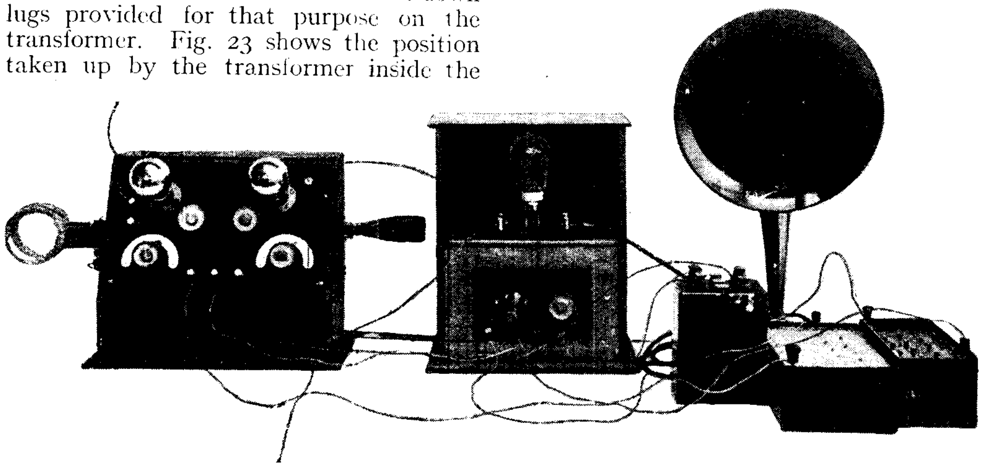
Care must be taken in purchasing the low-frequency transformer, as any other than a power transformer will be quite unsuitable and will be burned out if used for the purpose of this amplifier. It should be able to take an anode potential of at least 300 volts without risk of an insulation breakdown, or of being burnt out. The transformer is mounted on a small ebonite base, as shown in Fig. 21, by means of four 6 B.A. screws to hold down lugs provided for that purpose on the transformer. Fig. 23 shows the position taken up by the transformer inside the cabinet, and illustrates the fixing of the ebonite plate base, where a countersunk wood screw is used at each corner.

Some of the wiring of the valve holder, panel and the transformer may be done at this stage, as easier access to the inside of the panel is possible before the front



BACK OF POWER AMPLIFIER

Fig. 25. With the hinged portion of the back let down, the interior of the instrument is seen



POWER AMPLIFIER CONNECTED TO RECEIVER AND LOUD SPEAKER

Fig. 26. In this illustration the amplifier is shown connected up to a two-valve set on the input terminals, and to a loud speaker on the output side. The amplifier appears in the centre of the photograph

is attached. The wiring diagram of the power amplifier is given in Fig. 24. The two terminals to the left are connected to the output of the receiving set preceding it, while the terminals to the right, across which the condenser is wired, form the output of the power amplifier. This stage of the assembly is shown in Fig. 22. The wiring may be completed, taking care to remove any trace of soldering flux or other material liable to cause electrical leakage.

The wiring is shown completed in Fig. 25. Fig. 26 shows the finished instrument connected up to the output terminals of a two-valve set. The output terminals of the power amplifier are connected to the loud speaker. The valve used in the power amplifier is a Marconi Osram L.S. 5B. Two high-tension batteries, joined in series, are used, which give the anode of the power valve a positive potential of 150 volts. A separate tap of 60 volts is required for the valves in the two-valve set shown in the photograph. In the operation of the power amplifier the best combination of grid and anode potential may be found by experiment. As a general rule, however, it will be found that the more anode voltage used, the larger will be the number of grid cells required.—*W. W. Whiffin.*

POWER BUZZER. Form of induction coil, the primary circuit of which includes the make-and-break device and the transmitting key, and the secondary the earth circuit. The two terminals of the latter are two earth plates or pins.

The power buzzer was largely used for signalling during the Great War, the Parleur buzzer, as developed by the French, being one of the best-known types. With such a buzzer signals could be received over a mile or more, using a two- or three-valve low-frequency amplifier.

The buzzer was worked with a 10 volt battery, and the distance between the earth plates or pins was some 300 ft. The receiving amplifier was connected to earth plates about 600 ft. apart. The power buzzer method is a method of signalling through the earth without wires. The distance over which such signals may be read is strictly limited to a few thousand yards, dependent very much upon the nature of the soil between the transmitting buzzer and the receiving apparatus, and is more interesting from a military point of view than from a purely wireless one.

POWER FACTOR. In an alternating current circuit the power factor is the ratio of the real power to the apparent power. In an A.C. circuit the electro-motive force and the current may or may not be in phase. If ϕ is the angle of lag or lead, then $\cos \phi$ is the power factor, expressed as an equation :

True power = Apparent power $\times \cos \phi$.

See Alternating Current ; Phase Angle.

POWER VALVE. Any valve capable of generating high-power oscillations.

Professor J. A. Fleming points out that that a high-power generating valve must necessarily be a large valve, because there is a certain limit to the electron density of the thermionic current (about 1 ampere per square centimetre when employing a drawn tungsten wire filament). The cylinder or plate must have a certain surface, or it soon becomes incandescent by the electron bombardment. This necessitates a certain complexity of structure to sustain the metal parts.

The bulbs of large generating valves are made either of heat-resisting glass or silica, or partly of glass and partly of metal, as copper or nickel. In the last-named instance the metal part of the bulb also forms the anode cylinder, and can be kept cool by a water jacket round it or by air blast. Valves of this type up to 10 kilowatts have been made, and valves up to 150 kilowatts are projected. Still higher power valves can be constructed of the two-electrode type on a system devised by Professor Fleming in which, when the filament is rendered incandescent by a high-frequency alternating current, the magnetic field embracing the filament is also alternating, and periodically rises to a maximum and intermediately falls to zero.

When the field is strong it exerts a deflecting action on the escaping electrons and turns them back again on the filament, stopping the thermionic current. When the field is zero this thermionic current takes its full strength. Hence the electron current is periodic, but as its frequency is twice that of the filament current, it can be used to step-up frequency.

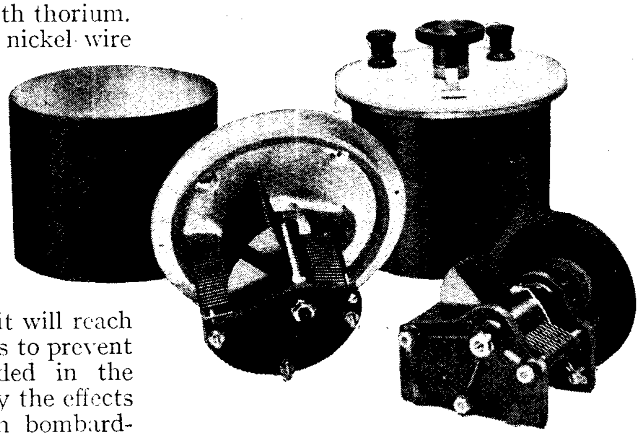
The anode of an ordinary power-transmitting valve is usually of nickel, tungsten, or molybdenum. In the American types it generally consists of two flat metal plates. In French and British valves it takes the form of a cylinder. The filaments are of drawn tungsten wire, which may or may not be impregnated with thorium. The grids are " thimbles " of nickel wire gauze. The vacuum is very high—less than a millionth of an atmosphere—and special pumps have to be employed to create it. Moreover, in order that the vacuum should be maintained during the life of the valve, it is necessary that during evacuation all metal-work shall be heated to a higher temperature than it will reach under working conditions, so as to prevent gases from remaining occluded in the metal until they are ejected by the effects of high voltages and electron bombardment in service.

Instead of using very high power valves, a number of smaller valves are sometimes connected in parallel ; but there are limitations to this method, owing to the fact that the valves do not share the load equally unless their characteristics are closely similar. For broadcasting purposes a valve of from 5 to 7 kilowatt size is usually employed. For naval purposes, owing to the necessity of keeping the number of valves and their controls within reasonable limits, silica valves are frequently installed where several kilowatts have to be handled by valves of comparatively small dimensions. In these the anode is very much larger than in the glass-enclosed valves, and is built up of narrow molybdenum strips, which are plaited into the form of a hollow cylinder.

A species of power valve is also used for purposes of wireless reception in connexion, more especially, with loud speakers. Beyond increasing the plate current, no special procedure is necessary in connexion with the employment of such amplifiers. In cases where it is necessary to operate a loud speaker so that music and speech can be heard all over a large hall, an amplifier of two power valves with a plate voltage of about 200 will be found amply sufficient.—*O. Wheeler.*

See Transmission ; Valve.

PRECISION CONDENSER. Any form of variable condenser in which every manufacturing precaution has been taken to ensure perfect stability of capacity for a given knob rotation. The vane type of variable condenser unfortunately lends itself peculiarly to the developing of faults after very little use, unless the very highest class design and workmanship is applied in its manufacture. The results of changing capacity are a considerable nuisance when the rapid tuning of a very selective receiver, for instance, is desired. Provided all other things are constant, it should be possible always to tune in a station of known wave-length with a given setting on a condenser dial. In the case of standard instruments, such as wavemeters, an absolutely reliable condenser is essential, for the condenser dial is calibrated directly in wave-length metres.



PRECISION CONDENSERS

Precision condensers are made with greater care than ordinary condensers. Two are shown above. One is in its ebonite air-tight case

Courtesy Sterling Telephone and Electric Co., Ltd.

Faults in the design of variable condensers may be divided into two classes, viz.: mechanical and electrical. The former class necessarily causes electrical changes, so their relative importance is equal.

One of the chief causes of condenser trouble lies in the vanes themselves. To ensure lasting uniformity, these must be of considerable thickness, particularly if made of aluminium. Brass plates are always to be preferred. During the process of stamping, metals tend to become warped, and if the vanes are not flattened before assembly, a permanent strain will be put on the supports which will, in the passage of time, tend to distort the whole structure. Another fault with the vanes themselves is that they oxidize, and the electrical resistance between the vanes and the spacer washers increases. Aluminium is a metal which oxidizes with great rapidity, and its only advantages lie in its light weight and the ease with which it may be stamped.

The supports on which the vanes of a variable condenser are mounted should preferably be slotted, and the vanes sweated into the slots. This system is infinitely superior to a thin rod pillar, with spacer washers which are frequently unequal in their length.

The bearings of a vane-type condenser are of considerable importance. A metal to metal bearing at both ends is an essential, and the top one should be of large diameter, in order to give good and lasting support, while the lower bearing should be of small dimensions in order to withstand a high pressure, so that a correspondingly good electrical contact may be obtained. The latter point may be assisted with advantage by using a light spiral spring ligament. No play of any kind is admissible in a precision instrument, and both spindle and bearing should be ground with the greatest accuracy.

A certain amount of "stiffness" is a good feature in a condenser, but this must not be accompanied by any "stickiness" in operation. The use of spring washers to achieve this end is to be avoided, for their strength of spring over a long time period is a doubtful quantity. Perfect smoothness of operation, combined with a certain amount of stiffness, may be obtained by the application of ground flat metal surfaces in contact, and this method is resorted to by the best makers.

Precision condensers by the Sterling Telephone and Electric Co. are illustrated. In the centre are shown the inside arrangements of that shown at the top. It will be seen that the vanes are carried primarily upon a heavy aluminium casting of great strength. The lower plate is of ebonite, and this carries an adjustable centre-bearing for the moving tier of vanes. These instruments are of the laboratory type, being contained within an air-tight ebonite case. The top of the latter is fitted with an engraved ivorine scale divided into a large number of equal divisions.

At the bottom of the picture is shown a similar condenser constructed for panel mounting. This shows clearly that the ebonite bottom plate is ribbed to give it additional mechanical stiffness.

The condensers illustrated are of the Sterling patent straight-line type, in which the design of the rotary plates is such that the capacity varies exactly in proportion to the number of degrees of turning movement. This feature renders calibration either in parts of a microfarad, or even wave-length, an easy matter. *See* Air Condenser ; Capacity ; Condenser ; Disk Condenser ; Square Law Condenser.

PRESSPAHN. This is the trade name of a manufactured insulating material. It is made from wood fibre and has an oily glazed surface. *See* Insulation.

PRESSURE, ELECTRICAL. Term used loosely as a substitute for electromotive force and potential difference. Since the two latter terms have not exactly the same meaning, it follows that misunderstandings may easily occur when the term "pressure" is used as a substitute for either, unless its precise meaning is indicated. To illustrate in a general way the distinction between the terms potential difference and E.M.F. the conditions obtaining in the following circuit may be considered :

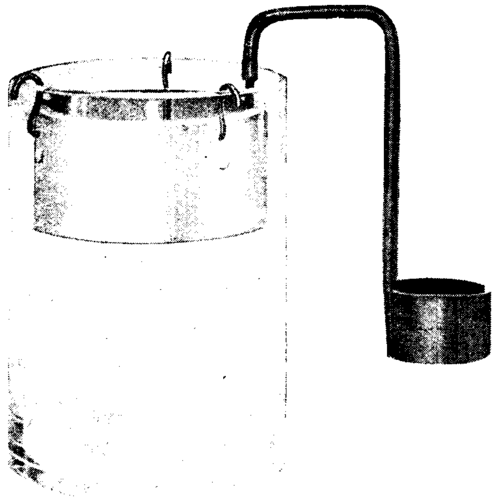
A battery on open circuit, *i.e.* with its terminals unconnected to any external circuit, is found to give a reading on an electrostatic voltmeter of 100 volts. This, then, represents the E.M.F. of that battery. Now if a resistance is connected across the battery in order to form an external circuit, a further reading on the same voltmeter will show a drop in the voltage to some such figure as 96 volts, depending on the exact nature of the suggested resistance forming the load. This reading of 96 volts represents the potential difference across the battery under the new conditions, or in other words, the force necessary to drive the current through the external circuit.

From the above experiment the following deductions may be drawn : (*a*) That the E.M.F. of a battery is the full voltage it is capable of producing while on open circuit ; and (*b*) that the P.D. must necessarily be less than the E.M.F., and depends for its value upon the conditions obtaining in the external circuit. *See* Electro-motive Force ; Potential.

PRIMARY. This word is generally used as an abbreviation of such expressions as primary circuit, primary coil. In a transformer, for example, two of the terminals are marked I.P. and O.P., or input primary and output primary, the input and output terminals of the primary coil or winding.

PRIMARY CELL. In electricity a simple cell for converting chemical energy into electrical energy.

The simplest form of primary cell consists of a glass vessel containing dilute sulphuric acid. In this is partly immersed a



CALLAND DANIELL CELL

Fig. 1. The Calland pattern of Daniell primary cell is a two-fluid gravity cell with zinc and copper electrodes

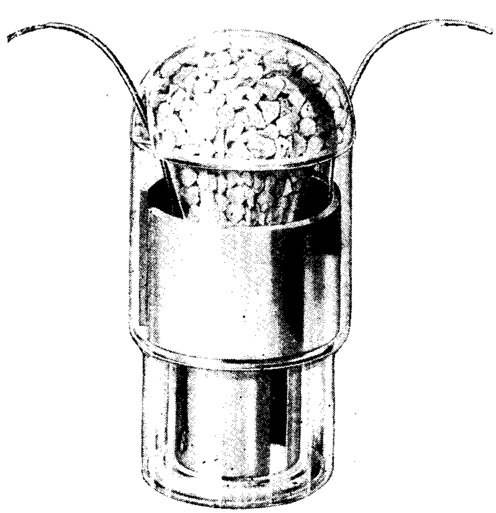
Courtesy Siemens Bros. & Co., Ltd.

strip of zinc and one of copper. When the upper ends of the strips are connected by a wire a current flows along the wire, and at the same time the zinc strip is slowly eaten away by the acid and bubbles of hydrogen are given off at the copper strip. A similar action to this is found in every type of primary cell. One of the plates is always eaten away, and on the other some element is deposited.

In the above kind of simple primary cell the current of electricity flows in the liquid from the zinc to the copper and in the connecting wire from the copper to the zinc. The copper strip is said to be the positive pole of the cell, and the zinc the negative pole. In the outside circuit the current is naturally flowing from the high potential strip to the low potential strip, while in the liquid it is being forced, as it were, from the low potential to the high potential. The action, in fact, is somewhat analogous to that of a pump pumping water from a low level to a high level. The chemical action of the acid on the zinc furnishes the energy which maintains the current in the circuit.

The action of such a cell is seriously interfered with by the evolution of hydrogen on the positive strip or plate. Hydrogen is a non-conductor, and as it collects on the plate the effective area is diminished and the internal resistance of the cell is increased. The deposition of the hydrogen bubbles on the plate also lowers the E.M.F. of the cell. This phenomenon is known as polarization, and all modern primary cells are constructed so as to eliminate polarization as far as possible. The action of a primary cell is also interfered with if the materials used are not pure. Zinc, for example, contains many impurities, as iron, lead, arsenic, etc., and these give rise to local currents over the surface of the plate. This local action is prevented by amalgamating the plate, *i.e.* coating its surface with mercury. The latter dissolves the zinc, forming a uniformly soft amalgam and as the zinc is consumed the impurities fall to the bottom of the cell.

Most of the primary cells are separately described in this Encyclopedia. The chief are the Daniell cell, Bunsen cell, Grove cell, Leclanché cell, bichromate cells, Clark cell and the various forms of dry cell, in which a paste is used instead of the solution of ammonium chloride. Various plates and various liquids are used, and more than one liquid may be used, as in the two-fluid cell, of which the Daniell cell is the best known example. In this cell a zinc plate is immersed in zinc sulphate and a copper plate in copper sulphate, the two liquids being separated by a porous pot or gravity. In the Leclanché cell a zinc rod is immersed in a solution of ammonium chloride and a carbon plate is placed inside a porous cup packed full of manganese dioxide



BALLOON PATTERN DANIELL CELL

Fig. 2. Cells of this pattern are designed to prevent diffusion between the two solutions inside the cell

and powdered graphite or carbon. The Calland gravity cell illustrated in Fig. 1 is a primary cell consisting of a modified Daniell cell and intended for use in series with several others.

The Calland type of cell consists of a glass cylinder containing a ring of zinc suspended from the rim by means of three copper hooks. Soldered to this ring is an insulated wire with two right-angled bends connecting the copper electrodes to the next cell. It is charged by adding pure copper sulphate crystals until the ring is covered, and then adding dilute solution of zinc sulphate until the zinc plate is nearly covered. The E.M.F. is that of the Daniell cell (about 1·07 to 1·14 volts, according to the density of the solutions).

The balloon pattern of Daniell cell, also known as Meidinger's cell, is shown in Fig. 2, and is designed to prevent diffusion of its two solutions and also to make it more portable. The electrolyte is copper sulphate solution, and the electrodes are of copper and zinc, copper being deposited on the former, and zinc dissolved from the latter.

The balloon-shaped flask (filled with copper sulphate crystals and water) is closed by a cork, but a glass tube inserted through this allows slow diffusion of saturated solution of copper sulphate into the lower inner glass, in which is immersed the copper electrode. The terminal passing down to this copper ring is well insulated. The zinc plate surrounding the lower portion of the balloon rests upon a ledge formed by an enlargement of the outer jar above the level of the cathode. This outer container is charged with a weak solution of magnesium sulphate (Epsom salts) containing, by weight, one part of salt to four parts of water. The cell has a low resistance (2 to 6 ohms) owing to close proximity of its two plates, but depolarization is not very effective on account of the small size of the copper electrode. *See* Accumulator; Cell; Daniell Cell; Dry Cell; Leclanché Cell; etc.

PRIMARY CIRCUIT. The first circuit; a current through which induces a current in another circuit known as the secondary circuit. *See* Primary Coil.

PRIMARY COIL. The coil at which the current enters in a circuit which depends upon the principle of mutual induction between two neighbouring circuits. In an induction coil, for example, a few turns of thick wire are wound round a core consisting of a bundle of soft iron wire. These few turns of thick wire constitute the primary coil. Surrounding the primary coil, but insulated from it, is a coil consisting of a very large number of turns of very fine wire, comprising the secondary coil. As a current grows or lessens in the primary, a current in the opposite direction is induced in the secondary. The transformer is a similar piece of apparatus, with primary and secondary coils. *See* Induction Coil; Inter-valve Transformer; Transformer.

PRINCE, CHARLES EDMOND. British wireless expert. Born in 1874 at Cape Town, and educated at Clifton and Faraday House, he joined Marconi's Wireless Telegraph Company in 1907, where he was concerned chiefly in research work on wireless telephony. In 1909 he carried out experiments in Italy and Switzerland with the first Marconi Field Station, and made a number of valuable improvements in the Bellini-Tosi direction finder. In the Great War he joined the R.F.C., and in 1915 instituted the first wireless telephone on aircraft.

PRINTING TELEGRAPH. General term applied to any form of telegraph receiving apparatus, whether wireless or wired, which can be made to record the received messages on paper, either in the form of an undulating continuous line, dissected dots and dashes, or actual printed characters. The apparatus for printing Morse signals in the form of dots and dashes and a continuous undulating line will be found described under the headings Morse Inker, High-speed Telegraphy and MacLachlan Recorder respectively.

The Wheatstone system is in general use for the printing of telegraphic messages, and in this system two operations are necessary. In the first place, paper strip is perforated in a special machine. The perforations are made on both sides of the strip, the holes down one side representing dots, and down the other dashes. When the whole message is recorded on the perforated strip in this manner it is fed into another machine, which passes the strip between a number of electrical contacts. Thus circuit is only made when the contacts meet through a hole in the paper. The machine is fitted with a device known as a selector, which automatically differentiates between the various combinations of dots and dashes and brings type bars into play, which print ordinary block letters upon another strip. The latter is broken into convenient lengths and gummed upon the telegraph form by the operator.

PROTON. Name given to the positive small mass or unit of electricity corresponding to the electron, or negative unit of electricity. In the modern theory of matter the nuclei of all elements are made up of protons and electrons. Sir Ernest Rutherford has pointed out that no evidence has yet been obtained to show that the proton exists in the same free state that the electron may be said to exist. The mass of the proton is very nearly that of the hydrogen nucleus, and the suggestion has been put forward that the proton is the hydrogen nucleus, the difference in mass being accounted for on the theory of relative energy possessing mass. The mass of an atom is supposed to be a measure of the number of protons in its nucleus. *See* Electricity; Electrons.

PROTRACTOR. A measuring instrument employed in determining and setting out angles. Two patterns are illustrated in Fig. 1. The upper shows a semicircular device divided in degrees, and of the type where the divisions are marked to read both right- and left-handed.

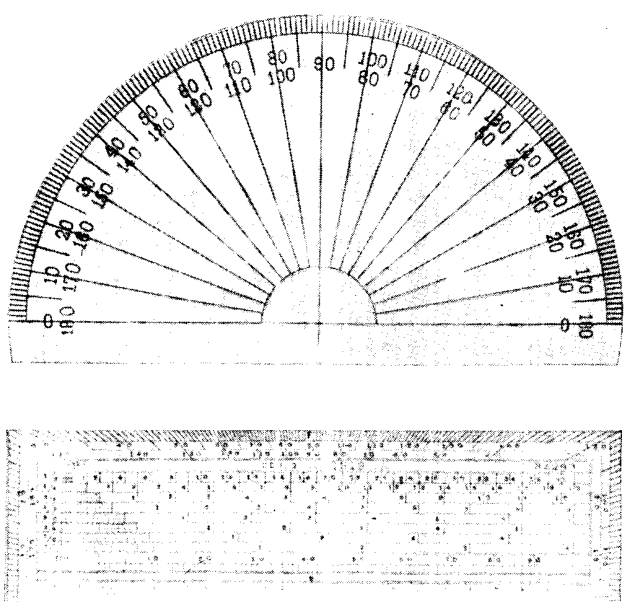
The device comprises the half of a circle and the markings show the degrees; the tens are indicated by numerals, fives by the longer line between them, and the separate degrees by the short lines.

Every tenth is indicated by numerals, and these are shown, as, for example, 10 and 170, this being a convenience when using the instrument, as the inclination of a line to the horizontal, either to the right or the left of the vertical line in the centre, can then be read at a glance. The lower instrument in Fig. 1 performs the same purpose, as the edges are marked with lines at an inclination to the horizontal. These correspond with the angular lines on the other pattern, and are similarly designated.

These instruments are engraved on ivory, and are practically indestructible in ordinary conditions of service. Cheaper patterns are made of celluloid, hardwood and steel, the latter preferably nickel- or silver-plated. Protractors are used in the setting out of work on the drawing board, the essential purpose being a ready means of locating the position of one object or part with another, in terms of the angular distance between them.

The use of a simple protractor is illustrated in Fig. 2, where the protractor is shown resting against the edge of the T-square, and the line at the desired angle being drawn by setting a ruler or set-square with one end at the centre of the protractor. The working edge of the ruler or square is then adjusted to the desired angle and the line drawn accordingly.

One application for wireless work is in the setting out of the best place for an aerial, as, if the magnetic north be ascertained by a compass and marked on a plan of the site, the angular bearing of the aerial to the cardinal points of the compass is easily ascertained by working from a line drawn due north and south on the plan. Consequently, if the bearings of a



SEMICIRCULAR AND RECTANGULAR PROTRACTORS

Fig. 1. Two protractors in common use are shown. Both are of ivory, and divided off into degrees by radiating lines

Courtesy Negretti & Zambra, Ltd.

Fig. 2. The straight edge of the protractor rests along the line to which a line at the desired angle is to be drawn. One point of the set square is at the basic centre of the protractor

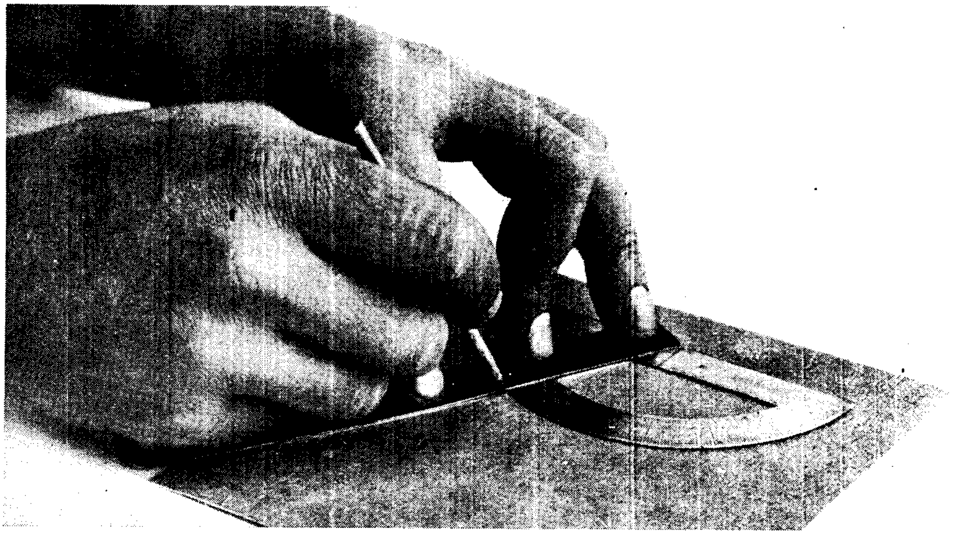


Fig. 3. This is a hollow protractor, which is more convenient in use in many cases than the type shown in Fig. 1. It is made of steel, while the one above is of celluloid

METHODS OF USING A PROTRACTOR IN APPLICATIONS OF WIRELESS THEORY

station which it is desired to listen to are known, the aerial direction can be determined by the aid of the protractor and the direction marked on the plan.

The protractor is also of great use in setting out a piece of work, such as a sheet of metal, prior to cutting it to shape, or in the preparation of a special dial.

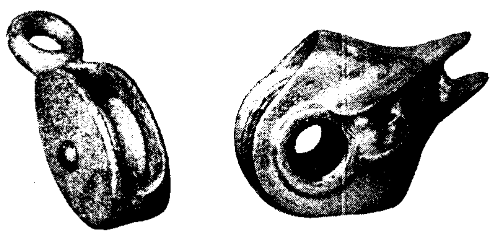
The same principles are applied, and the instrument used in a similar manner to those for draughtsmen's use, but in this case a hollow protractor is to be preferred, as shown in Fig. 3.

Measurements are made as before from the centre of the horizontal line, guiding the scribing point with a steel rule in the manner illustrated. Protractors should be kept in a box or drawer when not in use, and wood and ivory patterns in a cool dry place; metal types should be wiped over with an oily rag to keep them in good order.

Other patterns of protractor are made, including those with a self-contained arm which acts as a ruler, and those with a vernier device enabling the instrument to measure to minutes of arc, but those illustrated are the most serviceable to the experimenter. *See* Compass; Drawing; Set-square.

Pt. This is the chemical symbol for the metallic element platinum (*q.v.*).

PULLEY. General term for a small wheel mounted within a framework. The use of pulleys in wireless is largely re-



PULLEYS FOR WIRELESS USE

Two varieties of pulley used in wireless are illustrated. These are used for halyards and other ropes. The pulley on the right is often used for hoisting aerial wires

Courtesy Economic Electric Co., Ltd.

stricted to the vicinity of an aerial mast, as they are then needed for the guidance of the halyard and other ropes. Two examples are illustrated. That on the left is a small pulley made throughout of galvanized iron. The pulley is mounted within a framework or block, and turns on a fixed central spindle. An eye is formed integrally with the frame, and is intended for the attachment of the rope, or other means of fixing to the mast.

The pulley on the right is a superior pattern, as the block or body is made of aluminium alloy, with a hollow spindle made of stout bronze. The pulley is of aluminium alloy, and turns freely on this tube. The rope is attached by passing it through the hole in the spindle and splicing it around the grooved portion opposite to the pulley. This results in a very light pulley, and one that is effective in use.

In both patterns the rope is prevented from coming off by the shrouding or surrounding walls of the body. It is important in choosing pulleys for wireless work to select those not liable to rust, and to note that the pulley fits nicely within the body, and that there are no rough places which might chafe the rope; nor should there be any chance for the rope to slip off the pulley and jam between it and the body.

The correct size of pulley for any particular work should be governed by the strain it is called on to bear, but generally the width of the pulley should be slightly more than the diameter of the rope to be employed with it. Double and treble pulleys are those with two or three pulleys in one body. *See* Block.

PULSATING CURRENT. A unidirectional current which rises or falls regularly, defined by the American Institution of Electrical Engineers as a current equivalent to the superposition of an alternating current upon a continuous current. A pulsating current can be produced by an ordinary generator if the circuit is broken during each half-revolution, so that its circuit is completed only when current is generated in one direction. For this purpose a pulsating current commutator may be employed. *See* Current.

PUNCHES. Name applied to a number of small tools. Those used in wireless work are chiefly the patterns for working in wood, metal and ebonite, and a suitable selection for the experimenter is illustrated in Fig. 1.

Essentially a punch comprises a long, generally cylindrical, body and a tapered

PUNCHES SUITABLE FOR THE WIRELESS EXPERIMENTER

Fig. 1. From left to right the photograph shows a hollow or cup punch, matting punches, centre punch, nail punch, wad punch, soft square punch, and three driving punches

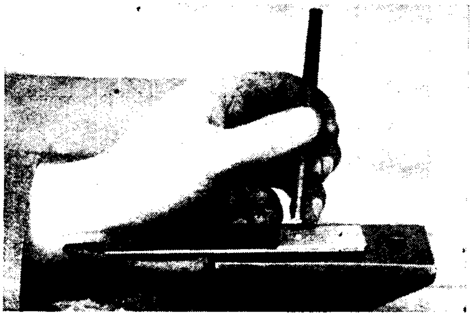


Fig. 2. Shallow depressions or centre pops for starting a drill are made by holding the punch vertically on the exact spot and hitting with a hammer

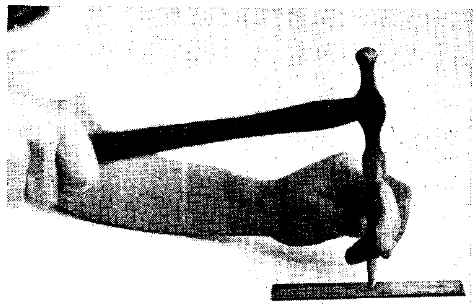
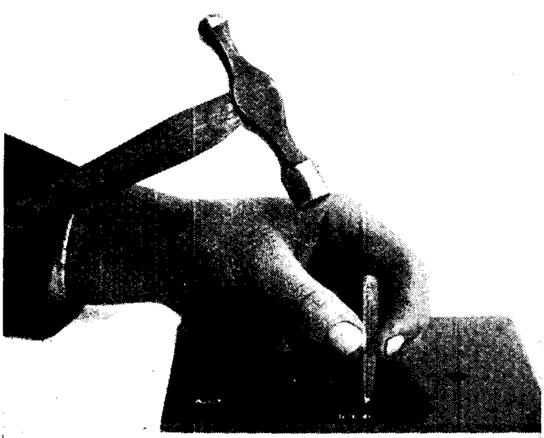


Fig. 3. Here a snap-head punch is in use for shaping the head of a rivet; a light rivet hammer is used in this case

Fig. 4. Nails are being driven below the surface of the woodwork by using a nail-set punch



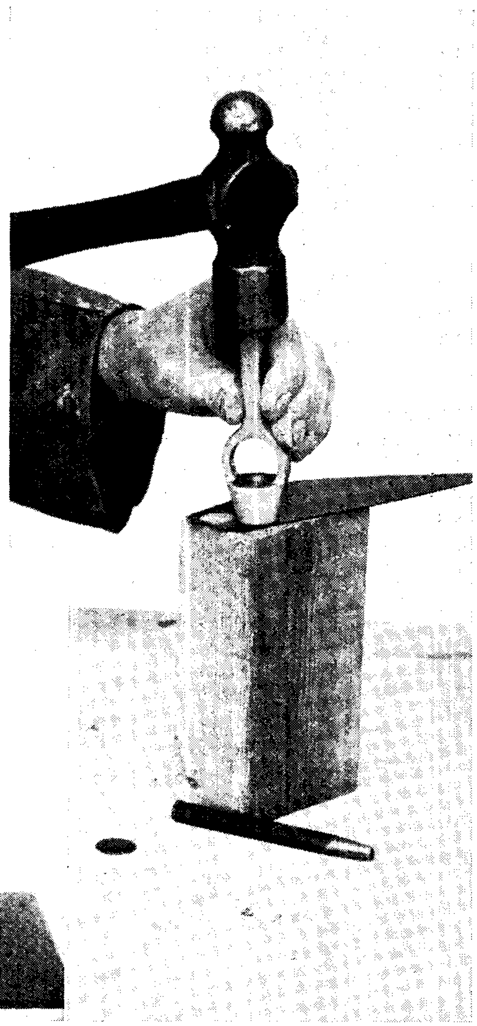


Fig. 5 (left). Ebonite panels can be lettered by using a name punch or numeral punch, which should be slightly heated. Fig. 6 (right). Washers are made by using a wad punch and hammer. The punch in use is cutting a disk from a piece of fibre

HOW DIFFERENT TYPES OF PUNCHES ARE USED

portion terminating in a shaped portion, the form of which is determined by the purpose of the punch. The opposite end is generally chamfered or rounded, as it is struck by the hammer, and unless this be done the end of the punch would speedily be roughened and the spread-out parts would break off and fly towards the face of the worker. Commencing from the left, the punches illustrated in Fig. 1 are hollow or cup punches, matting punches, centre punch, nail punch, wad punch, soft square punch and three driving punches.

Apart from the small tools illustrated, there are a number of other punches, including the top tool used in a fly-press or power press for shaping metal and other material by power, a method extensively employed in the industry for the manufacture of many wireless components.

Making a Centre Pop

The normal way of using a punch is shown in Fig. 2, where the operation of making a centre pop is illustrated. In this example the punch is a centre punch, and used to make a shallow conical depression in the surface of metal prior to starting a drill. The punch is held in a vertical position with the left hand and struck a sharp blow with a light hammer held in the right hand. It is important that the punch be upright and the hammer descend so that it strikes the top of the punch fair and square in the centre. Otherwise the hammer will glance off the punch or the punch will be driven sideways.

Soft or driving punches are so named because the metal of which they are composed is left soft and not hardened, as is necessary with a centre punch. This is done so that the punch will not be so liable to bruise the work, and also to add to the effective strength of the punch. It is used for driving taper pins into place, and on other similar work.

The wireless experimenter will be well advised to acquire the habit of using a soft driving punch for such purposes as driving out a peg from a spindle, or in the removal of an unwanted peg. The punch should be pressed firmly on the end of the piece to be removed and held axially with it, while the opposite end of the punch is struck with a hammer. If this be done with a punch smaller in diameter at the end than that of the peg, it will avoid bruising it, as would be the case were it smitten directly with the hammer, which would burr up the end of the pin and make it difficult to remove.

Another useful punch for the wireless experimenter is the hollow or snap-head punch, illustrated in Fig. 3. This is used to shape the head of a rivet after it has been turned or roughly shaped by the hammer. The method of use is to hold the punch over the rivet head and work it slightly from one part and then another, thus gradually working a neat rounded head on the rivet. The face of the punch is made hollow or rounded to permit of this result. The size of punch used should be appropriate to that of the rivet. The punch should be driven by a light rivet hammer with a succession of sharp, light blows.

When nails are driven into woodwork, the heads ought to be driven below the surface with a nail punch, or nail set, as it is sometimes called. This operation is shown in progress in Fig. 4, and the same remarks apply with regard to keeping the punch upright. These nail punches usually have lines across the face to afford a grip on the nail. The size of punch used should be about the same diameter as that of the nail head or slightly smaller.

Wad punches are used for cutting large disks of thin material, such as thin fibre, for the making of a few washers. These punches have a cylindrical open end, and this part is pressed on to the work, as shown in Fig. 6. The top of the punch is then struck a heavy blow, driving the punch through the material. If two punches of dissimilar size be used, washers are speedily made from thin material.

Wad Punches and Their Uses

The smaller wad punches are liable to choke with disks of material, as they are forced up the hollow part of the punch. This is dealt with by sharpenening the punch by grinding the exterior, and by ejecting the wad with a long rod passed through the slot in the side of the punch. When using wad punches they should be placed on a lead block, or on the end grain of a piece of wood, as shown in Fig. 6, to avoid damaging the cutting edges.

Matting punches are made in many patterns, and used for producing a deckled or roughened background on carved work, such as that on elaborate wireless cabinets. They are used by pressing them on to the face of the work and striking them with a hammer.

Name stamps or punches are most useful to the wireless experimenter, as by their aid the various markings required on a panel can readily be produced. These punches are simply ordinary hard steel punches, with the face fashioned with a letter or numeral. They are generally sold in sets and of different sizes; $\frac{1}{8}$ or $\frac{3}{16}$ are the most useful sizes for general work, and refer to the height of the letter.

The punches are used on steel or metal by pressing them firmly into place and hitting them with one sharp, heavy blow. When employed on ebonite, the punch should be slightly warmed and then pressed on to the work, and struck a comparatively light blow with a light hammer, as shown in Fig. 5. This forces the punch slightly into the surface; the depression thus formed is then filled with white or some other such colouring matter. and thus exhibits the desired finished character.

The punch should not be overheated, or the temper will be drawn and the punch ruined.

PUPIN, MICHAEL. Austro-American wireless authority. Born in Hungary, October 4th, 1858, he went to the United States at the age of 16, and was educated at Columbia University, Cambridge University, England and Berlin. In 1891 he was appointed professor of mathematical physics at Columbia University, where he carried out an important series of researches in wireless telegraphy and telephony.

His patents for selective tuning were taken up by Marconi's Wireless Telegraph Company. In 1916, in conjunction with E. H. Armstrong, he patented a regenerative method of lessening the interference due to atmospherics. Dr. Pupin is an ex-president of the Institute of Radio Engineers.

PURE WAVE. Term used in America to denote a wave which complies with the U.S. Government requirement that the energy in either of two coupled circuits should be within 10 per cent of that in the other circuit.

PYRITES. General term applied to compounds of iron and sulphide, and also for the group of metallic sulphides, as copper pyrites, arsenical pyrites, etc. Many of the pyrites are important crystal rectifiers, as iron pyrites, copper pyrites, and chalcopyrites. *See* Crystal; Chalcopyrites; Perikon; etc.

Q

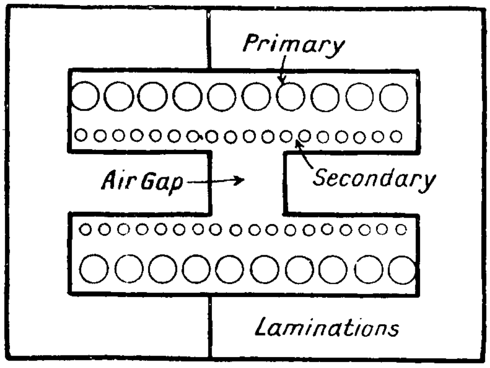
QUADRATURE. Term used in alternating current work, applied to the condition in such a circuit where there is a phase difference of 90 degrees or a quarter of a period. *See* Lead; Phase; Phase Angle.

QUADRATURE TRANSFORMER. This is a special type of transformer used in conjunction with certain kinds of wattmeter. Its function is to supply the moving coil circuit of the wattmeter with a current which is proportional to and in quadrature with the current in the main circuit.

The figure is a diagrammatic representation of a quadrature transformer, representing a cross-section through such an instrument. It will be seen that the laminations are of an " E " formation, but that the central limb is considerably shorter than usual, resulting in a comparatively long air gap.

The primary is wound over the secondary; both are situated in the space between the inner and outer limbs of the " E." The result of the long air gap is to bring the flux into a condition where it is coincident in phase with the exciting ampere turns.

While this feature could perhaps be obtained more simply with an air-cored transformer, an iron core is chosen because it reduces the size that would be necessary by reducing the magnetic reluctance, and also the iron acts as a magnetic shield and renders the instrument immune from the effects of stray magnetic fields. *See* Wattmeter.



QUADRATURE TRANSFORMER
Between the two short arms of the two E-shape laminations is an air gap. The windings of the transformer are shown in section

THE QUANTUM THEORY OF ENERGY

By J. H. T. Roberts, D.Sc., F.Inst.P.

The theories of Electricity, Matter and Energy are necessarily closely related. Here is given a clear and authoritative account of the most modern theory of energy and its constitution. Reference should also be made to the headings Electricity; Electron; Energy; Ether

It has long been known that matter is not infinitely divisible, but consists of discrete units known as molecules and atoms, and electricity has recently been shown to possess a similar granular structure and to consist of electrons and protons. Now the question arises as to whether energy is continuous, or whether it resembles matter and electricity and consists of a collection of small quantities not further subdivisible.

There are many physical phenomena which suggest strongly that energy is not continuous, but does actually partake of a granular structure; on the other hand, there are many phenomena which are difficult to explain on such a view.

The "quantum theory," which was introduced by Planck in 1901, is based upon the above view of the discontinuous nature of energy. It takes its name from the "quantum," which is the term applied in this theory to the "particle of energy." The quantum (of energy) is thus analogous, in many respects, to the atom (of matter) and the electron or corpuscle (of electricity). Although analogous, it must not, however, be supposed that the quantum resembles the atom or electron in any physical sense.

Practical Applications of the Theory

The phenomenon which will serve most usefully to illustrate the practical application of the quantum theory is that of the emission of electrons from a substance when the latter is exposed to electromagnetic radiation (and the converse generation of radiation when electrons impinge upon a substance). X-rays provide examples of these two converse phenomena, for it is the impact of the electrons against the target in the discharge-tube which gives rise to the X-rays, and these rays in turn, when incident upon other bodies, may throw out electrons from those bodies. In the case of radiation whose frequency lies in the visible or ultra-violet region, the ejection of electrons from substances owing to the incidence of the radiation is known as the "photo-electric effect."

Now, the curious thing is that the frequency of the incident radiation determines whether any electrons will be thrown out of the substance or not, and further, if electronic emission occurs, the maximum energy with which electrons leave the substance also depends upon the frequency of the incident radiation. There is, for any substance, a certain minimum frequency known as the "threshold frequency" (usually signified by n_0). If radiation above this frequency falls upon the substance, electrons will be thrown out, whilst if the radiation be below this frequency no such emission will occur.

Energy Imparted by Radiation

The higher the frequency of the radiation (assuming always that it is above the threshold frequency), the greater will be the maximum energy with which electrons will be ejected from the substance. In fact, the total energy imparted to an electron in these circumstances is equal to hn, where n is the frequency of the radiation and h is a certain universal constant known as "Planck's constant" (the value of Planck's constant is $6{\cdot}55 \times 10^{-27}$ erg-seconds). If radiation of frequency n_0 falls upon a substance (n_0 being the threshold frequency for the substance), electrons will be emitted, but their energy will be only just sufficient to release them from the substance and they will have no resultant velocity. If radiation of frequency n (higher than n_0) falls upon the substance, electrons will be ejected with velocities sufficient to carry them away from the substance.

The energy in the first case is hn_0, and in the second case hn. Thus the excess energy in the second case, over and above that required to get free from the substance, is $hn-hn_0$, or $h(n-n_0)$. If m is the mass of the electron and v the velocity with which it is ejected from the substance, since its kinetic energy is $\frac{1}{2}mv^2$, it follows that $\frac{1}{2}mv^2 = h(n-n_0)$

This is known as Einstein's relation, and it has since been very strikingly confirmed by experimental observations, notably by Millikan, who opposed the ejected electrons by an electrostatic field and equated $\frac{1}{2}mv^2$ to the potential energy of the electrons when they came to rest after having travelled a certain distance against the field; this distance could easily be measured. Since the frequency of the incident light is easily controllable, this forms a convenient method for the determination of Planck's constant. In order to give an idea of the magnitudes of the threshold frequencies, n_0 for sodium is $5 \cdot 15 \times 10^{14}$ sec.$^{-1}$, which corresponds to about the green light of the spectrum.

Energy Governed by Frequency

The important point to observe (for the present purpose) is that the energy of the moving electron can be expressed as equal to the difference of two quanta. If more intense radiation of the same frequency be allowed to fall upon the substance, *more* electrons will be emitted, but none will have a greater energy than that given by Einstein's relation. Thus the amount of the emission depends upon the intensity of the radiation, but the maximum energy of the individual electrons is governed, not by the intensity, but by the frequency of the radiation. This is very important.

From a great deal of evidence it seems to be established that whenever an electron strikes a substance, causing the emission of radiation, the energy associated with the radiation is given by hn, and the same relation holds whenever the incidence of radiant energy upon a substance gives rise to electronic emission.

Certain questions now arise: Is energy transmitted through space in a corpuscular manner, similar to that conceived by Newton in connexion with the transmission of light? Does an electron system expend energy only in definite amounts, and when an electron absorbs energy, does it ever absorb less than one quantum at a time? If an electron absorbs and emits energy only in quanta, is it reasonable to suppose that its total energy at any time is an integral number of quanta?

When an electron is ejected from an atomic system by the action of incident radiation, was the energy of the electron already resident in the atomic system and merely "tripped off," as it were, by the radiation, or was the energy absorbed from the radiation and gradually stored until there was sufficient for the emission? It is easy to arrange experimental conditions where the intensity of the incident light is so small that (on ordinary assumptions as to continuous distribution) it should take a very long time before one quantum could be absorbed by an electron system.

Under these conditions, however, the electron emission is found to commence instantly This may be adduced as supporting the "trigger" theory, or it may mean that the energy is not distributed continuously over the wave-front, but is concentrated in "spots." This will be understood better from the following more detailed consideration. Suppose we have a source of radiant energy (a candle) and we calculate the amount of radiant energy per second which reaches an atomic system (a piece of sodium) placed at a certain distance (1 mile) from the source, on the assumption that the energy spreads out continuously and approximately uniformly in all directions. This is a very simple calculation, and we may take it as assuming that the amount of such radiant energy falling upon the atomic system is proportional to the solid angle subtended at the source.

When these conditions are so arranged that it should take a very long time for an atomic system to receive one quantum, the electronic emission nevertheless starts instantly. The emitted electron has obtained one quantum of energy from somewhere, and the magnitude of that quantum is proportional to the frequency of the incident light. It cannot have come from the incident light, on the ordinary assumption. Where has it come from?

"Bundles" of Energy

If, instead of imagining the radiation to proceed more or less uniformly over an ever-increasing sphere, we think of the energy as being shot out in various directions like a shower of particles, each particle comprising a "bundle" of energy, as it were, we see that certain electrons will receive perhaps a whole bundle of energy, which will represent considerably more than would be their share according to the ordinary solid-angle theory. Thus a corpuscular view of the emission of energy provides an explanation of certain of the observed facts.

There are, however, other observations which seem to be capable of explanation only on the continuous-wave theory of energy emission. The principal of these is the phenomenon of interference. It is interesting to note that this was the chief stumbling-block in the way of Newton's corpuscular theory, too. Ingenious attempts have, however, been made to reconcile the wave and corpuscular theories by supposing that the quantum of radiant energy may actually have something of the structure of a train of waves, and although this "corpuscular train" may be large compared with the wave-length (so that it comprises a considerable number of waves, thus accounting for interference), it may nevertheless be small compared with the number representing the velocity (*i.e.* the distance travelled by the radiation in unit time), thus accounting for its corpuscular characteristics.

The quantum theory is closely bound up with theories as to the constitution of the atom, and, like those theories, is still very incomplete. Moreover, even in its present form, the quantum theory is by no means universally accepted by scientists. The following quotation from Eddington, in his "Space, Time and Gravitation," sums up the position of the quantum theory admirably:

"Physical reality is the synthesis of all possible physical aspects of nature. An illustration can be taken from the phenomena of radiant energy or light. In a very large number of phenomena the light coming from an atom appears to be a series of spreading waves. In many other phenomena the light appears to remain a minute bundle of energy, all of which can enter and explode a single atom. There may be some illusion in these experimental deductions, but, if not, it must be admitted that the physical reality corresponding to light must be some synthesis comprehending both these appearances. How to make this synthesis has heretofore baffled conception. But the lesson is that reality is only obtained when all conceivable points of view have been combined."

QUENCH. To extinguish completely the spark in a spark gap at the instant when the energy in the primary circuit first becomes zero. *See* Quenching.

QUENCHED GAP DISCHARGE. The discharge in a quenched spark-gap system, in which the gap is cooled by breaking it up into a series of narrow gaps, the latter being kept cool by a rapid radiation of the heat produced by sparking. *See* Quenched Gap Transmitter; Quenched Spark Gap.

QUENCHED GAP TRANSMITTER. A radio-telegraphic transmitter employing a quenched spark (*q.v.*). A standard model is the 1½ kw. Marconi quenched gap transmitter, which before the introduction of valve C.W. transmission was very largely installed for use in ships. This apparatus was designed to transmit on all wave-lengths between 220 and 800, but is normally adjusted so that by switching rapid changes may be made from 450 to 600 or 800 metres. The generator is an inductor type 1½ kw. motor alternator suitable for running from a 100 volt D.C. supply, and delivers current at 500 cycles, 200 volts, to the transformer. The transformer has a transformation ratio of 200 : 8,000. The two halves of the primary are connected in series, and the secondary is connected through suitable air chokes to the high-frequency circuit.

The quenched spark gap is built up of eight heavily silvered copper plates, which provide a seven-gap discharger suitable for working on any power up to 1½ kw., according to the number of gaps used and the voltage applied to the terminals of the transformer.

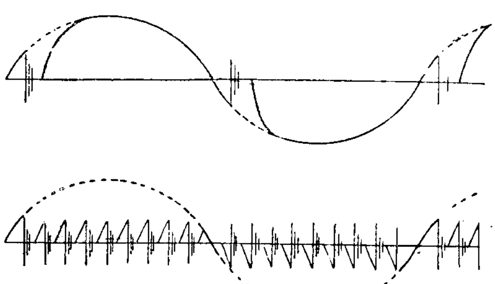
The quenched gap discharger is mounted on the front of the transmitter base. The transmitting condenser is a mica condenser in oil with a capacity of ·01 mfd. suitable for working on 8000 volts. The usual jigger and A.T.I. are provided, also the aforementioned three-way wave-changing switch, a wave-shortening condenser and an aerial ammeter. The aerial tuning inductance is wound on a square wooden former, of No. 20 gauge wire and heavily insulated; it is tapped through ebonite insulating bushes. A coupling of about 17 per cent is required to produce good quenching and high aerial current. Good quenching is obtained with the set when the aerial circuit is actually in tune with the primary. But sharper tuning may be obtained when the aerial is detuned 3 per cent.

Detailed instructions for working the 1½ kw. quenched gap transmitter, and for obtaining a quench curve, are given in Hawkhead and Dowsett's "Handbook of Technical Instruction for Wireless Telegraphists." They are not produced here, as spark transmission has been largely superseded by valve C.W. *See* Quenching; Quenched Spark; Quenched Spark Gap; Transmission.

QUENCHED SPARK. A form of electric spark which, owing to the nature of the electrodes, is rapidly extinguished after allowing one or two oscillations to pass. The process known as quenching is separately described under that heading, and an indication of the improvement effected by the use of quenched sparks is given in the two accompanying diagrams.

The sine outline represents the voltage of an alternator making 500 alternations per second. In the ordinary spark diagram there are two sparks occurring in the alternator's period, each setting its circuit into oscillations having a frequency of 200,000 per second, these being prolonged through a time of one four-thousandth of a second. In the quenched spark diagram eight or nine discharges are shown in each half-period, and these occur at intervals of one ten-thousandth of a second and give short trains of oscillations.

It should be understood that the oscillations in the case of both diagrams are those of the reservoir circuit rather than of the antenna. It will be observed that in the first instance the "idle time" may be as much as 90 per cent, while in the second it may not be more than 40 per cent of the whole.

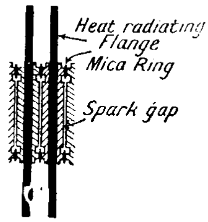


QUENCHED SPARK

In the top curve is represented the voltage of the aerial when excited to give one spark per second off the alternating supply voltage. In the bottom curve, nine sparks for every reversal of the alternating supply voltage are being produced

Thus either more energy is emitted by the quenched spark in the same time or, given equal power, the quenched spark will produce the same result as the ordinary spark with lower voltage. The latter condition is the more usual in practice. Additional improvement of quenched spark transmission would doubtless have resulted from further diminution of the "idle time" and equalizing of the oscillations, but for the introduction of newer and more efficient valve methods. *See* Quenched Spark Gap; Transmission.

QUENCHED SPARK GAP. A type of gap used for stopping quickly the oscillations of a closed circuit, and thus enabling the open circuit to oscillate at its own frequency. The use of this gap is due to the discovery by Wien that a number of very short gaps between electrodes of large surface will also produce one discharge per alternation of the charging current, and also that this discharge may be made synchronous with the amplitude of the alternations. The quenched spark gap operates effectively on comparatively low voltages, gives rapid quenching of the oscillations of the closed circuit with close coupling of the oscillation transformer, and is practically noiseless in operation. This rapid quenching with close coupling enables the maximum amount of energy to be radiated from the open or aerial circuit, and greater distances can accordingly be covered with the same power.



WIEN SPARK GAP

Part of a quenched spark gap is shown in section

The quenched spark gap consists of a number of heavy copper disks with grooves turned in their faces close to the outer edges of the disks. The latter are assembled in a rack with insulating air-tight washers between them, the inside edges of the washers covering the grooves. The disks and washers are bolted tightly together to prevent the entrance of air; the space between the sparking surfaces of a set of plates in the standard Marconi instrument does not exceed ·001 in. The number of sets of plates employed depends upon the voltage of the charging current, approximately 1,200 volts being required for each gap.

The method by which a quenched spark gap is kept cool by the rapid radiation of the heat produced by sparking is illustrated in the figure.

The type of quenched spark gap described above may be worked on voltages as low as 6,000. For continuous operation at high power a method of cooling is necessary, a blast of air discharged by a small motor being used in some Marconi apparatus. But in the Marconi transmitting system the quenched spark gap is only applied to comparatively low power sets, the synchronous rotary type being employed for high power installations.

Any gap which causes a quick breakdown of the vapour bridge between discharges after passage of a spark by cooling of the electrodes may be described as a quenched spark gap, but the term is more particularly applied to the method detailed above of employing a number of small gaps between comparatively large metal disk electrodes. *See* Quenched Spark; Quenching.

QUENCHING. Term applied to any arrangement for extinguishing a spark (*q.v.*) as soon as it has passed from the primary or condenser circuit of a transmission set to the secondary or aerial circuit, and so preventing it from returning. The effect of thus quenching or cooling the spark gap is to stop the oscillations in the condenser circuit as soon as one or two of them have passed. The aerial circuit is thus left free to oscillate at its own frequency, with the result that only waves of one length are radiated.

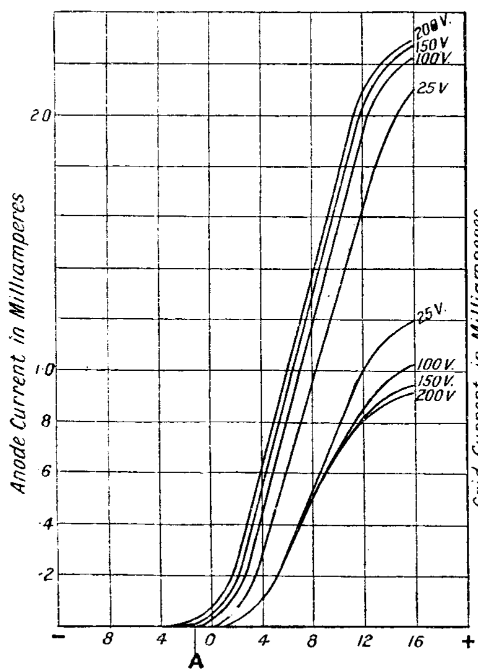
In the operation of apparatus in which the method of quenching is employed the coupling is very tight, so that the energy may be very quickly transferred from one circuit to the other. The actual quenching is usually performed by breaking up the total spark gap into a series of narrow spark gaps and keeping the latter cool. In this way the conductivity of the gaps disappears very quickly after the spark ceases, and this loss of conductivity prevents the spark being re-formed by the reaction of the oscillations in the secondary or aerial circuit upon the primary or condenser circuit.

Consequently the energy does not pass back again from the aerial to the condenser, but the aerial oscillations continue steadily till all the energy in the aerial circuit is either radiated away in the form of electric waves, or has been converted by the various resistances into heat. In this way the beats of aerial current which occur when the ordinary spark gap is used and the consequent radiation of a double-humped wave (*q.v.*) are avoided. *See* Quenched Gap Transmitter; Quenched Spark; Quenched Spark Gap.

QUICKLIME. Sometimes known as caustic lime, is the residuum left by the burning of limestone in a kiln. The action of the burning in the kiln is to drive off carbonic acid in the form of gas. A calcareous earth or lime is left behind in a nearly pure state, and this is known as quicklime. The material possesses peculiar thermal qualities, and, when freshly mixed with water, heat is generated and the lime disintegrates, and finally is reduced to a powdered state, the lime then being slacked. This operation must be allowed plenty of time, and when lime is used for building purposes it ought to remain in a slacked state for at least a month before use or the lime will work and ruin the structure. Quicklime is used as a constituent in many lime washes, such as are needed for the walls of a workshop and other places. It is also used in the slacked state for making mortar, such as may be needed for the brickwork associated with various erections used in connexion with wireless work.

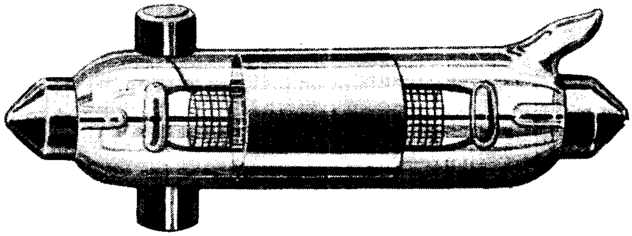
QUICKSILVER. This is a popular name for the metallic element mercury, so called from its appearance and mobility. *See* Mercury.

Q VALVE. Type of three-electrode receiving valve designed primarily for rectifying. An illustration of the Q



CHARACTERISTIC CURVES OF Q VALVE

Fig. 1. Anode current-grid volts, and grid current-grid volts characteristics are shown in this series of curves of the working conditions of a Q valve



Q VALVE FOR RECEPTION

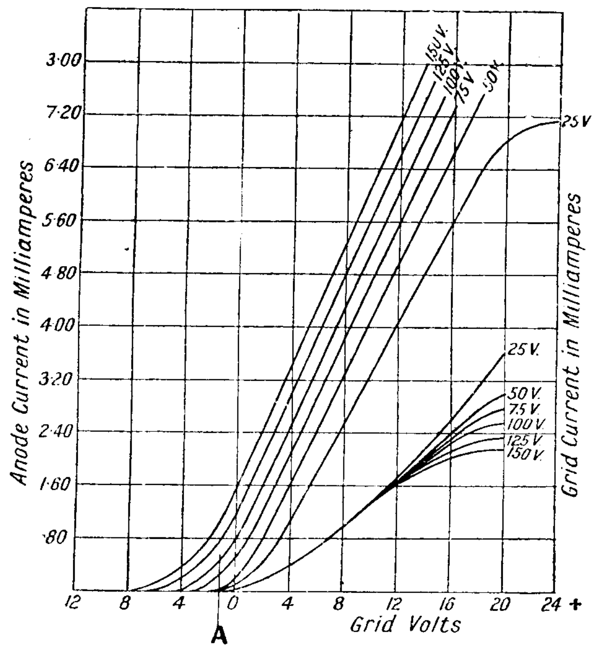
Fig. 2. Primarily the Q valve was intended for rectifying. It has three electrodes, and contact is made by end clips

valve appears in Fig. 1. From this it will be seen that it is of the tubular type of valve, having small contacts arranged at either end and at the sides. This construction is responsible for a considerable reduction in self-capacity, as compared with the usual four-pin type of socket. The Q valve has an anode of very large diameter, which is supported by being a tight fit within the glass tube. The grid is of the wire mesh type, and is considerably longer than the anode. A current of ·45 amperes at a pressure of 5 volts is necessary for the heating of the filament.

When used as a rectifier, the Q valve requires an anode potential of 25 volts normally, but as an amplifier a normal voltage of 150–200 is necessary. A characteristic curve for this valve, showing its operating features under all conditions, is given in Fig. 1.

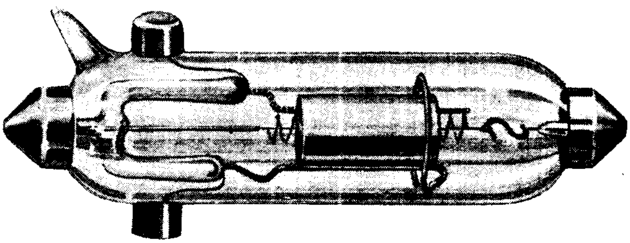
QX VALVE. A three-electrode receiving valve of similar external appearance to the Q valve, which is designed more for general purposes. Reference to Fig. 1, which is an illustration of the QX valve, will show that the anode is of normal dimensions, and is surrounded near one end by one turn of wire. The latter has one end fixed to the anode, and the other left free to spring against the interior walls of the tube. By this means the anode is kept in position. The grid of this valve is of the conventional open spiral type, while the filament has a spring attached to one end in order to prevent it sagging. As this valve is of very similar appearance to another type (the V24), the end of the tube is frosted, as a distinguishing mark.

The filament current for the QX valve is ·75 amperes, while the voltage is 5. A characteristic curve is shown in Fig. 2. From this it will be seen that the best anode potential for rectifying is in the neighbourhood of 25 volts, while for amplifying 100 volts is an average figure.



CHARACTERISTIC CURVES OF QX VALVE

Fig. 2. Series of curves of the QX valve, showing anode current-grid volts and grid current-grid volts characteristics for various working conditions



QX VALVE FOR GENERAL PURPOSES

Fig. 1. Like the Q valve in appearance, the QX valve has three electrodes, and the anode is surrounded near one end by a turn of wire

R

RADIAN. Unit of circular measure of angles. It is the angle subtended at the centre of a circle by an arc whose length is equal to the radius of the circle. The angle is independent of the size of the circle, and is therefore a constant angle. It is equal to $180/\pi$ degrees, or approximately 57·295 degrees. Angles in circular measure are generally denoted by Greek letters, so that when the angle θ is mentioned it means the angle θ radians.

RADIATION. The emission of energy in the form of electro-magnetic waves. *See* Electrolines; Transmission.

RADIATION COEFFICIENT. The energy radiated from an aerial is equal to the product of the square of the current as measured on a hot-wire ammeter at the foot of the aerial and a composite factor dependent upon the design and effective height of the aerial and the wave-length transmitted. This factor is called the radiation coefficient, but is more usually known as radiation resistance.

RADIATION RESISTANCE. The damping experienced by oscillations in an aerial is due chiefly to the expenditure of energy in overcoming resistance and in radiating pressure waves in the ether. Radiation, therefore, acts as a form of resistance to the oscillations, and the value of this radiation resistance, which is a factor depending upon the design, effective height and wave-length of the aerial, may be measured by that amount of resistance which, inserted in the aerial circuit, would cause an equivalent amount of damping as radiation.

RADIO. This is an American term which is synonymous with the word wireless. It is gradually coming into more extensive use, however, in Great Britain. Thus radio-telegraphy and telephony is the same as wireless telegraphy and telephony. The word is also used in such expressions as radio-frequency, meaning high frequency or frequency such as appears in wireless circuits.

RADIO-ACTIVE. Term used in connexion with a number of substances which, like radium, constantly and under normal conditions of temperature, etc., emit energy in the form of electrons. Uranium, thorium, actinum, their compounds, etc., are examples of such substances. Rutherford showed that the radiations from radio-active substances were of three distinct types, which he called the alpha, beta and gamma rays.

The alpha rays are positively charged particles, each of mass four times that of the hydrogen atom, and moving at a very high speed. The beta rays are high-speed negatively charged particles, now known as electrons; they are identical with cathode rays. The gamma rays are of short wave-length. *See* Cathode Rays; Electron.

RADIOCITE. Trade name of a crystal rectifier. It is a treated form of iron pyrites with a lustrous golden colour. It is very sensitive, and a good piece of radiocite is very nearly free from insensitive spots. It should be used with a gold cat's-whisker. *See* Crystal.

RADIO COMMUNICATION. The art of transmitting signals by means of radiated ether waves. Communication depending on the propagation of such waves, guided by tangible conductors between definite receiving stations, or through the earth between electrodes, is not included. *See* Broadcasting; Transmission.

RADIO COMPASS. Apparatus designed to indicate the direction of a source of wave emission. Until the recent advances in the use of thermionic valves it was almost essential that some form of external aerial should be used, of large enough dimensions to pick up sufficient energy to operate a crystal detector, and the triangular aerials of the Bellini-Tosi system were largely adopted. To-day, however, the necessity for such aerials is non-existent, entailing as they do a considerable ground area for erection, and the frame or loop aerial has come to the fore as a direction finder. Compactness and portability are two advantages which should appeal to the amateur, while for accuracy of results it is in no way inferior to other systems.

When the plane of a loop aerial is in direct alinement with a source of radiation, signals of maximum intensity are obtained, due to the greatest phase difference existing between the two currents induced in the vertical sides of the frame. The strength of signals falls off as the loop is rotated from this position, becoming zero when at right angles to the transmitting station. Preference is sometimes given to the method in which two readings of minimum intensity are taken, and the angle made by the two positions bisected to give the required direction.

It is immaterial whether the frame is of the solenoid or pancake type, but as far as possible tuning should be accomplished by a variation of capacity, a reasonable maximum being ·001 mfd. Tappings should be avoided, and separate frames constructed to cover the band of wave-lengths required. If, however, the use of loading coils is unavoidable, they should be of small diameter and preferably screened, otherwise they will pick up energy on their own account and render unreliable directions as indicated by the frame.

As regards the amplifier required for use in conjunction with the loop, with an aerial, say, 4 ft. square, the largest size consistent with portability and ease of manipulation in a room of average size, three valves are a minimum, one of which should certainly amplify at radio-frequency. Good results cannot be expected with fewer than this, due to the inefficiency of the frame as a receiving system. *See* Bellini-Tosi Aerial; Direction Finder; Frame Aerial; Goniometer; Hanging Set; Robinson Direction Finder.

RADIO-FREQUENCY. The frequency at which radio signals are transmitted or received. Frequency and wave-length are relatively connected with one another, and are dependent upon the inductance and capacity in the transmitter or receiver circuits, which, except in one or two isolated circuits connected with receivers, includes the characteristics of the aerial.

In the transmission of telegraphy only one frequency is generally used, but in telephony a further frequency, namely, the speech or music modulation, is superimposed on the frequency of the carrier wave (*q.v.*)

When speaking of receivers it is usual to denote the frequency of all currents in the circuit prior to the rectifier as being of radio- or high-frequency—after rectification they are known as audio-frequency, or low frequency. *See* High Frequency; Low Frequency.

RADIO-FREQUENCY AMPLIFIERS AND THEIR USES

How to Increase the Effective Range of a Small Receiver

It is not for long that the amateur is content with the circumscribed range of the small-size receiver, and indeed the expansion of that range by adding radio-frequency amplification is no impossible task, as will be found in this article, which gives full theoretical and constructional details of several types. Reference should also be made to Amplifier; High-frequency Amplifier; etc.

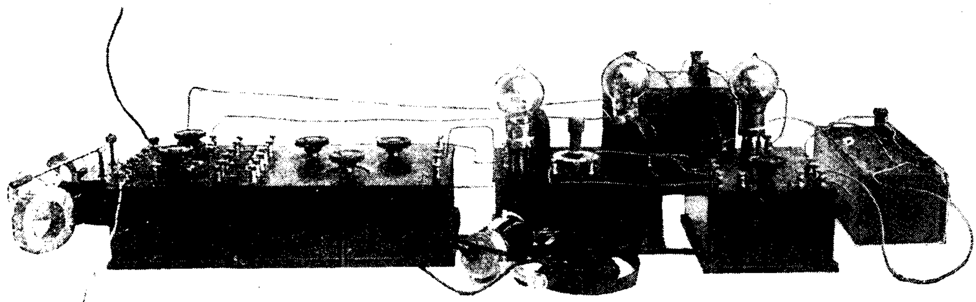
A radio-frequency amplifier is a unit for amplifying the high-frequency currents before they are rectified. In this Encyclopedia types and construction of a number of radio-frequency amplifiers are given under the heading High-frequency Amplifier.

The construction of a radio-frequency amplifier in the form of a small unit that can be added to almost any receiving set for the purpose of increasing its effective range of reception is a matter well worth the attention of the amateur experimenter. There are many forms of radio-frequency amplifier which can be used for the purpose, and the disposition of the parts may be modified as circumstances demand, such, for instance, as the use of a case of such dimensions that it will suit the others enclosing the receiving set or possibly the power amplifier.

One design that has proved successful in use is illustrated complete with tuning and detector units in Fig. 1. In this design two stages of radio-frequency amplification are provided, an inter-valve coupling being effected by means of radio-frequency transformers. Those illustrated are the standard Sterling plug-in transformers suitable for ordinary broadcast wave-length, but others of other make will no doubt give satisfactory results.

One of the secrets of success in the application and use of radio-frequency amplifiers is to watch very carefully the insulation of every part, and particularly to take care that surface leakage is reduced to a minimum. This may be accomplished by using the very finest grade of ebonite for the panel and other parts that may support any of the components, and also to keep the wires as widely spaced as possible, running them in parallel lines only when it is unavoidable, and to set the transformers in such positions that they will not set up interaction effects either between themselves or any other parts of the apparatus.

In this design this point has been dealt with by placing the transformers in line with each other diagonally on the top of the panel, as these positions make them



RADIO-FREQUENCY AMPLIFIER IN OPERATION

Fig. 1. Two stages of high frequency are used in this instrument. The two H.F. valves are mounted on one panel to the left of the detector-valve panel. The amplifier is used in conjunction with a tuner and detector

most remote from adjacent apparatus and also minimize interference between them.

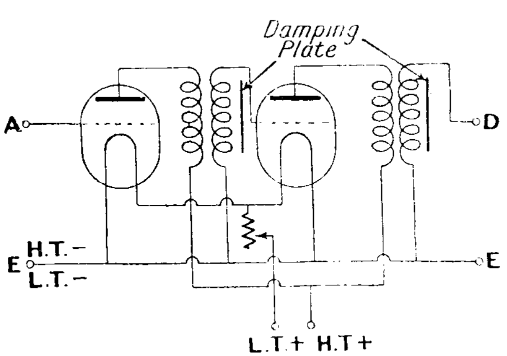
The first step in the construction of the set is to study the circuit diagram, Fig. 2, and gain a comprehension with regard to the whereabouts of the respective components. After this the ebonite panel should be marked out, cut to shape, squared up, the centres for the various components marked as shown in Fig. 4, and the fixing and other holes drilled. The panel measures $7\frac{1}{8}$ in. in length and $5\frac{1}{8}$ in. in width, and should be about $\frac{3}{16}$ in. to $\frac{1}{4}$ in. in thickness.

The exact placing and disposition of the various components will have to be adjusted to suit them, but in any case it is preferable to use separate sockets for the valves in preference to a holder, as there is then less capacity effect between them. These sockets should be passed through clearance holes drilled in the ebonite and be held firm with a washer and nut on the underside. The valves are located in opposite corners of the panel, and the sockets to receive them are clearly visible in Fig. 5.

An ordinary filament rheostat controls the valves, and its resistance should be appropriate to the voltage of the valves that are intended to be used. That in the illustrations has a 6 ohms resistance, and controls a 4 volt current. The valves used are the Marconi Osram R type valves. As the filament resistance is placed in the centre of the panel, between the two transformers, a special ebonite knob is turned up from rod $\frac{3}{4}$ in. in diameter and $2\frac{1}{2}$ in. in length. The lower part is drilled and tapped to fit on to the spindle of the filament resistance, and is secured to it with a large diameter lock nut, which also serves to hold the dial. The upper part of the knob is knurled to provide sufficient grip for the fingers. Its form and general disposition are shown in Fig. 6, which should sufficiently illustrate this feature to ensure its successful construction.

The next step is to fit up the filament resistance, screw it to the underside of the panel, as shown in Fig. 7, and fix the other terminals with lock nuts. A view of the upper part of the panel is shown in Fig. 3, which also indicates the whereabouts of the connecting terminals and the simple dial used in conjunction with the special filament resistance knob. This dial may be turned to shape from celluloid or thin ebonite, or cut from white cardboard, carefully smoothed on the edges, and marked out with a number of equal divisions, the "off" and maximum positions being separately indicated.

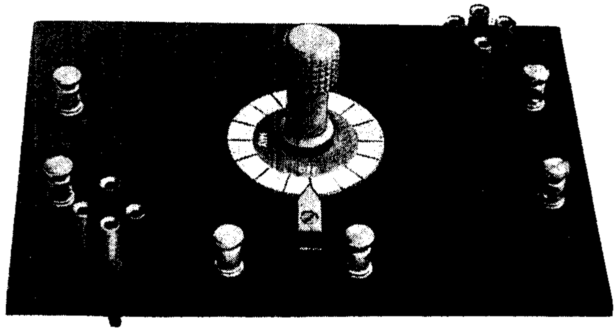
This dial is raised about $\frac{1}{8}$ in. above the surface of the panel, and for easy reading a little block of ebonite is provided and screwed to the top of the panel, as can be



RADIO-FREQUENCY AMPLIFIER CIRCUIT

Fig. 2. In this diagram is the circuit arrangement of the two-stage high-frequency amplifier in Fig. 1. Note the damping plates

seen in Fig. 3, and the pointed end of the block cut away so that the point projects above the upper surface of the dial and gives an accurate reading. The transformers may either be fitted into their special holders and simply screwed to the top of the panel, and wires taken from the holders to the different components of the set, or plates attached to the holders, when this can be done, as it tends to reduce capacity effects and also eliminates any possible loss in conductivity between the plug and socket connexions.



PANEL FOR RADIO-FREQUENCY AMPLIFIER

Fig. 3. Valve sockets are mounted in the corners of the panel, and the filament-resistance turning knob and dial are of uncommon design. The dial revolves and the pointer is stationary

In this set the four prongs of the transformer are simply pushed through holes drilled in the ebonite panel. The ends of the prongs then protrude on the underside of the panel. Connexions are effected by taking stout wires flattened at the ends and slipping them into the slots in the prongs, bending the ends of the wires at right angles to them. The wires are held in position by means of a crossbar of ebonite with little notches on the underside. This bar is screwed to the underside of the panel, as shown in Fig. 8.

As a further aid to insulation the other ends of the wire should be covered with systoflex or rubber tubing before the ebonite bar is screwed down, and after this has been fixed the wires are bent over

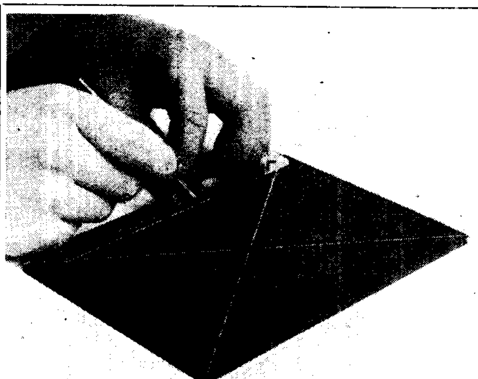


Fig. 4. Success in high-frequency amplification depends upon the proper spacing of the components; the panel must therefore be marked out accurately

Fig. 5. Sockets for the valves are mounted separately, rather than using standard valve holders, to lessen the capacity

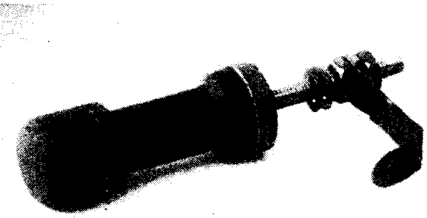


Fig. 6. For the rheostat a specially designed knob and spindle are used. These may easily be made by the amateur

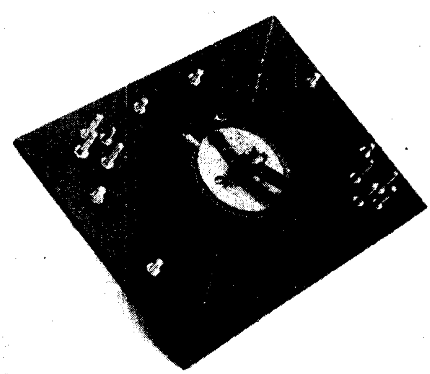


Fig. 7. Mounted exactly in the centre is the filament resistance, with the legs of the valve sockets on either side

PANEL CONSTRUCTION OF THE RADIO-FREQUENCY AMPLIFIER

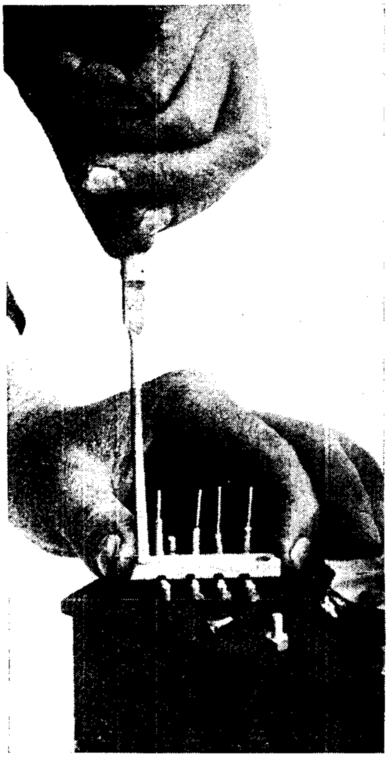


Fig. 8. Leads of the radio-frequency transformer are fixed by an ebonite bar. Note the notches in the underside

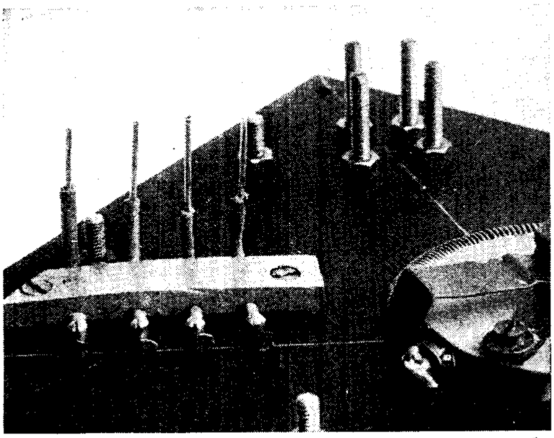


Fig. 9. Ends of the transformers are shown connected; the wires are covered with systoflex before the bar is screwed down

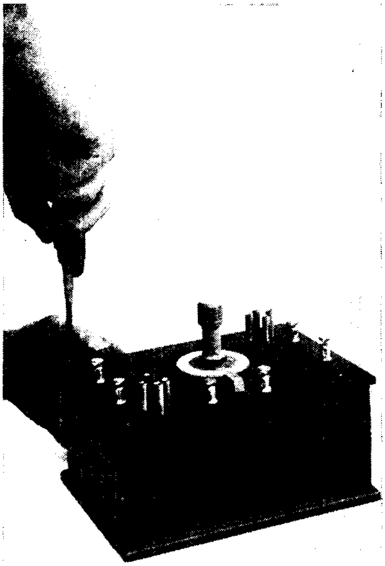


Fig. 10. Screws holding down the panel should be countersunk. This photograph shows the general appearance of the case

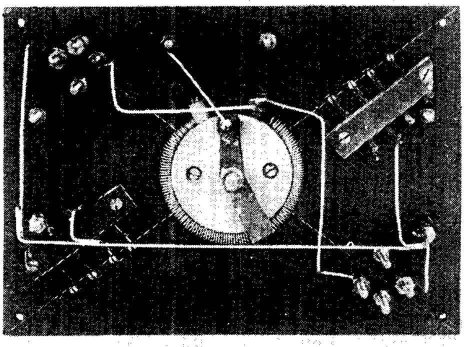


Fig. 11. Wiring, here shown in the first stage, is best carried out with ordinary tinned copper wire of about No. 18 gauge

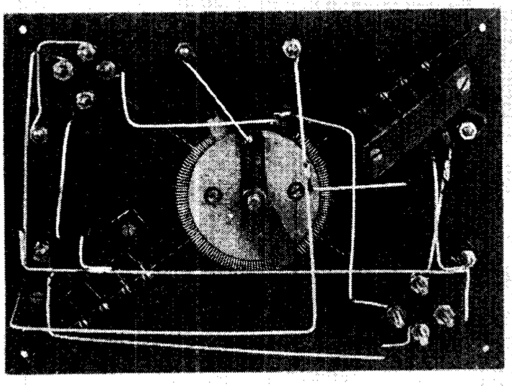


Fig. 12. Wires should be spaced as widely as possible, being bent away from each other. This is the final stage in the wiring of the set

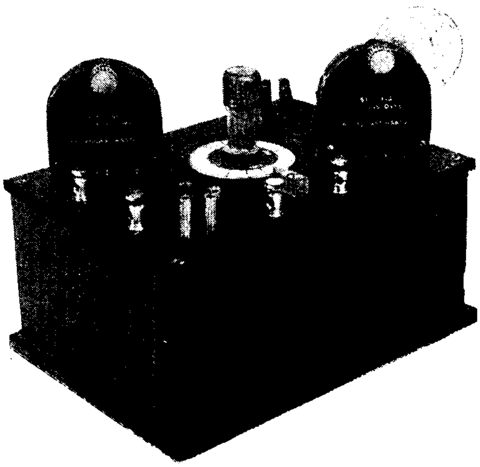
DETAILS OF RADIO-FREQUENCY AMPLIFIER CONNEXIONS at right angles, as shown in Fig. 9. With this arrangement it is quite possible to remove the transformers and change them for others of higher value, but it necessitates removing the panel from the case.

Four screws, one at each corner of the panel, will suffice to hold the panel and case together. The screws should be of brass, have countersunk heads, and be about ¾ in. to 1 in. in length. The case illustrated in Fig. 10 has a simple moulded base, measures 7 in. in length, 5 in. in width and 3 in. deep, and can easily be made as described under the heading Cabinets (*q.v.*), or purchased ready for use.

The wiring is next taken in hand, and should be carried out in accordance with the wiring diagram. The first stage in the wiring is illustrated in Fig. 11. The wiring is best carried out with ordinary tinned copper wire about No. 18 gauge. The wires should be as widely spaced as possible, and as few of them should run in parallel lines as is reasonably possible.

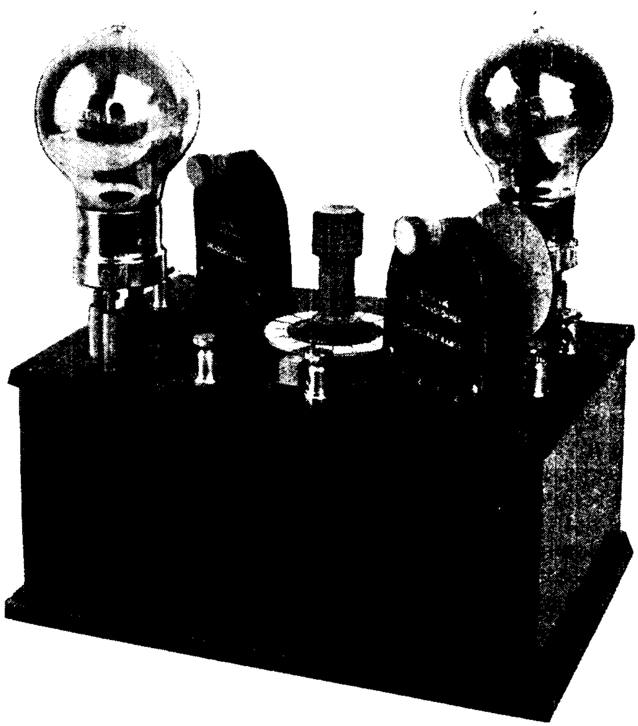
The next step in the wiring is to connect up the aerial terminal with the grid of the first valve and the plate of the first valve with one side of the primary of the first transformer, working progressively through the wiring until the whole is complete, as shown in Fig. 12. Although not apparent from this illustration, the wires are widely separated, some of them standing about 2 in. away from the underside of the panel. When the wiring is complete, each separate run should be tested for electrical continuity, and every trace of soldering acid, metallic dust or any other dirt should be thoroughly and speedily removed by brushing with a small brush dipped in petrol, allowing the whole to dry, and then completing the work by dusting with a dry brush.

The panel is then screwed to the top of the case and the instrument is completed as shown in Fig. 13. This illustration clearly shows the damping plates which form a feature of the Sterling transformers and are used for tuning purposes. The set complete with its valves is illustrated in Fig. 14, and is then ready for attachment between the tuning and detector unit. The connexions to the left of the illustration



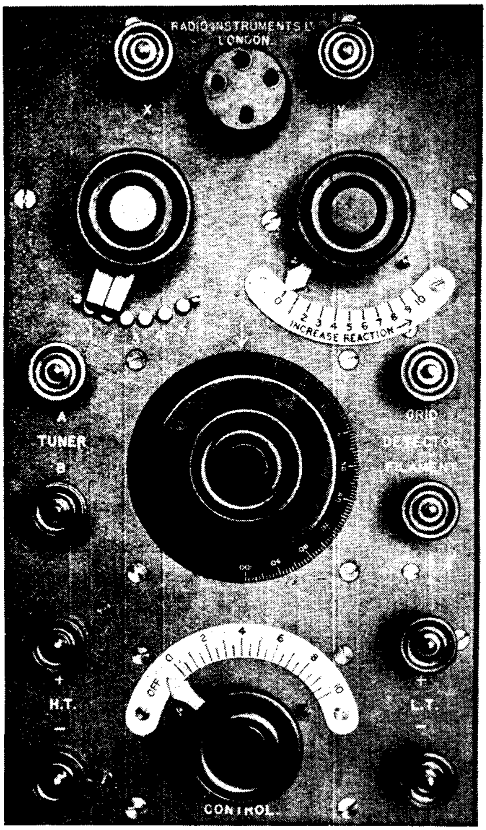
TRANSFORMERS IN POSITION

Fig. 13. High-frequency transformers of the radio-frequency amplifier are mounted diagonally at opposite corners from the valves



RADIO-FREQUENCY AMPLIFIER COMPLETE

Fig. 14. Sterling R.F. transformers of broadcast range are used. The valves being mounted, the amplifier is ready to wire up to the tuner, batteries and detector



ONE-VALVE RADIO-FREQUENCY AMPLIFIER

Fig. 15. No extra plug-in coils are required for high wave-lengths in the one-valve radio-frequency amplifier. A tuned anode circuit is used

Courtesy Radio Instruments, Ltd.

in Fig. 14 are taken to the aerial and earth sides of the tuning unit respectively. The two terminals to the right of Fig. 14 connect to the grid of the detector valve or a crystal detector. In the case of a valve set the second terminal is connected to the high-tension negative and low-tension negative, if the set is wired in that way, otherwise to the normal earth terminal of the receiving set. The two terminals in the front of the set are for high-tension positive and low-tension positive respectively.

It should be noted that in adding a radio-frequency amplifier to a valve detector, or to a crystal detector embodying a stage of audio-frequency amplification, it is necessary that the main connexions between the high and low tension batteries be of similar polarity throughout. Thus, if the detector has a high-tension negative and low-tension negative connected together, the same procedure must be adopted and the radio-frequency amplifier wired accordingly, otherwise a direct short circuit will occur in one or other of the batteries.

When in use the filament of the radio-frequency amplifying valve should burn at normal brightness, the tuner be set for the nearest broadcast station, and the two damping plates moved on the radio-frequency transformers until signals are heard, after which the complete receiving set should be adjusted until the loudest signals are heard. It will be found that adjustment of the radio-frequency filament resistance will often check any tendency to howl that may occur, as will the critical adjustment of the two damping plates; it will also have the effect of greatly increasing the signal strength.

Fig. 15 shows a complete radio-frequency amplifier using the tuned anode circuit and made by Radio Instruments, Ltd. This unit is intended for use in any set where the tuner can be conveniently separated by the detector or other radio-frequency panel. The whole instrument is entirely self-contained, no additional coils for the higher wave-lengths being required.

At the top of the panel are the reaction terminals, below which is the valve holder. The knobs next to the latter are for coarse wave-length tuning and reaction control respectively. In the centre of the panel is the knob and dial fixed to the anode variable condenser, while to the left of this are the terminals for connexion to the tuner, and to the right are the terminals for connexion to the detector panel. The remaining knob controls the filament resistance, which is of the standard Radio Instruments type, being wound upon a flat former. On either side of this are terminals, the use of which is clearly indicated.—*E. W. Hobbs.*

RADIO-FREQUENCY TRANSFORMER. Expression applied to a transformer used in the anode circuit of a valve to amplify the incoming signals at radio-frequency. The term is synonymous with high-frequency transformer (*q.v.*). The application and operation of radio-frequency transformers are dealt with in respect to numerous receiving sets in this Encyclopedia under such titles as Amplifier; Crystal Receiver; Dual Amplification; Reflex Set; Transformer, etc.

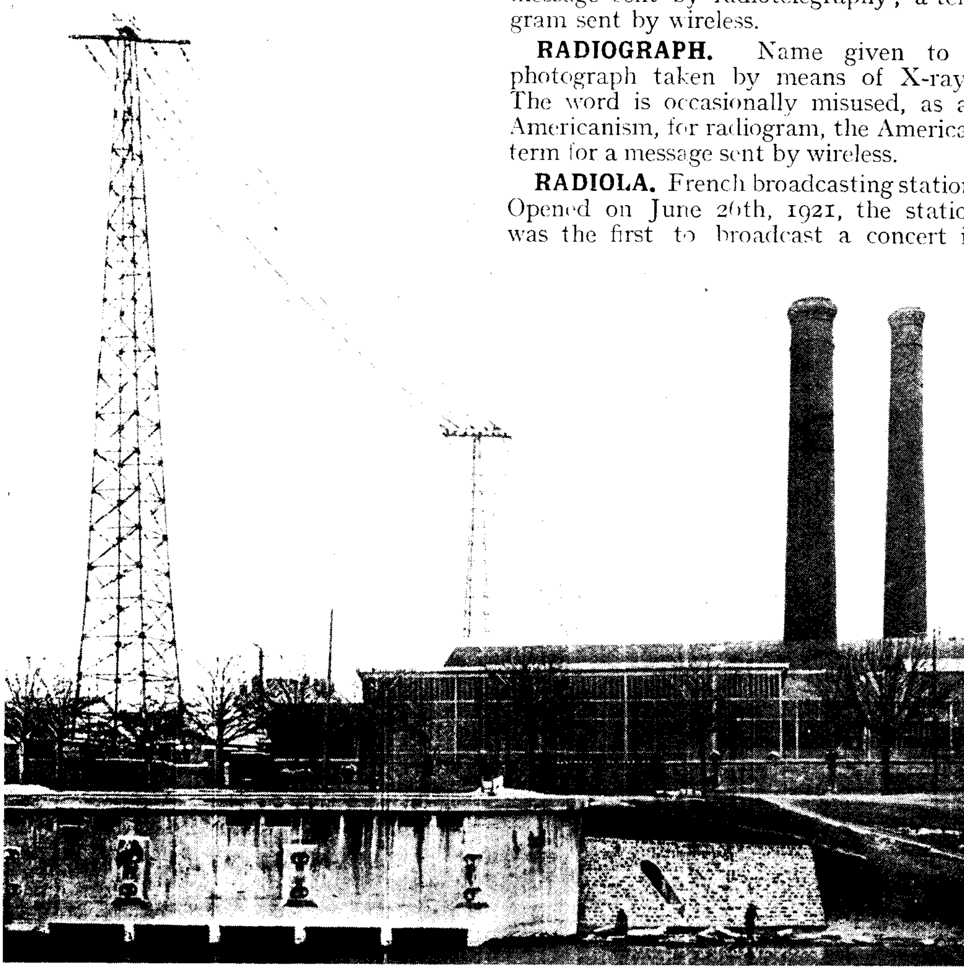
RADIOGONIOMETER. Instrument used in direction-finding apparatus, especially the Bellini-Tosi system. In this system there are two aerials at right angles to one another, and they are each connected to a coil which forms part of the radiogoniometer. These coils are wound at right angles to one another and mounted on a hollow cylinder, and inside them is mounted a further coil of wire. The aerial coils are called field coils and are fixed. The third coil is known as the search coil, and is movable inside the other two coils. The search coil is connected to the receiving unit, the other two to the loop aerials. In pages 229–230 these connexions are shown.

The radiogoniometer is usually contained in a box with the necessary terminals on its top. Switches enable either aerial to be disconnected so that only one aerial at a time may be used while the receiving set is being adjusted for preliminary reception. In using the radiogoniometer it is customary to find the positions from which no signals are being received, as these points are more sharply defined than the points of maximum audibility. These points are taken as the mid points between the points of zero audibility. *See* Bellini-Tosi; Direction Finder; Goniometer; Robinson Direction Finder.

RADIOGRAM. American term for a message sent by radiotelegraphy; a telegram sent by wireless.

RADIOGRAPH. Name given to a photograph taken by means of X-rays. The word is occasionally misused, as an Americanism, for radiogram, the American term for a message sent by wireless.

RADIOLA. French broadcasting station. Opened on June 26th, 1921, the station was the first to broadcast a concert in



LEVALLOIS TRANSMITTING STATION OF THE SOCIETE FRANÇAISE RADIOELECTRIQUE

Fig. 1. Although those in charge of the Radiola transmissions are dissatisfied with the location of their station, Levallois being a manufacturing district where much metal is concentrated in the form of machinery, and as such unsuited to satisfactory broadcasting, nevertheless the transmissions are effectively received all over England. Three control panels are employed, and an aerial 110 metres long, with due east-west orientation; the wave-length used is 1,780 metres

France, but it was not until November 6th, 1922, that regular concerts were broadcast.

The studio of Radiola is situated at 79, Boulevard Haussman, Paris. This room, like many other broadcasting studios, is hung with thick curtains to keep out all external noises. The power amplifier is in an adjoining room, and is connected up to the microphone in the usual way. The power amplifier room contains the control panels as well.

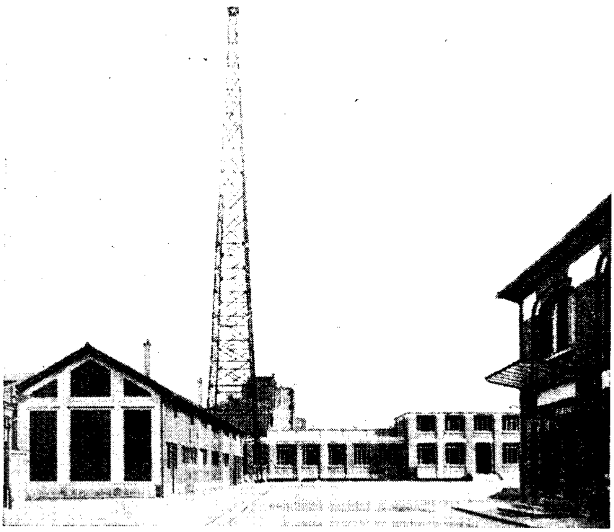
The actual transmitting aerial of Radiola is situated at Levallois, but the situation is unfavourable for transmission on account of the factories in the neighbourhood and the consequent masses of metal, in the form of machinery, which interfere with transmission. Fig. 1 gives a general view of the five-wire aerial that is used. Transmission takes place on 1,780 metres. The aerial runs due east and west, and has an earthing system consisting of 400 square metres of zinc plates.

There are three control panels, one for the modulating valves which superimpose the sound waves upon the high-frequency current generated by the valves of the third panel. The remaining panel contains the rectifying valves. Fig. 2 gives a general view of the control room. On the left are seen the control panels, and on the right the aerial regulating coils.

Between the rectifying and oscillating valves there is a system of condensers and inductances, which prevent the high-frequency oscillations from reaching the low-frequency apparatus and smooth out the ripple of the converted current. They also have the effect of keeping the anode voltage of the oscillating valves constant. In the grid circuit of the oscillating valves is an oscillating circuit, and the grid circuit is also coupled to the transmitting aerial. In the aerial-earth circuit is placed a variable inductance and variometer to adjust the circuit to the transmitting wave-length.

CONTROL ROOM AT THE RADIOLA STATION

Fig. 2. Radiola concerts are transmitted by the Société Française Radioélectrique at Levallois. The above photograph shows the transmitting and control room. The valve panels are shown on the left, and on the right are the aerial regulating coils



ANOTHER VIEW OF LEVALLOIS

Fig. 3. Rising 65. ft. above the station buildings are the tall lattice masts that support the inverted L transmitting aerial. The latter is 160 metres in length

Fig. 3 shows another general view of the station and one of the lattice masts supporting the aerial. The latter is an inverted L aerial, the wires from one end being joined together at the entrance to the station. The masts are 65 ft. in height, and the length of the aerial is 160 metres.

RADIOPHARE. Half American, half French term for a wireless lighthouse or beacon. It is the name used for a wireless station which is continually sending out signals, so that ships fitted with direction-finding apparatus may determine their positions.

RADIUM. One of the chemical elements. Its chemical symbol is Ra and atomic weight 226. It is a silvery-white metal which tarnishes rapidly on contact with air. Its chief source is the mineral pitchblende. Radium is remarkable for its radio-active properties and for giving off the rays of high frequency which form one end of the gamut of ether waves, of which wireless waves form the other end. *See* Ether; Frequency.

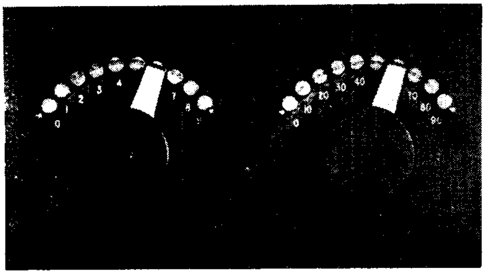
RADIUS. In geometry name given to the straight line drawn to the circumference of a circle or the surface of a sphere from their centres.

RANGE. The range of a transmitting set or a receiving set depends upon so many varying and uncertain factors that it is impossible to lay down hard-and-fast rules as to the distance a given aerial will transmit with a given power, or how far a given receiving set will pick up signals.

On the broadcasting map facing page 282 a number of circuit diagrams are given, enabling sets to be constructed to cover ranges up to 520 miles as a minimum. The actual construction of all these sets is separately described in this Encyclopedia. The distances shown there, however, are minimum distances. For example, it is stated that the four-valve set will cover a range of 520 miles. This it will normally do, though usually signals are readable on such a set at double the distance. Under the heading Distance of Reception, the whole question is further discussed in this Encyclopedia.

The distance of transmission is exactly as variable as the distance of reception. It depends upon the wave-length used as much as upon the power and upon other factors. Short waves, for example, travel much better over sea than land, and the nature of the land between the receiving and transmitting stations has an important bearing on the distance of transmission. Blanketing by trees, hills, houses, etc., has a considerable effect, and may prevent any precise calculations being made. It is a common experience for ship sets of only one and a half kilowatts to transmit over a range of 1,000 miles, but this is greater than their normal range, and such sets could not be guaranteed to carry over such a distance. Telephonic communication has been constantly carried out over ranges of several hundred miles with less power. *See* Broadcasting; Distance of Reception; Fading; Transmission.

RANGE SWITCH. Expression applied to a form of switch having a number of separate contacts, wired in such a way that a specific portion of the inductance coil may be utilized at will, the purpose being to vary the effective wave-length to which the set can be tuned. The function of a range switch is therefore to provide on a receiving set a convenient means of varying the inductance value, and consequently the wave-length for reception.



RANGE SWITCH

Fig. 1. Fine tuning is obtained by the set of contacts on the left, and coarse on the right of this separately mounted range switch

Courtesy Economic Electric Co.

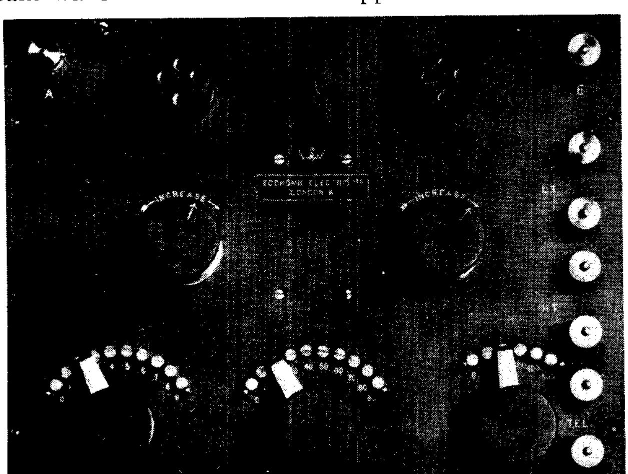
Such switches comprise essentially a movable contact arm and a series of contact studs, the whole mounted on an ebonite plate or small panel. For fine tuning, a convenient arrangement consists of two separate contact arms and two separate sets of contact studs, the whole being mounted on a small panel somewhat in the manner illustrated in Fig. 1. If the wiring of the inductance coil be suitably arranged and tappings be taken to the proper spacings, one of the range switches can be connected to a series of tappings separated only by a small number of turns between each tap, the other switch having tappings more widely spaced, proportions in both cases being appropriate to the scope of the receiving set or the maximum or minimum wave-lengths to which the inductance can be tuned.

In use, the coarse tuning switch is set to the nearest available tapping point, and the fine tuning switch adjusted accordingly. Instead of building up a separate range switch as an independent unit, it may be incorporated on the panel of a simple receiving set, such as the two-valve panel illustrated in Fig. 2. In this case three range switches are used, that on the left controlling nine tappings of only one turn each, the middle switch with tappings at every 10 turns, and the right-hand switch tappings at every 100 turns.

Alternatively, the tappings may be taken to the inductance coil in such a manner that any desired wave-length value may be arrived at by suitable positioning of the two switches to correspond with specific broadcast or other wave-lengths. With such an arrangement tuning condensers are scarcely necessary, although one or more may be incorporated either in series or parallel with the aerial tuning inductance, preferably of the vernier type. *See* Coil; Switch.

RAYLEIGH, JOHN WILLIAM STRUTT, third Baron (1842–1919). British physicist. Born at Langford Green, Essex, November 12th, 1842, he was educated at Trinity College, Cambridge, where he was senior wrangler and first Smith's Prizeman. In 1879 he was appointed Cavendish professor of experimental physics in succession to Clerk-Maxwell, a post he held until 1884. In 1887 he became professor of natural philosophy at the Royal Institution, a post he held until his appointment as president of the Royal Society in 1905. In 1908 he was appointed Chancellor of Cambridge University, and died June 30th, 1919.

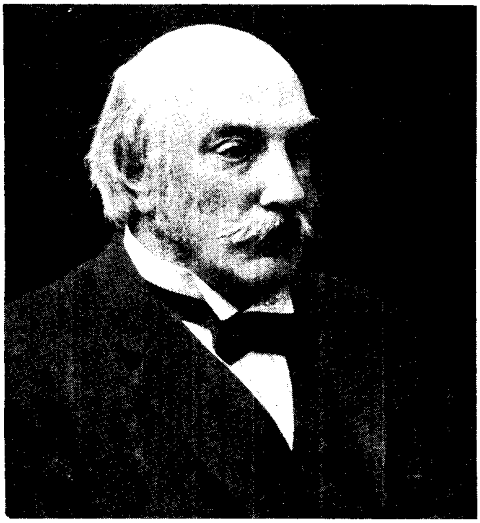
Rayleigh was one of the most brilliant experimental physicists of the nineteenth century. He had not only a remarkable power of mathematical analysis, but was equally skilful in carrying out the experimental proofs of his theoretical researches. Many of his experiments were carried out with home-made apparatus which showed



VALVE PANEL INCORPORATING RANGE SWITCH

Fig. 2. Mounted on an E.E.C. panel is this three-range switch, providing three sets of inductance tappings: left, one-turn, centre, ten-turn, and right, 100-turn contacts

Courtesy Economic Electric Co.



LORD RAYLEIGH

Former Chancellor, Cambridge University. He was a brilliant physicist, and among his invaluable contributions to the science of wireless are the detection of the gas neon and the discovery of many inert gases in the atmosphere

Photo Russell

an astonishing insight on the part of Rayleigh into the essentials and non-essentials of the particular problem he was tackling. He threw a fresh light on nearly every branch of physics, from the theory of gases to elasticity, sound and hydrodynamics; from optical phenomena to wave theories and electric and magnetic problems. Due to the care with which he carried out his experiments, he was the first to detect the presence of neon in the atmosphere, the forerunner of the discovery of a number of inert gases in the atmosphere in minute quantities. To electricians the Rayleigh balance, for absolute current measurement, is as well known as it is important. He also suggested a method for measuring the capacity of a condenser.

Lord Rayleigh was one of the original members of the Order of Merit. In 1882 he was awarded the Royal Medal, in 1899 the Copley Medal of the Royal Society, and in 1904 the Nobel prize for physics.

REACTANCE. In a direct current circuit the opposition to the flow of current is a factor dependent upon the resistivity, cross-sectional area and length of the metal composing the circuit. The changing nature of alternating current, however, introduces other problems, and Ohm's law no longer holds good. In addition to having to overcome ohmic resistance, an alternating electro-motive force is further opposed by the back electro-motive force of inductance. This extra "resistance" added to the circuit when current is flowing is known as reactance, and is proportional both to the frequency and inductance, as shown by the expression

$$2\pi n L$$

where n = frequency and L inductance in henries.

The essential difference between ohmic resistance and reactance lies in the fact that whereas the former reduces current by causing energy to be dissipated in the form of heat, the latter brings about the same effect by setting up a back electro-motive force against the applied force, so that very little energy is actually wasted.

A condenser offers little opposition to the passage of an alternating current of high frequency, and the resistance effect or reactance of capacity is given by the formula

$$\frac{1}{2\pi n C}$$

where C = capacity in farads, showing that this quality varies inversely with frequency and capacity.

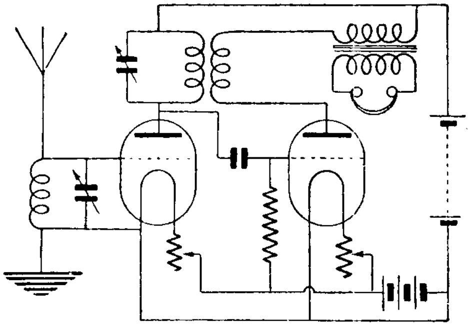
Since the presence of a condenser in an alternating current circuit causes the current to lead the electro-motive force, and inductance causes a current lag, the two effects are in opposition, and the reactance due to a combination of the two is given by the expression

$$2\pi n L - \frac{1}{2\pi n C}$$

To sum up, that part of the total impedance due to causes other than ohmic resistance is termed the reactance of a circuit.

REACTANCE CAPACITY. Term applied to the method of high-frequency amplification in which a reactance coil, either self-tuned or in parallel with a small variable condenser, is placed in the plate circuit, and the amplified voltage passed on to the next valve through the agency of a small fixed condenser, as illustrated in the diagram, which shows a typical circuit. The function of the anode circuit is to provide the necessary high impedance to ensure that the valve operates in the most efficient manner possible and gives maximum voltage amplification.

This system possesses several distinct advantages over the two other methods



REACTANCE CAPACITY

Wiring diagram of circuit employing reactance capacity. Amplification thus obtained has several advantages over resistance and transformer methods.

in general use, viz.: resistance and transformer coupling. Equal efficiency is obtained on all wave-lengths, from the highest to the lowest, whereas the resistance amplifier is unserviceable on wave-lengths under, say, 2,000 metres, and practically useless under 1,000 metres. Above these limits there is not much to choose between the two methods, except that resistance coupling is aperiodic.

On the lower wave-lengths the capacity of the valve electrodes, so detrimental to the resistance amplifier in shunting the anode resistance, actually serves a useful purpose in tuning or helping to tune the reactance coil.

The inter-valve condenser for ordinary purposes should have a capacity of about ·0003 mfd. The exact value is not critical, but it must be remembered that the reactance of capacity is inversely proportional to frequency, so that the higher the wave-length required to be received, the larger must this condenser be. The grid leak may be from 2 to 3 megohms.

The one disadvantage of this circuit lies in the ease with which valves tend to oscillate when the anode and grid circuits are tuned to exactly the same wave-length, due to electrostatic reaction provided by the valve electrodes. The type of valve used should therefore have as small a capacity as possible, the V24 being specially adapted to this method of amplifying. This tendency to oscillate may be obviated to a certain extent by connecting the grid leaks to the positive end of the filament, or by using a potentiometer for the same purpose, viz.: to give a positive bias to the grid. A condenser of fairly large capacity, say ·1 mfd., across the high-tension battery, and the use of high-frequency chokes to replace the grid leaks may also be tried.

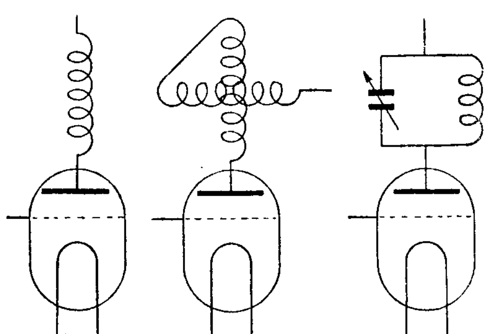
Also variable reaction may be used without causing serious re-radiation, if the reaction coil is coupled to the anode of the first valve. Even if this valve does oscillate, only energy in the grid circuit is transferred back to the aerial.

REACTANCE CIRCUIT. In the reactance-capacity method of coupling high-frequency amplifiers, if a simple reactance coil is used in the anode circuit, as shown in the figure at *a*, maximum voltage amplification is possible only on that particular wave-length which has a frequency corresponding to that of the coil. This circuit may, however, be made to cover a wider band of wave-lengths either by constructing the coil on the variometer principle or, better still, by using a small variable condenser in parallel, as in *b* and *c* respectively.

The effective resistance of the anode circuit to oscillating currents is equivalent to $\frac{L}{CR}$ ohms, where L = inductance in henries, C = capacity in farads, R = resistance in ohms.

As it is the object of the circuit to provide as great an impedance as possible, the proportion of inductance to capacity should be high, and the ohmic resistance of the wire used of a low value. In practice capacities above ·0002 mfd. cannot be used without loss of amplification.

Tuning is very critical in an amplifier using this circuit, due to the fact that maximum amplification occurs only when



THREE METHODS OF REACTANCE

Three reactance systems are shown here: *a*, a simple coil used in the anode circuit; *b*, a variometer coil; *c*, wider range of wave-length obtained by variable condenser the anode circuit is tuned exactly to the same wave-length as the incoming signals, and very little if it is mistuned even in the slightest degree. While this is of inestimable value in eliminating interference, it leads to certain difficulties when two or more valves are used. When searching for signals the time period of the anode circuits must always be identical, or oscillations which may be amplified by one valve will not affect another because of slight mistuning, and poor results ensue.

Condensers by means of which the capacity of two circuits may be varied simultaneously, the two sets of moving vanes being mounted on a common spindle, may be employed with considerable advantage, always provided that identical values of inductance are in parallel with them. *See* Interference Eliminator; Reactance Set.

REACTANCE COIL. Although this term is often used synonymously with reaction coil, a meaning more in keeping with the definition of reactance occurs in its application to chokes.

A typical example is afforded in receiving apparatus which embodies the reactance-capacity method of coupling valves required to amplify at radio-frequency. In this case such a coil replaces the anode resistance of the resistance amplifier, and has the same function. While presenting a very considerable impedance to oscillating currents of a frequency corresponding to the wave-length to which the coil is tuned, the reactance coil offers but little ohmic resistance, so that the value of the high-tension battery may be kept low.

Such coils may be purchased to cover a wide band of wave-lengths, being self-tuned by the capacity of the windings and tappings taken at convenient points. It is, however, better to use a set of plug-in coils of the Burndept or duolateral type, tuning being effected by a small condenser, for although the self-tuned coil has the advantage of eliminating the adjustment of capacity, yet, even if very fine subdivisions are made, it is not possible for the natural time period of that part of the coil in circuit to be the same as that of the range of oscillations it is required to amplify. The result is maximum efficiency on one particular wave-length and reduced amplification on the remainder.

By using reactance coils wound with resistance wire, an amplifier may be made semi-aperiodic, and will function partly on the resistance and partly on the reactance principle. *See* Anode Reactance; Capacity Reactance.

REACTANCE COUPLING. Apart from the general application of this term in the sense of back, or retro-active coupling, the expression may conveniently be employed to cover the system of high-frequency amplification more usually known as reactance-capacity coupling, and dealt with under that heading. The valve is caused to amplify by inserting a high impedance in the form of a reactance coil in its plate circuit.

REACTANCE SET: HOW TO MAKE

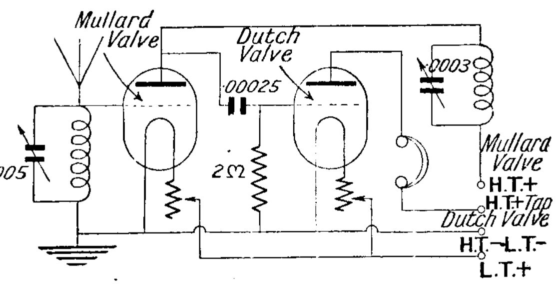
A Simple and Efficient Two-Valve Set Employing Reactance-Capacity Coupling

High-frequency amplification on the principle employed in this receiver is efficient over a long range of wave-lengths, and gives a purity of tone with speech and music superior to that obtained by the use of reaction. With a good aerial all B.B.C. stations should be received. See associated headings, as Amplifier; High-frequency Amplifier; Reactance Capacity

A two-valve set embodying reactance-capacity coupling between the first valve, which acts as a high-frequency amplifier, and the second valve, which acts as a detector valve, is shown in Fig. 3, and is a very simple two-valve set for the beginner to attempt. It is suitable for use with any make of valve. Those shown in the illustrations are respectively an Ora in the first stage, and a Dutch valve in the second stage.

The quality of music and speech is particularly good, possessing purity and clarity that is seldom obtained when reaction is used. Its absence necessarily reduces slightly the range of reception, and also the signal strength, but the present set will bring in several broadcast stations, and when carefully tuned, after experience in handling, should be capable of receiving practically all of them, dependent upon the excellence of the aerial and the location in which the set is erected.

The ordinary commercial plug-in coils are used for the aerial tuning inductance and for the anode reactance. Each of them is tuned by means of a variable condenser. Separate filament resistances are



SIMPLE REACTANCE CIRCUIT

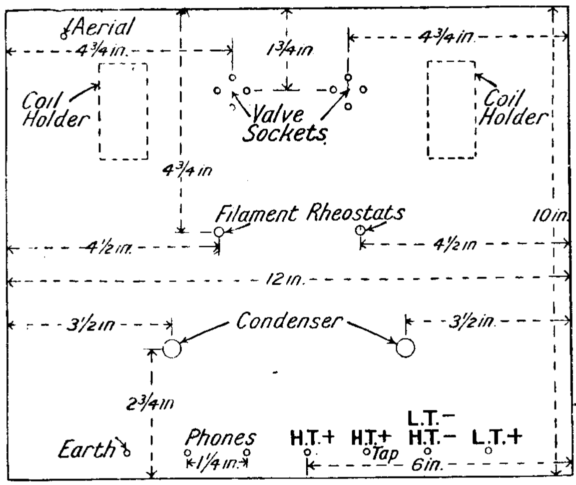
Fig. 1. The disposition of parts is seen in this wiring diagram for the reactance set shown in Fig. 3. This circuit should be studied in conjunction with Fig. 2

provided for the control of each valve, and the whole is mounted on an ebonite panel, which rests in a recess formed in the top of the simple case.

The advantage of this set is that the wiring is very simple. It is not difficult to tune when complete, and is economical in first cost. The circuit diagram is given in Fig. 1. This should be compared with the illustrations showing the wiring and other details. The dimensions and lay-out of the panel are given in Fig. 2, and in the construction of this set the best plan is to prepare this panel first.

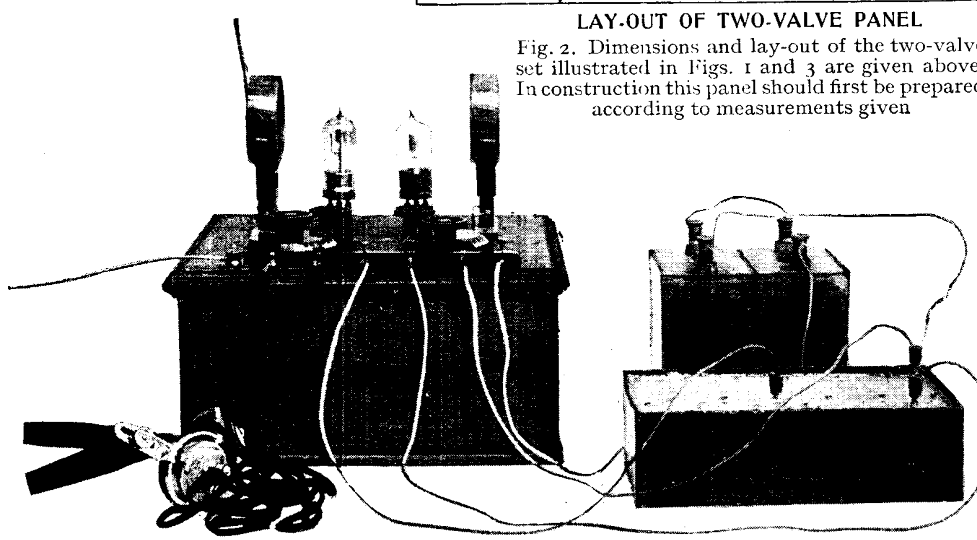
The panel may be of ordinary ebonite with a matt finish, or one of the more ornamental materials finished with mahogany or oak-coloured surface. After the panel has been shaped up and the various holes drilled it is fitted on to the top of the case, as shown in Fig. 4.

The case itself can easily be constructed from ordinary deal, and measures 5 in. in depth, and its external dimensions are the same as those for the panel. The corners should be mitred



LAY-OUT OF TWO-VALVE PANEL

Fig. 2. Dimensions and lay-out of the two-valve set illustrated in Figs. 1 and 3 are given above. In construction this panel should first be prepared according to measurements given



BEGINNER'S SET EMBODYING REACTANCE

Fig. 3. Reactance-capacity coupling is employed in this two-valve set between the Mullard valve on the left, acting as a high-frequency amplifier, and the Dutch valve on the right, used as a detector. The efficiency of this set is proverbial, and its merits can be most highly commended to the amateur

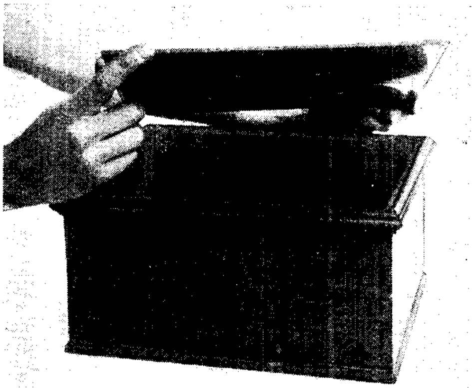


Fig. 4. The panel is cut and the holes drilled before fitting on the top of the case, which has been assembled and varnished

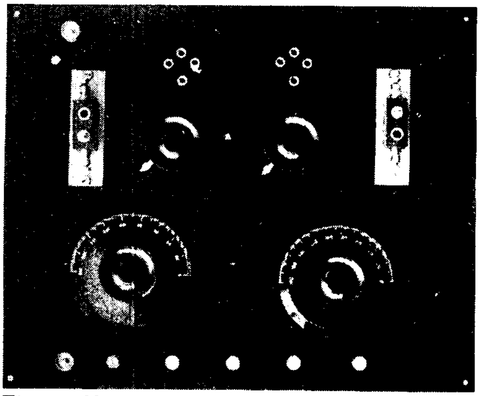
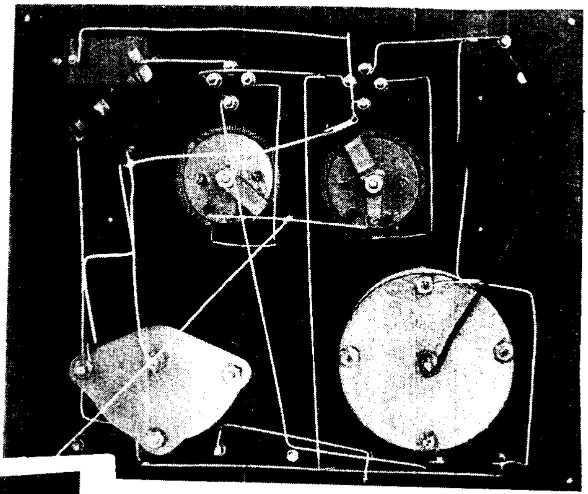


Fig. 5. Here is shown the disposition of the components on the panel, which is cut from matt-surface ebonite

HOW THE HOME-CONSTRUCTED REACTANCE SET IS BUILT UP

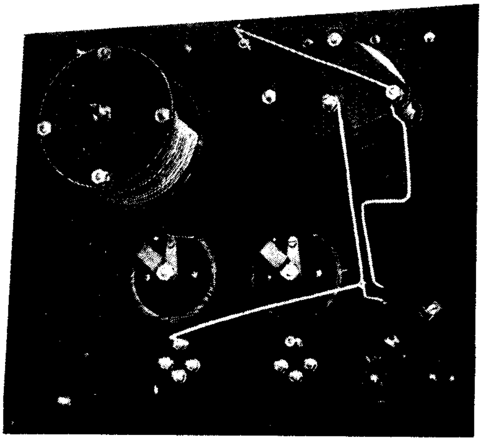
together and glued and pinned, the pinholes filled in with stopping, and the whole papered off smooth with very fine sandpaper. The sides should be $\frac{5}{16}$ in. in thickness, and the bottom, which is simply screwed to the underside of the side pieces, is finished with a simple half-round moulding, and should be about $\frac{5}{8}$ in. in thickness.

Some simple stock moulding, obtainable from any timber yard, is then mitred around the upper part of the case so as to form a rebate, this holding the panel securely and imparting a neat finish.



WIRING COMPLETED

Fig. 6. This view should be studied in conjunction with the theoretical circuit in Fig. 1



UNDERSIDE OF PANEL

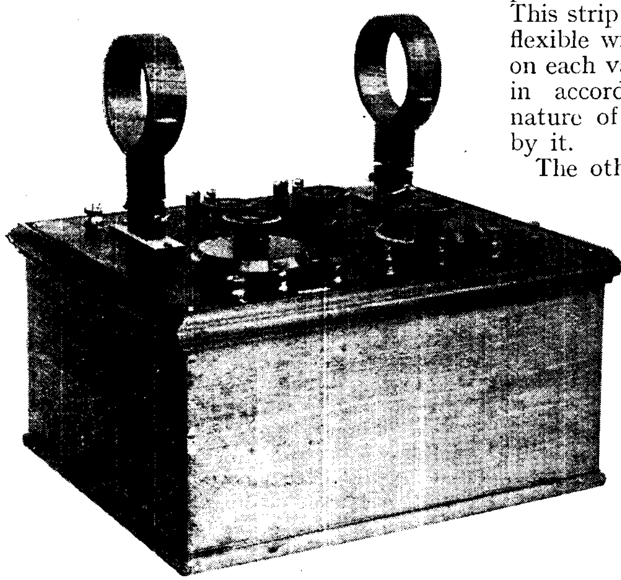
Fig. 7. Here is clearly illustrated the wiring of the reactance circuit and the position of the grid leak and condenser. Note the relative proximity of filament resistances to the valves

When the panel is completed the components should be attached to it. The chief items required are two single-coil holders, preferably with ebonite plates at the bottom of them to facilitate attachment to the face of the panel; one ·0005 mfd. variable condenser, and one ·0003 mfd. variable condenser; two filament resistances, the value being appropriate to the valve in use; eight valve sockets, two terminals for the aerial and earth connexions respectively, and five telephone terminals; a grid condenser with a value of ·00025 mfd., and a grid leak of a value of 2 megohms, together with clips for it, are also needed, as well as condenser dials, knobs, and tinned copper wire, about No. 18.

A plan view of the panel, showing the whereabouts of these fittings, is given in Fig. 5, while the underside of the panel is given in Fig. 7, showing the same fittings and also the positions of the grid leak and condenser, and the wiring from the reactance coil to its tuning condenser to the plate of the valve and a lead taken to the high-tension positive terminal. This circuit forms the reactance circuit.

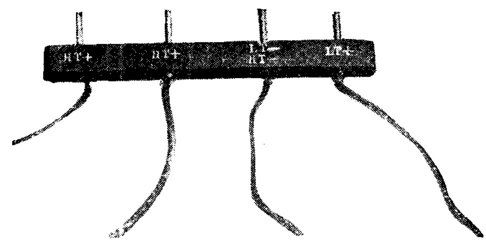
The whole of the wiring is carried out with tinned copper wire, with the exception of one flexible wire lead from the aerial tuning condenser to the aerial terminal. This flexible wire is used, as in the make of condenser used in this set the centre spindle rotates, and necessitates the use of the flexible wire so that it can move in harmony with the spindle. Any good quality components can be employed in the set.

The whole of the wiring is shown complete in Fig. 6, which should be carefully studied in conjunction with the circuit diagram. When the wiring is completed, the panel should be screwed to the top of the case, the condenser dials and knobs fitted, and the dials so placed on the spindles that when the whole of each moving plate of the condenser is between the fixed plates, the indicating mark on the panel registers with the zero mark on the condenser dial.



COMPLETED REACTANCE SET

Fig. 8. Here we see the coils in place and the set virtually ready for use. No. 2½ Burndept and No. 4 Burndept honeycomb coils may be used



FOUR-PRONG CONNECTING PLUG

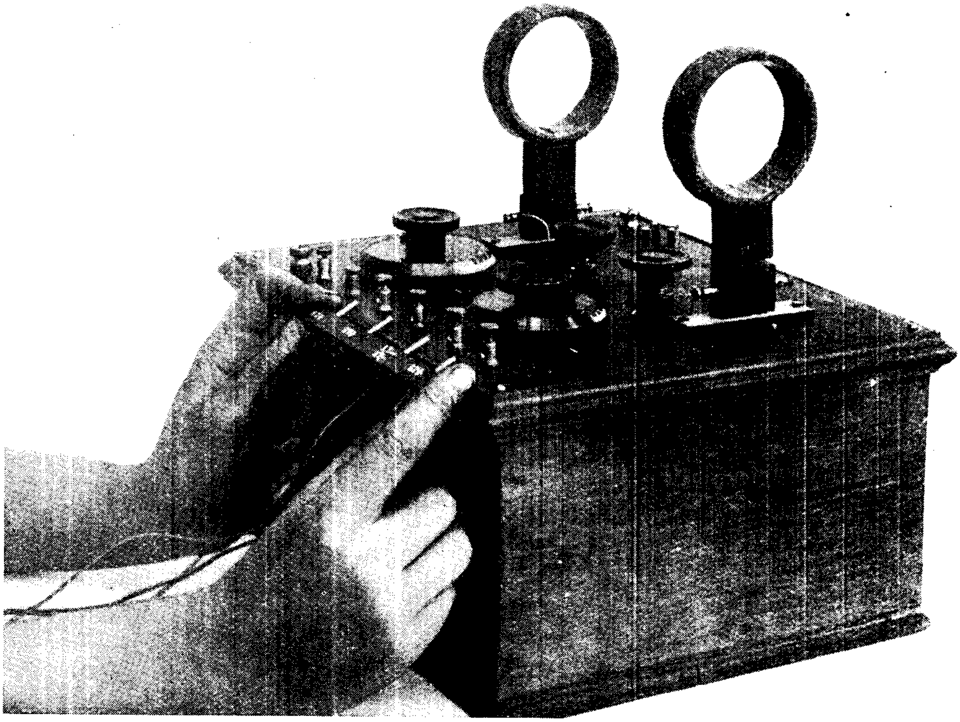
Fig. 9. For easy connexion of high- and low-tension batteries with the set this home-made plug will be found most useful

The two coils are then inserted into the coil holders, their value being dependent upon the size and type of aerial used and the wave-length to which the set is to be tuned. Under normal conditions of broadcast reception a No. 2½ Burndept or No. 35 Igranic honeycomb coil can be used in the aerial tuning coil holder, and a No. 4 Burndept or No. 75 Igranic honeycomb in the reactance coil holder. These coils are shown in Fig. 8.

To facilitate connexion between the high- and low-tension batteries and the set, a strip of ebonite about ⅜ in. in thickness, ½ in. broad and about 6 in. in length should be prepared, and four valve legs fitted to it to register with the position of the four telephone terminals on the panel used for the battery connexions. This strip is shown in Fig. 9. A separate flexible wire is soldered to the terminals on each valve leg and the ebonite marked in accordance with the polarity and nature of the current which is supplied by it.

The other ends of the flexibles may be provided with red wander plugs for the high-tension positive, and black for the high-tension negative, and with a loop or tag for connexion to the low-tension battery, so that there will be no risk of confusion in reconnecting them to the batteries at any time.

The method of attaching the four-prong connector to the terminals is clearly shown in Fig. 10, by using the terminals known as telephone terminals. The valve legs have simply to be pushed into the holes in the posts and the set-screws on the



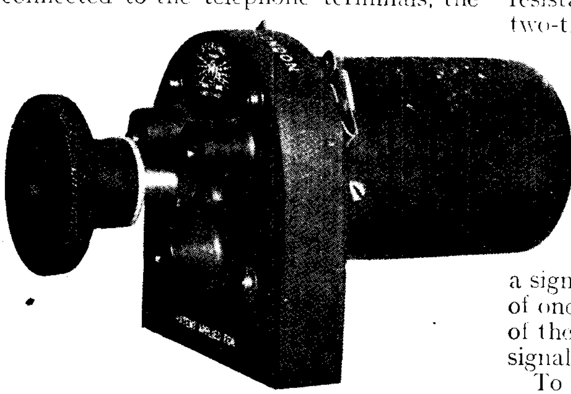
REACTANCE SET WITH FOUR-PRONG CONNECTOR

Fig. 10. Above is shown the method of attaching the four-prong connector illustrated in Fig. 9. The valve legs used in the connecting plug are pushed into the terminal pillars, and the set-screws above tightened home. The set is now complete and ready for the valves, which are placed in the holders between the coils

top tightened down; when not in use the connector is removed from the set. The set being completed, the valves are placed in the holders, the telephones connected to the telephone terminals, the aerial and earth connexions completed, and the set is ready for use.

Tuning will be found to be fairly sharp. As a first attempt the first filament resistance should be turned on to about two-thirds of its travel, the second filament resistance turned full on, the aerial tuning condenser should be brought to about No. 40 division on the dial, and the anode reactance condenser to about No. 60 on the dial. Both dials should then be slowly and simultaneously rotated backwards and forwards for a short distance until a signal is heard, when careful movement of one or both condensers and adjustment of the filament resistances will bring the signals in at good strength.

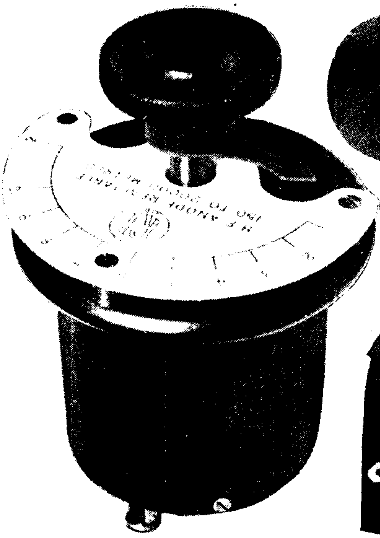
To receive on the higher or lower wave-lengths, coils of appropriate value should be used in the two coil holders. The filament and anode voltages should be appropriate to the valves in use.—*E. W. Hobbs.*

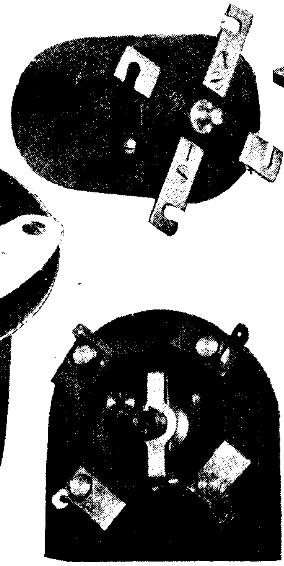


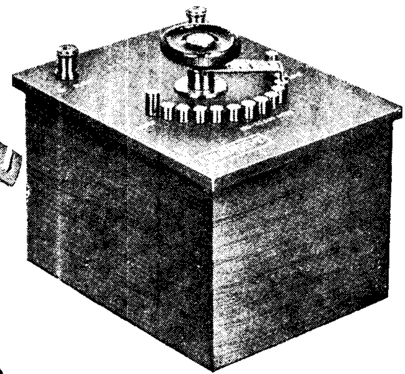
ANODE REACTANCE UNIT

Fig. 1. Three brass-bushed tapped holes are provided in the Sterling reactance unit for mounting to the Panel. Reaction is controlled by the large knob

Courtesy Sterling Electric and Telephone Co., Ltd.







REACTANCE UNITS
Fig. 2 (centre). Two views of the back of the Sterling unit, showing the connexions. Fig. 3 (right). The Burndept semi-aperiodic reactance. Fig. 4 (left). A protected unit giving a range of 150 to 20,000 metres

REACTANCE UNIT. Device used in the anode circuit of a high-frequency amplifying valve.

The Sterling reactance unit, illustrated in Figs. 1 and 2 is fitted with a detachable winding. The complete unit is shown in Fig. 1. It will be seen from this photograph that this instrument is intended for panel mounting, there being three brass-bushed, tapped holes for this purpose. The knob in the front controls the amount of reaction, as required. Fig. 2 clearly indicates the method adopted for facilitating the removal or replacement of the rear unit, so enabling a fresh coil to be quickly substituted to cover any particular range of wave-length which may be desired.

There are four spring contacts arranged on the back of the front portion of the combined instrument. These contacts are studs, having a large flat head, at the rear of which is a flat springy strip. The cylindrical portion of the instrument has four stiff contacts arranged in the same manner as the contacts on the front portion. The slots in these contacts are so made that they slide under the heads of the studs. On being fitted in that position, the flat springs beneath the stud heads spring up and make good electrical and mechanical contact.

The spindle is divided, one end having a slot cut right across, and the other a driving pin. The latter engages with the slot when the coil unit is placed in position and secured, and thus enables the knob-spindle to turn the rear portion.

The Burndept reactance-capacity unit illustrated in Fig. 3 is of the semi-aperiodic type. It consists of windings arranged within a bobbin. The latter is of boxwood. Eleven tappings are made on the windings, which allow a wave-length range of from 180 to 20,000 metres. In the mounted type these connexions are brought out to a twelve-studded switch. A feature of this instrument is that, within small limits, other conditions in the set in which it is used do not affect its wave-length. For this reason a chart is supplied with it, illustrating exactly the range covered on each tapping.

Another type of anode reactance unit is illustrated in Fig. 4, and consists of a containing case in which. the inductance is well protected from dust and damp. The inductance is wound on a grooved cylinder, and is provided with a set of twelve tappings, which enable the inductance to cover a wave-length range from 150 to 20,000 metres. The spindle is carried right through the former on which the inductance is wound, and is connected to the switch studs at the farther end. The capacity of the winding renders the coil self-tuned, and obviates the necessity for a tuning condenser. This type of reactance is particularly suitable for short wave-lengths. *See* Coil; Reaction; Tuning.

REACTION: ITS MEANING AND USES SIMPLY EXPLAINED

Theory and Practice of this Important Method of Increasing Signal Strength

In this important article the meaning of reaction is explained, and a number of circuits given employing reaction. The reader should also consult such cognate headings as Capacity Reactance; Dual Amplification; Reflex Circuits; Regeneration. See also Oscillation

When two circuits are so placed relative to one another that any increase or decrease in the current flowing in one causes an increase or decrease in the second circuit, and when, further, this increase or decrease is added to the current already flowing in that circuit, the currents will add and continue to build up, until reaching a limit imposed by the physical properties of the circuits.

Before considering the special cases of reaction as applied to wireless circuits, it is perhaps well to consider a very simple form of reaction in a simple telephone circuit (Fig. 1).

On the left-hand side of Fig. 1 there is a microphone, M_1, a telephone earpiece, E_1, and a battery, B_1, whilst the earpiece is connected to the microphone by means of a transformer, T_1.

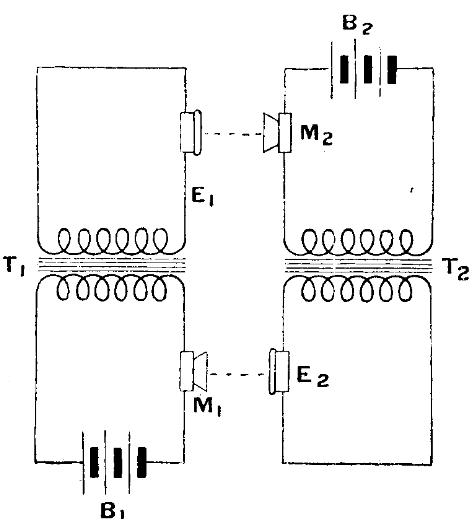
If the microphone M_1, is spoken into the voice will be clearly heard by anyone listening at the earpiece E_1, whilst the second similar circuit, M_2, B_2, T_2, E_2, on the right-hand side, would behave in a similar manner.

Now, if the two circuits are arranged as in Fig. 1, with the microphone M_1 opposite and close to the earpiece E_2, whilst the microphone M_2 is opposite and near to E_1, we have circuits capable of reacting on one another.

If the circuits are connected up in an absolutely silent room nothing will happen, but if the slightest sound is made one of the microphones will detect it. Suppose it is the microphone M_1. The sound causes the resistance of this microphone to vary; a variable current flows from the battery B_1 through the transformer T_1, causing the diaphragm of the earpiece E_1 to vibrate. The small noise given out by E_1 is picked up by the microphone M_2, which, in its turn, varies its resistance, and so the current from B_2 produces a larger movement of the diaphragm of E_2 than the original movement in E_1. E_2 then sends out sound waves, which are greater than the first noise which started the cycle in operation.

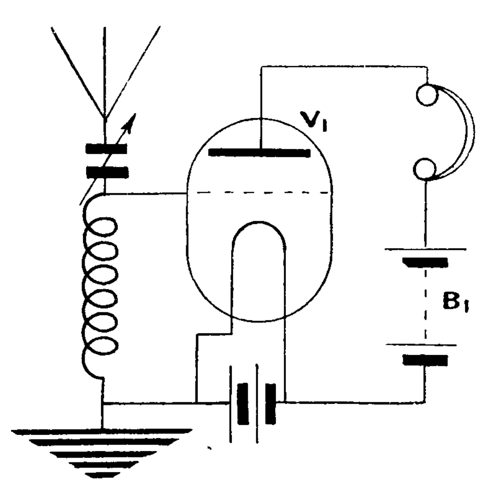
M_1 now acts in a more powerful manner, and E_1, in its turn, emits powerful sound waves. So the cycle continues, until the earpieces E_1 and E_2 are vibrating violently and emitting a "howl" which can be heard at a considerable distance.

If M_1 is moved towards E_2 the degree of reaction is altered, and the note will



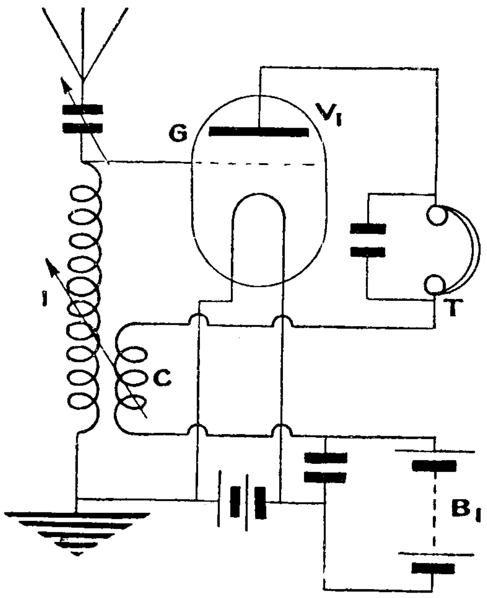
TELEPHONE CIRCUIT EXPLAINING REACTION

Fig. 1. Two telephone circuits illustrative of the general principle of reaction are shown. For explanation of diagram letters see text



VALVE CIRCUIT WITHOUT REACTION

Fig. 2. Here is shown a simple three-electrode valve circuit. Direct action holds here, for aerial and anode circuits are not coupled



SIMPLE REACTION CIRCUIT

Fig. 3. To the simple valve receiver of Fig. 2 has been added a coil, which is included in the anode circuit for purposes of reaction

become more powerful, whilst the same effect may be obtained by varying the coupling between E_1 and M_2.

In this case the low-frequency oscillations build up until the diaphragms of the telephones reach their limit of deflection. In wireless receiver circuits the effect of reaction is to allow the oscillations produced by the weak incoming signal to build up until they become powerful.

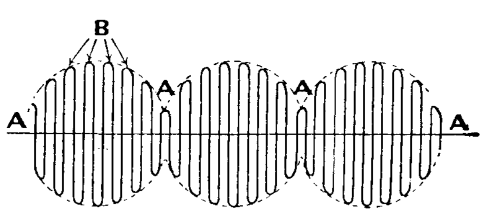
Consider first the simple receiver shown in Fig. 2. In this case there is no reaction employed, although there is an augmentation of the signal strength due to the "trigger" action of the three-electrode valve, for very small changes in the grid of V_1 make big changes in the current flowing from the battery B_1 through the telephones. This is, however, a direct action; the current which flows from B_1 does not change the grid potential, for there is no coupling between the aerial circuit and the anode circuit.

If, however, a coil is included in the anode circuit, as at C in Fig. 3, and if this coil is made so that it may be inductively coupled to the aerial inductance I, then any variable current which flows from B_1 through C will induce a variable potential in the coil I. These changes of potential affect the grid, which, again, allows a larger current to flow from B through the coil C and telephones T.

The actual time taken for this building-up effect is very small: in fact it will only be the time taken for a few of the radio-frequency oscillations to pass. On a wave-length of 300 metres there are 1,000,000 cycles a second, whilst an average musical note will have a frequency of, say, 2,000 a second. Therefore, if a single note in the music which is being transmitted is sustained for one-tenth of a second, there will be 100,000 cycles of radio-frequency, and these will be split up into 200 groups, each of which would give a curve similar to Fig. 4 if drawn out by an oscillograph, where A, A, A, A are the half-periods of the musical note-frequency, whilst B, B, B, B are the corresponding half-cycles of the radio-frequency.

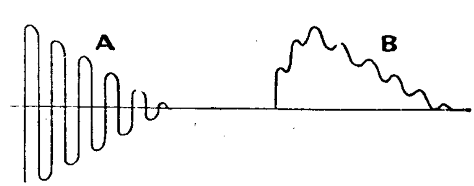
If in place of considering the receiver as receiving a sustained musical note, we consider that it is being used to detect single sparks from a distant transmitter, then the effect of reaction becomes even more apparent.

If a receiver of the type shown in Fig. 2 is in use, or if one of the type depicted in Fig. 3 is employed, provided that in the latter case the coil C is so arranged that there is no coupling between it and the coil I, then the single spark in the distant transmitter will produce electro-magnetic waves which will set up a corresponding



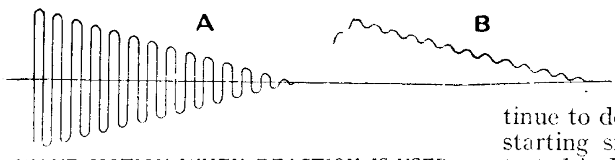
AUDIO- AND RADIO-FREQUENCY

Fig. 4. Drawn out by the oscillograph, this curve shows how a note of music is split up. A, A, A, A are half-periods of note-frequency; B, B, B, B, half-cycles of radio-frequency



WAVE MOTION WITHOUT REACTION

Fig. 5. When there is no reaction—as when the circuit in Fig. 1 is used—the above wave motion results. A, damped waves; B, oscillations of the telephone current



WAVE MOTION WHEN REACTION IS USED

Fig. 6. If the receiver used in Fig. 3 is employed the above wave motion is produced. Note the more sustained oscillations

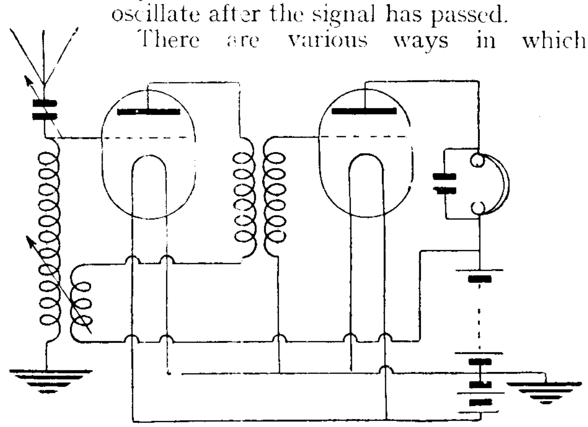
current in the receiver, the damped waves being depicted as A, Fig. 5, which will produce a telephone current as shown at B in the same figure, for, due to the resistance of the receiver circuits, the oscillations are soon damped out.

If now the reaction coil C, Fig. 3, is turned or moved so that it has a tighter coupling with I, then the oscillations produced in the receiver will be more sustained, as shown in Fig. 6, A and B, whilst if the reaction is still further increased, the set begins to oscillate when the first signal strikes the aerial, and does not stop oscillating when the signal has passed. In the extreme case the receiver may start to oscillate, and continue to do so, without the assistance of a starting signal. This condition is illustrated in Fig. 8, in which it will be noticed the oscillations at first build up, and then remain constant for an indefinite time.

The best adjustment of the reaction coil is that at which the receiver offers minimum resistance to the incoming signal, whilst at the same time the reaction coil is so adjusted that the set will continue to oscillate after the signal has passed.

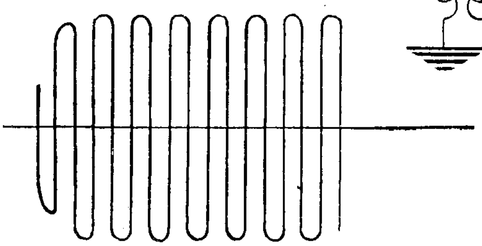
There are various ways in which reaction may be obtained. The simplest is that already shown in Fig. 3.

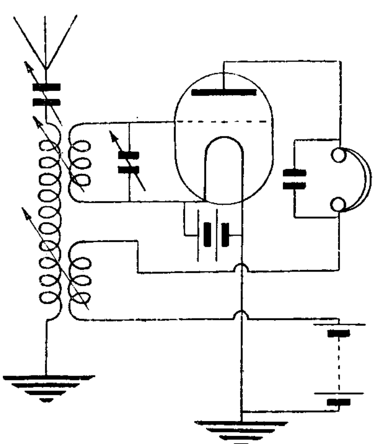
Whilst Fig. 7, which employs a coupled grid, is in many respects similar to Fig. 3,

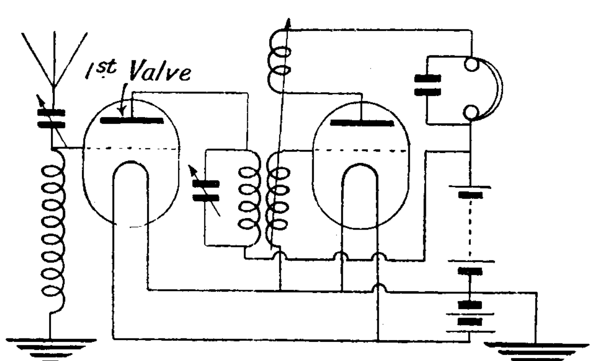


REACTION ON THE SECOND VALVE

Fig. 7. If reaction is employed on the second valve from the aerial, it will not cause the aerial to oscillate

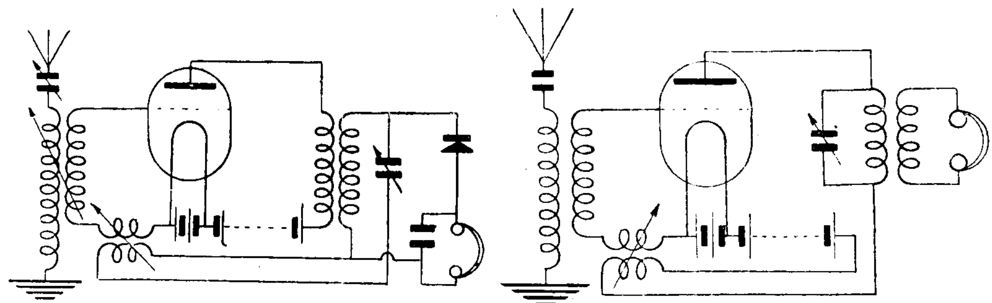






REACTION CIRCUITS AND THE CURVES PRODUCED

Fig. 8 (top, left) illustrates the curve showing the wave motion when the reaction is increased, the receiver oscillating of its own accord. Fig. 9 (lower left) is a coupled grid circuit If reaction is increased too much here, the aerial radiates continuous waves. Fig. 10 (lower right). In this two-valve circuit the anode of the first valve is coupled to the grid of the second, producing an effect similar to that of the circuit in Fig. 3



FURTHER RECEIVING CIRCUITS EMPLOYING REACTION

In Fig. 11 (left) a crystal is used for rectification in this circuit. Fig. 12 (right) shows a circuit employing a telephone transformer, with reaction betwe n the plate and grid

if reaction is pushed too far both sets suffer from the common defect of causing their aerials to radiate continuous waves.

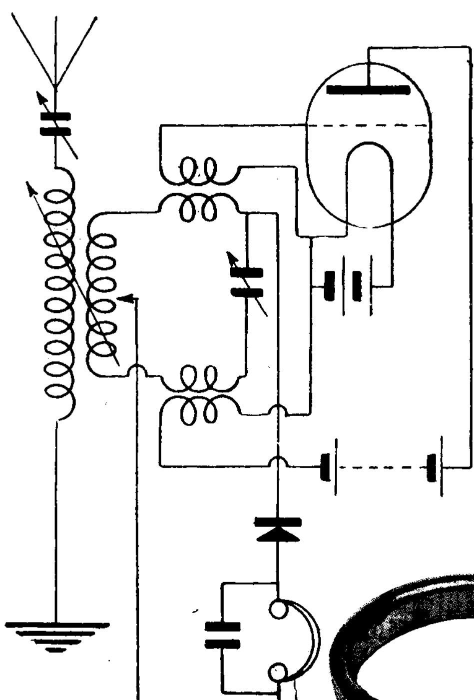
If several valves are to be employed, the anode of the first valve may be coupled to the grid, as shown in Fig. 10, the effect being similar to that of the circuit in Fig. 3.

Several valves may, however, be employed without causing the aerial to oscillate, provided that the reaction is arranged on the second or third valve from the aerial, as shown in Fig. 10.

Some other arrangements of receiver circuits employing reaction are shown in Figs. 11, 12 and 13, of which 11 and 13 employ crystal rectification.—*R. H. White.*

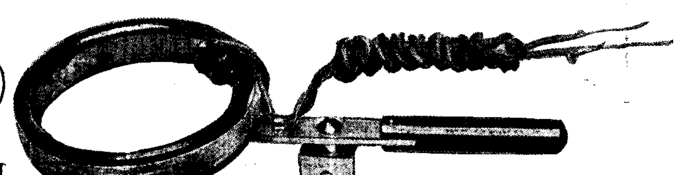
REACTION COIL. Inductance coil which is coupled to the aerial or other inductance in a receiving set. Under this general heading come all those forms of coils which are used for the purpose of reaction. Basket coils, plug-in coils, ball reactances, etc., are all suitable for reaction coils. Usually a reaction coil is a secondary coil in a circuit. Common applications are from the anode circuit of a detector valve to the aerial inductance coil or to another coil in a primary or secondary circuit. In receiving and other sets not provided with a reaction coil a small unit such as that illustrated can be added by screwing a bracket piece, which acts as a pivot bearing for a moving arm, to some convenient part of the apparatus. One end of the arm has an ebonite handle; the other carries a former wound with wire of the desired number of turns and gauge thickness.

The connexions are effected through the medium of a pair of heavily insulated flexible conductors to any desired points in the circuit. Reaction coils are described



VALVE AND CRYSTAL CIRCUIT

Fig. 13. This set embodies one valve and crystal rectifier, using reaction on the secondary and through other coils to the plate and grid



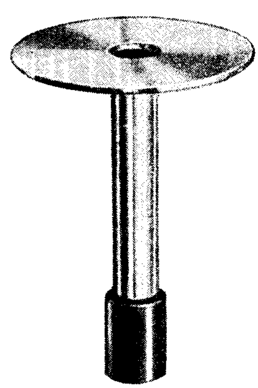
REACTION COIL

This is a most useful unit which can be quickly added to a set not itself provided with a reaction coil. An ebonite handle supports a former wound with wire of the requisite gauge in this Encyclopedia under their respective headings. The reader should also consult such articles as Anode Reactance, Capacity Reactance; Coil; Electricity; Inductance; Magnetism, etc.

REACTION CONDENSER. A condenser between any two parts of the external circuits of an ionic valve system primarily intended to cause reaction or negative reaction.

REACTION DAMPER. Name applied to a plate which when brought into the vicinity of an inductance coil or other piece of apparatus has a damping or semi-tuning effect on that coil.

One type illustrated as used by the G.E.C. consists of a flat disk with a metal stem capped with a small ebonite knob. This is in one application used above an anode reactance coil and is arranged to slide over the surface of the coil. Means are provided to adjust the distance between the damper and the coil, and thus provide a ready means for tuning. In the Gecophone two-valve set the damping plate or control disk is used in conjunction with a reactance coil and a loading coil to increase the wave-length range. Interchangeable reactance coils of the plug-in pattern are employed, and the damping plate allows the coupling between the coils of the reactance coil to be varied. The action of the damper is more fully described under Spade Tuner and under the heading Tuner in this Encyclopedia, where also appear other types of reaction dampers.



REACTION DAMPER
Employed for tuning, this damper plate is used with an inductance and slides over the surface of the coil
Courtesy General Electric Co., Ltd.

REACTION SET: HOW TO MAKE

An Easily Constructed and Highly Efficient Two-Valve Set

Here are explained in full detail the successive stages in the building-up at home of one of the most successful types of receiving sets, in which the principle of reaction governs the tuning and reception. The reader is referred to such cognate headings as Anode Circuit; Distortion; Howling; Inductive Coupling; etc.

An easily constructed set incorporating reaction is shown in Fig. 1, and consists of a valve detector followed by a stage of low-frequency amplification. The reaction coil is wound on a ball variometer rotor which is capable of a turning motion inside a tapped inductance which, with a variable condenser, forms the aerial tuning system. The control knob and dial are seen to the left of the set, while the condenser is operated by a similar knob and dial to the right. Between these controls are situated the switch for the aerial tuning and a control knob for the filament resistance. The latter regulates the low-tension supply to both detector and low-frequency valve.

For ease of construction, a baseboard is secured to the bottom of the ebonite panel to which the two valve holders, grid leak and condenser, and the transformer are fitted. This allows for wiring up the set quite independently of the cabinet, into which the set may be fixed when it is working satisfactorily.

The cabinet, which may be constructed from any well-seasoned wood, is a box, and takes a panel measuring 12 in. long and $7\frac{1}{2}$ in. high. These are inside measurements, and allow of any thickness of wood to be used without throwing out the size of the panel. The internal width of the cabinet is 7 in. The base overlaps the sides of the cabinet by $\frac{3}{4}$ in. at each side, and is fitted with an ornamental moulding. The moulding is mitred at the ends and screwed, or glued and pinned, to the base from underneath.

This method was adopted in the construction of the cabinet illustrated in Fig. 1, and gives a very finished appearance to the work. Fillets of wood about $\frac{1}{4}$ in. in thickness and $\frac{1}{2}$ in. in depth are screwed to the inside of the top and sides of the cabinet, and form the means for attachment of the panel. The depth at which the fillets are placed is dependent upon the thickness of the ebonite used. They should be placed so that the front edge of the cabinet comes flush with the panel.

The panel is cut from $\frac{3}{16}$ in. or $\frac{1}{4}$ in. ebonite to the sizes shown in Fig. 7. This diagram gives dimensions for all holes, with the exception of those used in

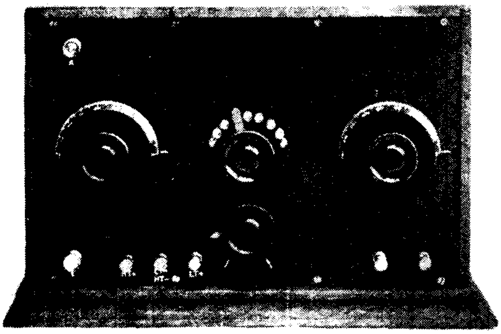


Fig. 1. Home-made reaction set, consisting of detector and stage of low frequency. The reaction coil is wound on a variometer rotor as in Fig. 3

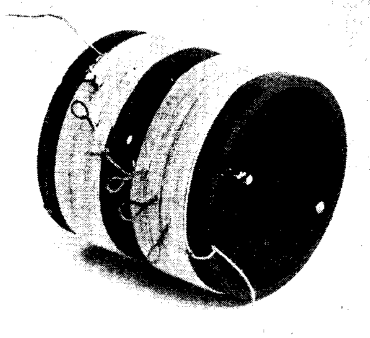


Fig. 2. Sixty turns of No. 24 D.C.C. wire, tapped at every tenth turn by loops, are used in this inductance

Fig. 3. How the rotor for reaction is wound. The same wire as for the inductance coil is used in making it

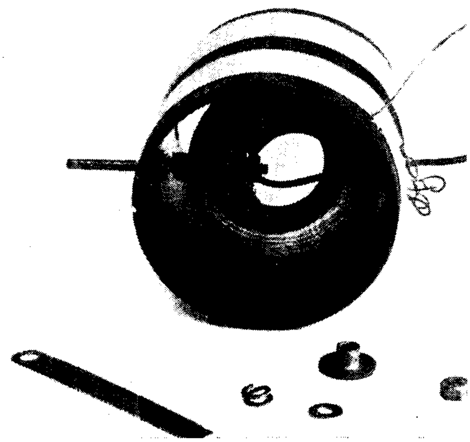


Fig. 4. Complete inductance and reaction unit. Panel bushes and other fittings which are required appear in the foreground

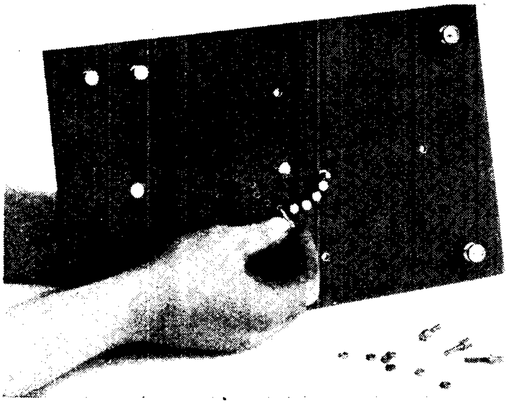


Fig. 5. How the switch studs should be fixed; they are held on the back of the panel by lock nuts, and the studs should be fitted in order

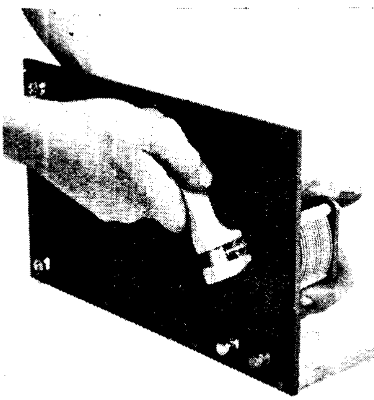
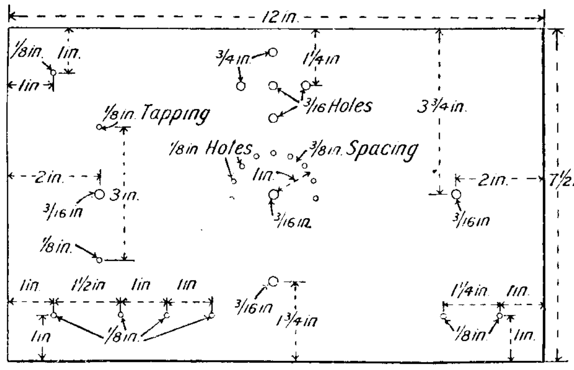


Fig. 6. The lock nut fixing condenser spindle should be carefully tightened while the condenser is held in position

STAGES IN THE EVOLUTION OF THE REACTION SET



LAY-OUT OF REACTION SET

Fig. 7. Before he proceeds to the actual construction of the reaction set described in these pages, the amateur should study these dimensions for the panel

mounting the variable condenser and the filament resistance. The holes for these two components cannot be given, as they depend on the particular piece of apparatus purchased. The spindle holes for these are given, however, and may be increased in size as required.

The tapped inductance is wound on a cylindrical ebonite former $3\frac{1}{2}$ in. in diameter and $3\frac{1}{2}$ in. in length. A hole of $\frac{3}{16}$ in. diameter is drilled centrally, and extends through either side of the tube. One of these holes helps to form a bearing for the rotor spindle, while a flexible insulated wire is passed through the other and connects to the rotor windings. Two $\frac{1}{8}$ in. holes are required to support the inductance former, and are drilled at each edge of the tube so that they fall in line with the rotor spindle hole. This line is at right angles to the edge of the inductance former.

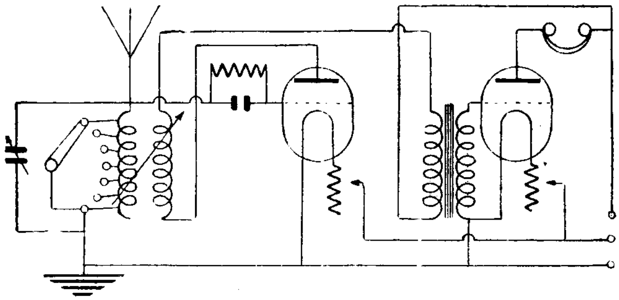
The former is wound with 60 turns of No. 24 D.C.C. wire. Winding is commenced $\frac{3}{8}$ in. from one edge, and tappings are taken from every tenth turn. A good method of making the tappings is to form a small loop where the tap is required, and to twist it round a few times. The winding is then continued until another tap is required, when the same operation is performed. When three tappings of 10 turns have been put on, the wire is taken to the other side of the rotor spindle hole, and is then continued at a distance equalling that on the first side of the rotor spindle hole. The wound inductance is shown in Fig. 2. The loops forming the taps are untwisted to within two or three turns, and the insulation removed with a sharp knife. They are now twisted up tightly, and are ready for connexion to the switch studs.

The rotor is of $2\frac{1}{2}$ in. diameter, and if not already provided, a hole of $\frac{3}{16}$ in. diameter is drilled through the centre. The rotor is wound with 28 turns on each half, the same wire being used as was wound on the inductance. Care should be taken that the wire runs in the same direction on each half of the rotor, or no reactive effect will be obtained. Fig. 3 illustrates the method of holding the rotor during the winding process.

The spindle of the rotor consists of a $2\frac{1}{2}$ in. length of 2 B.A. screwed rod, commonly known as stemming. One end is inserted in the spindle hole in the inductance former and a 2 B.A. flat washer fitted over the end. A spring washer now follows, after which another flat washer and a 2 B.A. locking nut are added in the order given. The rotor is now put inside the inductance, and turned until the end of the spindle meets the spindle hole in the rotor. The spindle is rotated until sufficient is showing inside the rotor to permit a flat washer and a locking nut to be fitted. Either end of the rotor winding is wound round the spindle between the rotor itself and the flat washer, after which the inside nut is tightened up. The remaining free end of the rotor winding is soldered to a short length of flexible wire passed through the central hole in the inductance former and the rotor.

This unit is now completed, and may be laid aside, ready for attachment to the panel. It is shown in Fig. 4, with the connecting strip, panel bush and smaller fittings in the foreground. The connecting strip, by which contact with one side of the rotor is made, consists of a 2 in. strip of thin sheet brass, cut to a width of $\frac{3}{8}$ in. A $\frac{3}{16}$ in. hole is drilled at one end, through which the rotor spindle is passed when mounting the unit.

The switch studs and the variable condenser are now assembled. In order to enable the former to be securely fixed, the method shown in Fig. 5 is recommended. In this method, fixing the studs and stop pegs is commenced at one end of the set of holes, each stud being rigidly fixed before proceeding to the next.



WIRING OF THE REACTION SET

Fig. 8. As some little difficulty may be experienced in the wiring of this set, it may be found advisable to begin with the aerial tuning circuit, proceeding afterwards in stages

At this stage the tapped inductance and rotor may be assembled. Before the spindle is inserted in the hole in the panel, a spring washer, a flat washer, and a brass strip are fitted over the end of the spindle in the order mentioned. The inductance is fixed to the panel by two No. 4 B.A. screws passed through holes already drilled to receive them. The inductance will not go right up to the panel, owing to the washers and the brass strip on the spindle. It is therefore packed up with one or two larger nuts or washers, which come between the inside of the panel and the outside of the inductance. The heads of the screws are to the inside of the inductance, and may now be screwed up firmly, as shown in Fig. 9.

The variable condenser is of the type having a central fixing, and is entirely held by a single nut screwed to the outside of the spindle bush, which has a threaded exterior. While turning the nut up tightly, the other hand grips the condenser to prevent its turning, as is shown in Fig. 6.

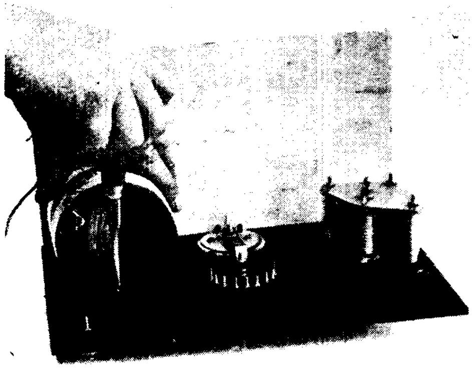


Fig. 9. Washers and nuts prevent the inductance from touching the panel

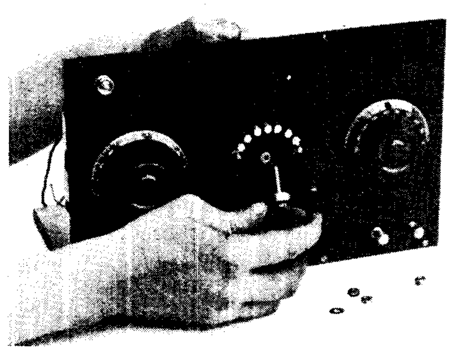


Fig. 10. The assembly of the switch contact arm and spindle on panel is shown

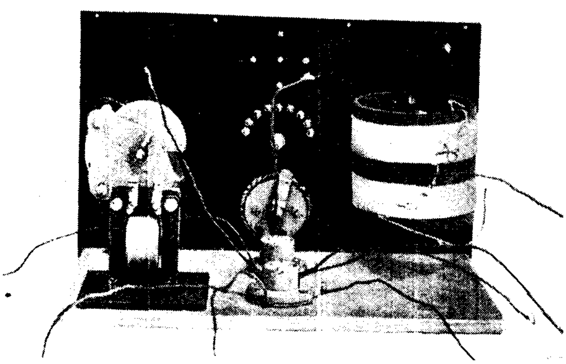


Fig. 11. Valve holders are assembled on the baseboard over thin disks of ebonite

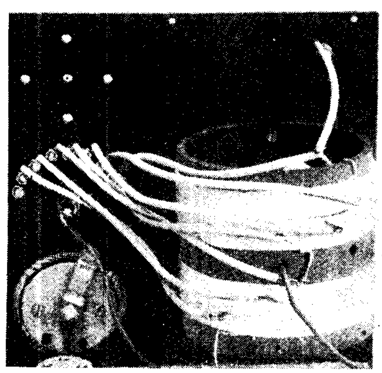


Fig. 12. Rubber-insulated wires connect inductance tappings to switch contacts

STRUCTURAL DETAILS OF THE REACTION SET

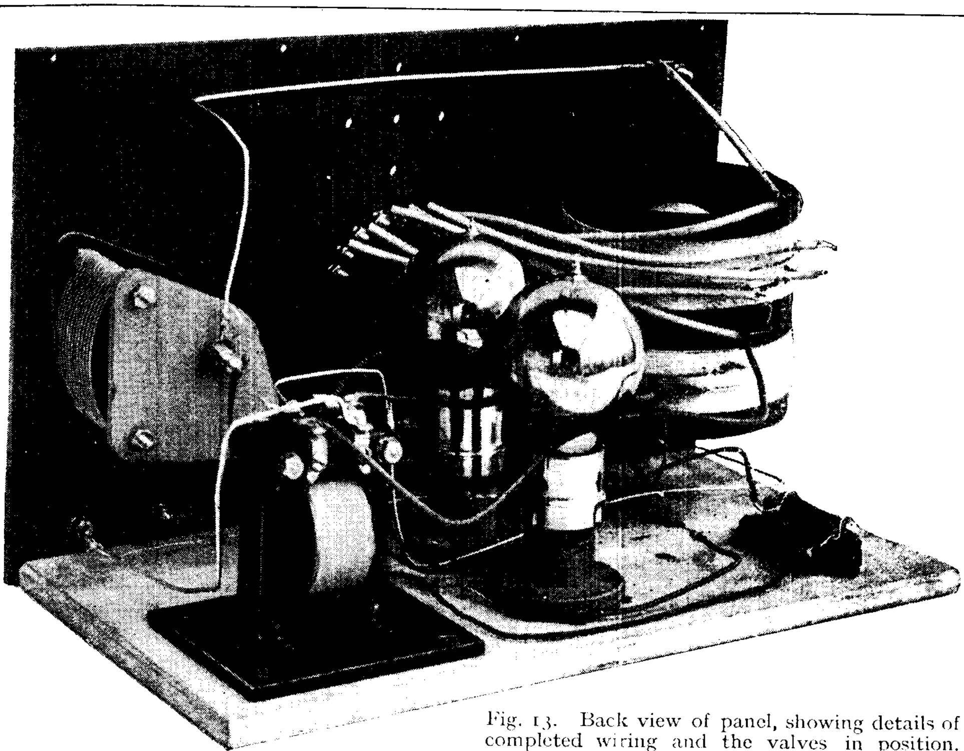


Fig. 13. Back view of panel, showing details of completed wiring and the valves in position. Note how the inductance leads are protected with systoflex

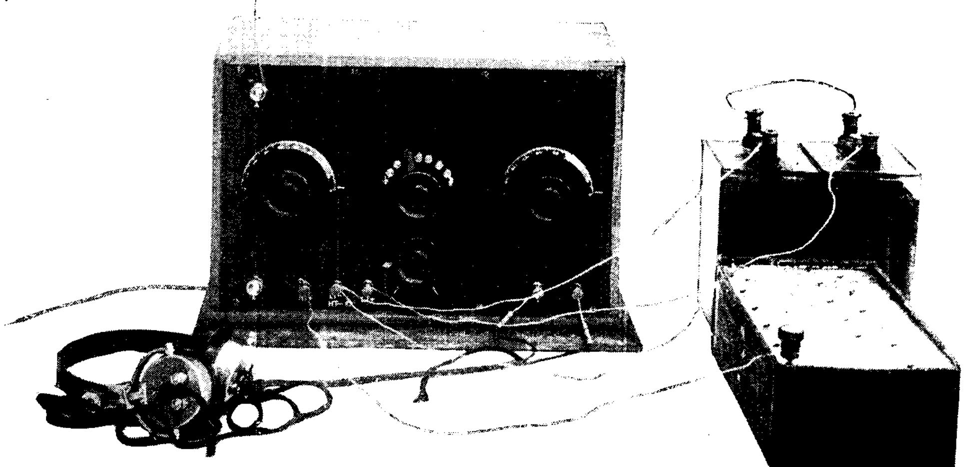


Fig. 14. Above is shown the reaction set entirely completed. High-tension battery and low-tension accumulator are linked up and telephones connected ready for use

LAST STAGES IN THE MAKING OF THE SET

The contact arm and spindle of the switch are now made and assembled as shown in Fig. 10. The correct pressure of the arm on the studs is made by a spring washer and two locking nuts fitted to the spindle on the inside.

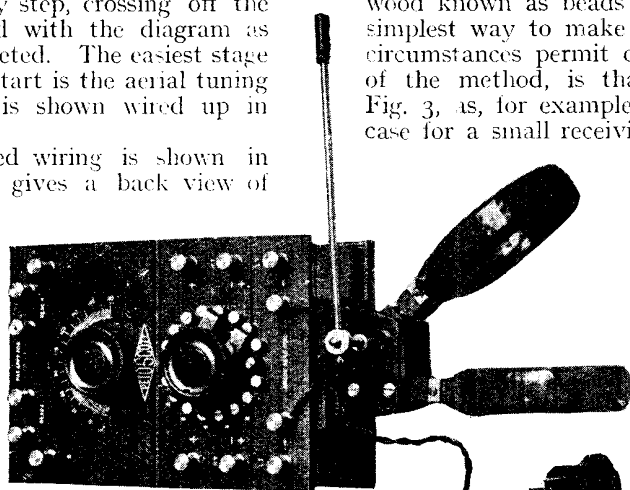
The valve holders are of the flanged type, and are screwed to the base. To allow this to be done the legs are cut off flush with the underside of the valve holder, and short connecting wires soldered to each. A disk of thin ebonite is now cut to the size of the valve holder flange and drilled corresponding to the fixing holes in the flange. Fig. 11 shows the position of the valve holders on the baseboard, where it will be seen that they are in line behind the filament resistance.

The low-frequency transformer is situated behind the tuning condenser, and is mounted on a small ebonite base. Any good quality iron-core transformer will be found suitable. The tuning condenser should have a maximum capacity of ·0005 mfd.

The grid leak and condenser are placed on the baseboard to the rear of the tuning unit. The former has a resistance of 2 megohms and the latter a capacity of ·0003 mfd. This completes the assembly of the components, and the set is now ready to be wired up. The wiring diagram is given in Fig. 8. If difficulty is found with the wiring, a good plan is to wire the set step by step, crossing off the wires connected with the diagram as they are completed. The easiest stage with which to start is the aerial tuning circuit, which is shown wired up in Fig. 12.

The completed wiring is shown in Fig. 13, which gives a back view of the completed instrument with valves in position.

A front view of the set in operation is illustrated in Fig. 14, where it is seen connected up to the batteries, aerial and earth terminals, and telephones.



REACTODE UNIT
A tuned-anode circuit is used here, with a switch for changing circuits quickly
Courtesy Peto-Scott Co., Ltd.

REACTODE UNIT. The illustration shows a type of reaction-capacity unit made specially for use in the Peto-Scott unit system. It is a form of tuned-anode circuit, but with the addition of a switch to allow different reaction arrangements to be quickly altered. The knob at the top of the instrument controls the tuning condenser. Below this is the switch, which enables a total number of six changes of circuit to be made. This switch is connected with the coils shown at the front of the cabinet. One of these is the anode coil and the other a reaction coil. The plug shown to the left of the instrument, attached to the flexible lead, is intended to be plugged into the preceding unit. It is used to convert that unit from a transformer-coupled high-frequency amplifier into a tuned-anode amplifier. *See* Capacity Reaction.

REBATE AND REBATE PLANES. A rebate is a long, narrow depression formed by cutting away one edge of the material, usually wood. The making of rebates for joints is a matter that will have to be dealt with by most experimenters who make wireless cabinets at home. A commonly used application of the rebate is illustrated in Fig. 1, and shows the frame of a door for a wireless cabinet, the inner edges rebated, and a panel fitted into the recess very much in the same way as a picture into a picture frame. The panel is fixed into the rebate by thin slips of wood known as beads or fillets. The simplest way to make a rebate, when circumstances permit of the adoption of the method, is that illustrated in Fig. 3, as, for example, the base of a case for a small receiving set. In this example two pieces of wood are used, with a combined thickness equal to that required for the base.

The lower of these pieces is made about ½ in. larger all round than the upper piece, the two are glued and screwed together, and the result is a practical rebated baseboard. Another application of a simple rebated joint is shown in Fig. 2, as applied to the corner of a case or box. The rebate is in this case simply sawn out of the edge of one of the parts with the aid of a tenon saw, and the joint made perfect by careful use of a chisel. Such joints are secured by glue, screws or nails.

When a small circular saw is available, the rebates can be sawn out by adjusting the table to such a height that the saw

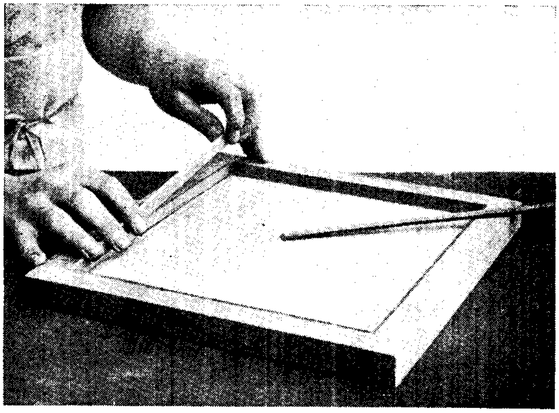


Fig. 1. The process of recessing known as rebating is here seen applied to the door frame of a wireless cabinet in a manner somewhat analogous to picture framing

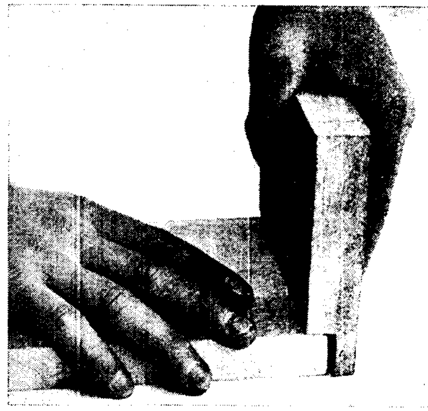
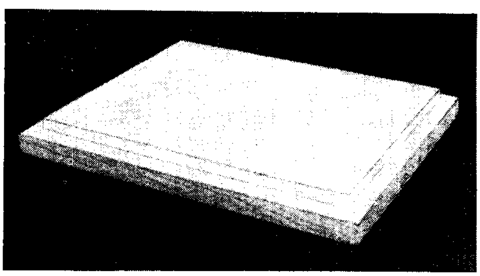


Fig. 2. Here is illustrated the application of a simple rebated joint such as might be used for the corner of a box

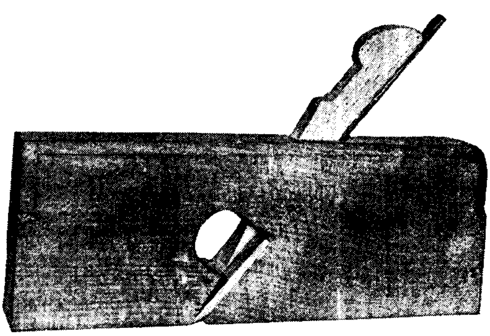
REBATING APPLIED TO CARPENTRY FOR WIRELESS PURPOSES

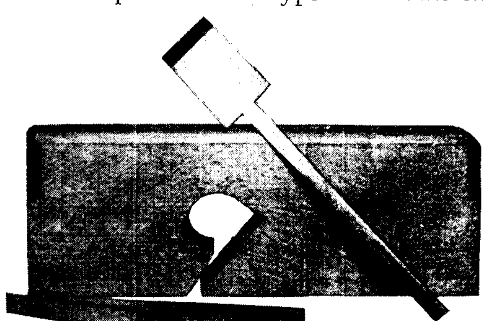
will cut only part of the way through the wood, and at the requisite distance from the edge. Another cut is then taken at right angles to the first, thus cutting out a small rectangular strip of wood. The step or shoulder is then cleaned up with a special plane known as a rebate plane.

There are many types of rebate plane, but the pattern illustrated in Fig. 4 is that commonly used, and gives quite good results. The plane consists of three pieces: the wooden body, made of hardwood, such as beech; the cutting iron, usually from $\frac{3}{8}$ in. to $1\frac{1}{4}$ in. wide, and the wedge which fixes it in place. An opening or mouth is cut across the body for the escape of the chips, and the iron rests upon the sloping back face of the body. The iron, shown removed in Fig. 5, is broad at the cutting part and narrow in the shank, as it has to pass through the body from the bottom upwards, and is held securely in the hole by the wooden wedge.



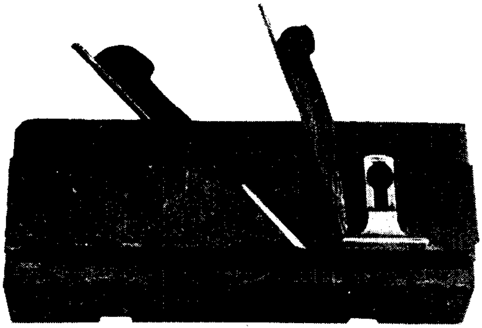
Other similarly shaped planes have the iron set at an angle across the body, and are known as skew-mouth rebate planes. These planes are chiefly used for cleaning up the rebate after it has been roughly cut with a saw, or by other means. When a plane is needed actually to plane away the material to form a rebate, a pattern known as a moving fillister is employed. An example of this type is shown in





REBATE PLANES FOR USE IN WIRELESS CONSTRUCTION

Fig. 3 (top, left) shows a built-up base with rebated edges. In Fig. 4 (left) is seen the ordinary type of rebate plane, while Fig. 5 (right) illustrates the same tool with iron and wedge removed. Notice the unconventional shape of the iron



MOVING FILLISTER PLANE

Fig. 6. The depth of the rebate is regulated in this tool by an adjustable vertical brass fence controlled by a set-screw

Fig. 6. It has an iron and mouth similar to the foregoing, but in addition an adjustable piece of wood called a fence attached to the bottom or sole of the plane. This is used to regulate the width of the rebate. The adjustable vertical fence, made of brass and controlled by a set-screw, provides for the control of the depth of the rebate; and to ensure a clean cut a small thin cutter blade secured with a small wedge is located at the front of the cutting iron. The use of such a plane is clearly illustrated in Fig. 8: the work is securely clamped to the bench and the plane worked along the edge until the rebate is deep enough.

When a small amount of work has to be done, or the actual size of the rebate is small and a fillister is not available, one way to overcome the difficulty is to use a cutting gauge for the cutting out of the rebate. The cutting gauge is a commonly used instrument, and is shown in Fig. 7 in the first stage of the making of a rebate by this method. The cutting iron on the stem of the gauge is adjusted to the depth and breadth of the desired rebate and secured with the wedge.

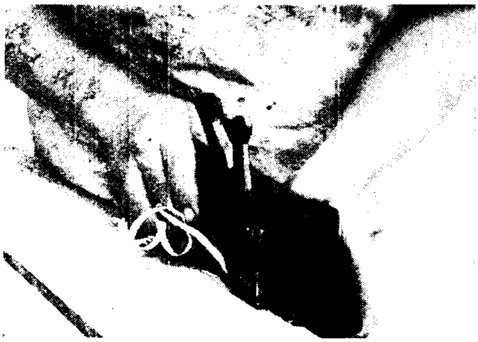
The face of the stock is then pressed against the edge of the work, and the instrument run along the wood from end to end until a thin slit is made in it. The wood is then similarly operated on from the second face at right angles to the first, as shown in Fig. 9, thus removing a rectangular slip of wood. If the cutter be very sharp and the work be done gradually a good clean rebate is the result.

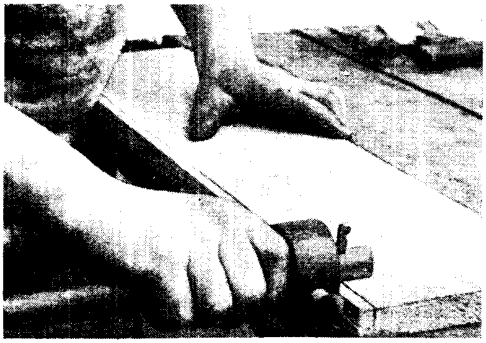
CUTTING GAUGE FOR REBATES

Fig. 7. The second stage in cutting the rebate. Slits at 90 degrees are cut with the gauge

If necessary, the faces of the rebate can afterwards be cleaned up with a sharp chisel held in a vertical manner and traversed along the face of the rebate, but only just taking a fine shaving off at a time.

In wireless work rebates should be planned so that the ends of any work that have to be rebated do not show the recess. Where possible, accomplish this by leaving a portion of the wood solid at the end of the rebate, or by stopping it with a small slip of wood exhibiting similar grain to the main part of the work. Other ways are to cut a recess with a chisel a little distance from the end of the wood, and to work the rebate between this and the other end of the work. *See* Plane.





STAGES IN THE MAKING OF A REBATE

Fig. 8. Using a moving fillister plane in making a rebate in a long piece of timber. Fig. 9 (right) illustrates the use of the cutting gauge in the first stage of the making of the rebate

RECEIVING SETS: HOW TO CHOOSE THEM

Practical Advice on the Selection and Construction of Receivers for all Purposes

Here is given a brief outline of the various kinds of receiving sets which are available for the wireless enthusiast, and some account of the principles underlying the amateur's choice. He should also consult the many articles in this Encyclopedia dealing with the making of receiving sets, as Amplifiers; Crystal Receivers; Frame Aerial; Hanging Set, etc.

A receiving set is a piece of apparatus comprising everything necessary to intercept signals transmitted by wireless and translate them into audible messages.

It may be a simple or very elaborate apparatus. Its size, type and design are governed by a variety of factors, the first being the purpose for which it is required. For example, one form of receiving set may be needed for high-speed commercial work dealing exclusively with spark signals or on the Morse code system. Others are limited to reception of speech and music broadcast from near-by stations.

The amateur is mostly concerned with the reception of telephony in the form of speech and music, and for other reasons, such receiving sets being dealt with at greater length in this Encyclopedia under their respective headings. Whatever the nature and purpose of the receiving set, it must comprise certain essential features.

Aerial and Earth Connexions

One is the addition of an energy collector, generally in the form of an aerial and earth connexion, but may consist merely of a few turns of wire on a light wooden framework, then known as a frame aerial or loop. Alternatively the set may work merely with an earth connexion, or even pick up signals with no other energy collector than the wires with which the set itself is wired. Often, however, an exterior aerial is used to collect the energy radiated from the transmitting station. The connexions from the aerial and earth are brought to the receiving set.

The first requirement in a receiving set is some means for tuning the set to make it capable of dealing with the signals at a particular wave-length on which the particular station which it is desired to hear is working. Common forms of such tuning elements comprise a coil of wire, known as an inductance (*q.v.*), and the capacity-coupled form of variable or moving condenser (*q.v.*). Connexions are then made from the tuning element to the receiving set, to the rectifier or detector. This may either be a crystal (*q.v.*) or a detector valve (*q.v.*). Both perform essentially the same function, to rectify the current pulsations and pass them on to the telephones. These render the electric current pulsations in the set audible to the human ear in the form of speech or music, or the familiar buzz of Morse or spark signals.

When a crystal detector is used in a receiving set, no additional source of energy is usually needed for reception over short distances. When a valve detector is used in a receiving set, it must be independently energized from two separate batteries, known respectively as the A and B or high- and low-tension batteries. Their function in the set is primarily to energize the valve.

Innumerable adaptations and modifications are necessary for the reception of the various forms of transmitted signals, all of which are dealt with under their separate headings in this Encyclopedia. For example, any set is capable of picking up spark signals, but for the reception of continuous wave calls an oscillator or some method of setting the receiving set in a state known as oscillation is needed. Customarily, a receiving set is mounted in a case or cabinet of some kind to render it a self-contained unit, except for the addition of the aerial and earth connexions and the local batteries.

Limits to the Amateur's Choice

The choice of a receiving set is a matter that calls for considerable thought if ultimate complete satisfaction is to result. There are many types of receiving set which vary as regards their price, range, and ability to give renderings of the desired signals. The amateur is practically limited to the reception of ordinary broadcast or telephony signals in the form transmitted from the broadcasting company's stations. Consequently, unless it is particularly desired to listen to signals transmitted by spark stations, or those sent out by ship and shore stations working on the Morse code, the choice is limited to those sets capable of giving reasonably good production of speech and music

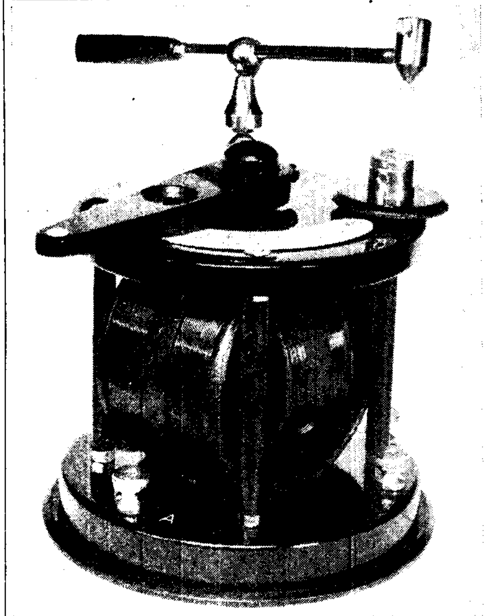


Fig. 1. The McMichael crystal set provides efficient reception inside a radius of 10 to 15 miles from a broadcasting station

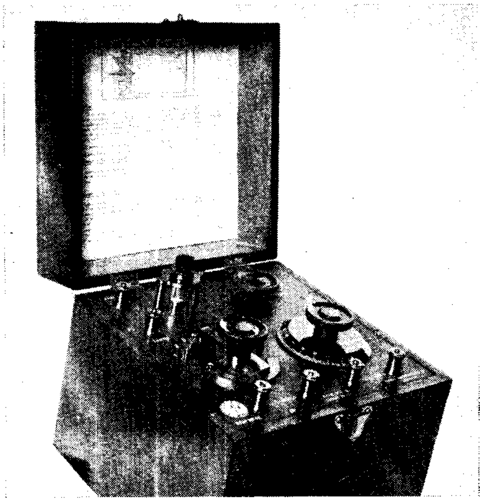


Fig. 2. H.F. or L.F. amplifiers may successfully be used to increase the signal range of the Radio Instruments Co.'s crystal set

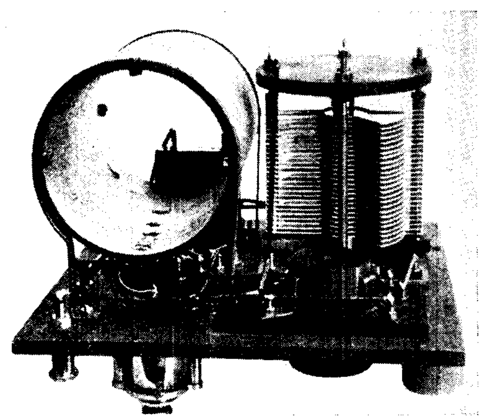


Fig. 3. Interior of set in Fig. 2, showing tapped inductance and condenser, which form the tuning system of the set

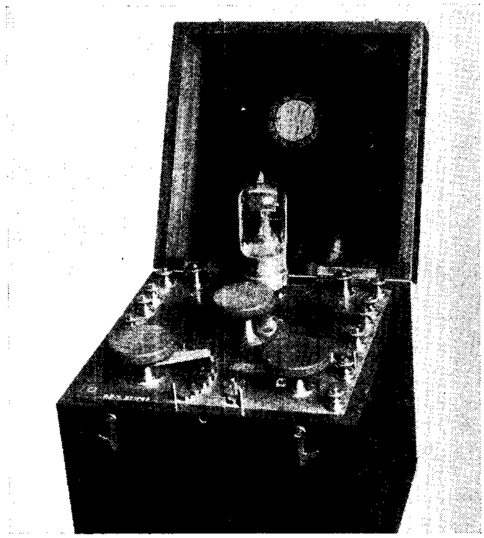


Fig. 4. Single-valve set by Economic Electric Co. suitable for reception up to 30 miles from the broadcasting station

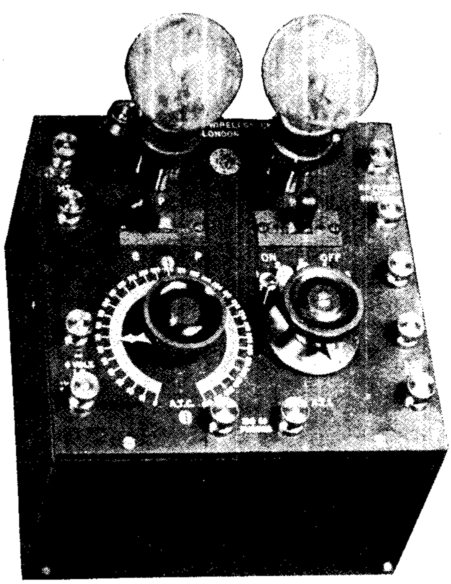
SIMPLE RECEIVING SETS FOR THE BEGINNER

Most of these sets are quite capable of picking up the other signals should it be desired to do so.

The next item, perhaps, is that of the cost of the set. This may vary from a matter of only a few shillings upwards to £100 or more, and is therefore a matter for purely individual consideration; but it is reasonably certain that the higher the price paid the better the workmanship and finish and the greater the care expended upon the set, and therefore the greater the likelihood that it will give the desired results.

The next item for consideration is the proximity or otherwise to a broadcasting station. When there is a station regularly transmitting within a distance of 10 to 12 miles, a simple crystal receiving set such as that in Fig. 1 should be adequate for ordinary headphone reception. By headphone reception is meant that the signals are sufficiently strong to actuate properly one or two pairs of headphones, but not strong enough to operate a loud speaker. Such a set would, however, be practically limited to reception from one station only. Should it be desired to listen to more than the local station, two courses are open. Either a high-frequency amplifier may be added to the crystal receiving set to increase its range, or a low-frequency amplifier added to it, or to the previous combination, to increase the strength of the signals, or a single or multi-valve set may be purchased, which would be powerful enough to pick up the desired stations with sufficient strength.

The first plan has an advantage for the pure beginner, as the experience gained with the crystal set gives a certain degree of familiarity with the working of the receiver and the peculiarities associated with its tuning. The addition of an amplifier to a crystal set is not as a rule satisfactory unless the crystal set itself is of high-grade construction with a reasonably selective tuning system; for example, incorporating a tapped inductance and variable condenser, as in Figs. 2 and 3. By a selective tuning system is meant the ability to tune in one or more stations with sufficient sharpness entirely to cut out or eliminate the signals from any other stations.



TINGEY TWO-VALVE SET

Fig. 5. Within a reasonably close radius of the broadcasting station this set gives very good loud-speaker results

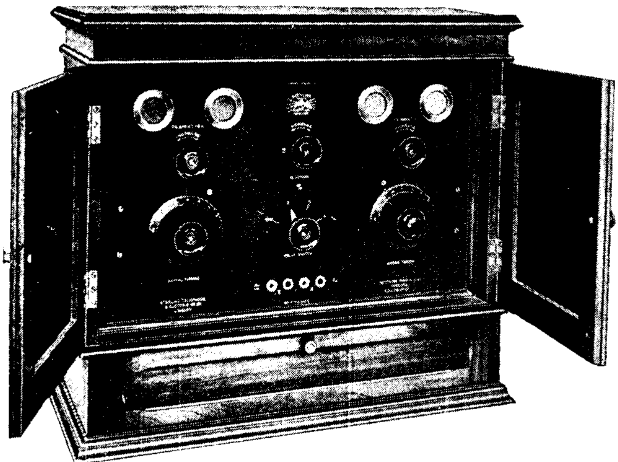
FELLOPHONE THREE-VALVE SET

Fig. 6. Practically all stations are picked up on the telephones, and near stations can be heard on the loud speaker

Very many crystal sets are not at all selective, for the reason that they are primarily intended for use in the vicinity of a broadcast station, and selective tuning is not necessary, as other stations cannot be heard. Consequently, to add amplification to a broad tuning set would merely amplify the signals from the local stations, and, although others at greater range could be heard, the local station could not properly be cut out, and the resulting interference would render reception from the longer distances unsatisfactory, if not impracticable. Sets can be purchased either complete with all accessories or as an independent instrument.

For distances up to about 30 miles or so from a broadcast station a single-valve set such as that in Fig. 4 would be satisfactory. The same remarks apply as regards selectivity and the addition of amplification as to the crystal set. Probably one of the most useful all-round types of receiving set is the two-valve embodying one stage of high-frequency amplification and one detector valve. Such a set should be capable of receiving several different broadcast stations, and as such sets usually embody at least two tunable circuits, the selectivity is greatly improved and any stations that can be picked up are usually to be heard without material interference from local stations. Such a set is practically limited to headphone reception.

If, on the other hand, it is desired to have loud-speaker results from a near-by station, within, say, a range of 25 miles



HANDSOME FOUR-VALVE CABINET

Fig. 7. The Sterling four-valve set is an exceedingly efficient instrument that will bring in all stations in Great Britain

or so, a two-valve set (an example is shown in Fig. 5), wherein the first valve acts as a detector and the second as a low-frequency amplifier, is necessary. One embodying a power valve is to be preferred, as the volume of sound is thereby considerably magnified, but the range of the set is not so high as the foregoing.

Supposing that it were desired to have both range and volume, as, for instance loud-speaker results from a near-by station and the ability to pick up practically any B.B.C. station as well as the transmissions from Paris, a three-valve set, of which one example is shown in Fig. 6, is to be preferred.

This should include one stage of high-frequency amplification, a detector valve, and one stage of low-frequency amplification. With such a set it should be possible to get good loud-speaker results from stations within a range of about 50 miles or so, and good headphone reception from the others. Owing to the greater range and power of such sets, it is more necessary that it should have a selective tuning system, a feature that can best be judged by actual trial or test with the set it is proposed to purchase.

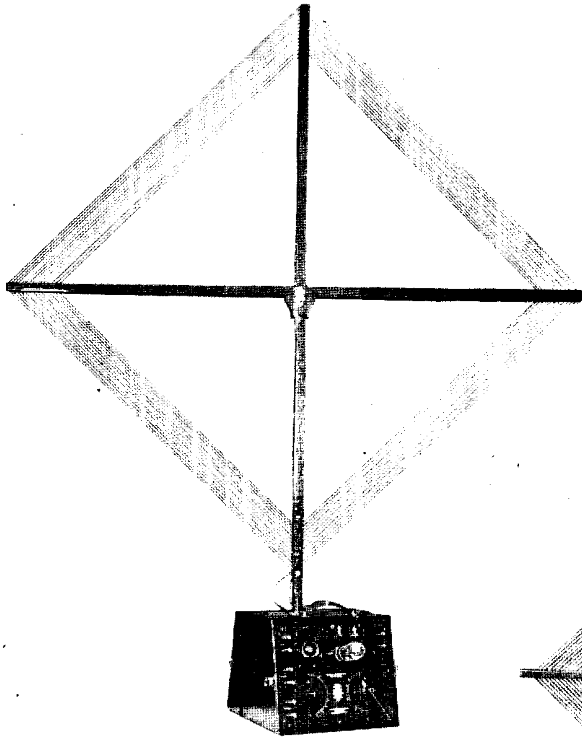
For practical results, tuning should be sufficiently sharp to cut out all sounds from any broadcast station other than that which it is desired to listen to at the moment. Where still greater range and power is needed, a four-valve set, exampled in Fig. 7, may be employed. Such sets, for a maximum range, would provide for three stages of high-frequency amplification and a detector valve. It would only be suitable for headphone reception, but should be capable of giving good results from all the broadcast stations in Great Britain, and also from many of the continental stations, and possibly, under favourable conditions, from the American stations.

A type of four-valve set that gives very good results in general use, as it possesses sufficient range to pick up all stations at headphone strength and a selection of three or four stations at loud-speaker strength, is one comprising one stage of high-frequency amplification, a detector valve, and two stages of low-frequency amplification, the last incorporating a power valve.

It is seldom that the amateur will need more than four valves, although sets may be made with five, six and seven valves, and are in extensive use, and generally capable of loud-speaker strength from all British broadcasting stations, most of the continental stations, and sometimes from American stations. They are, however, generally more critical in their tuning, and call for more skill and ability in handling than the simpler sets before mentioned.

It has been assumed that the foregoing sets employ the ordinary straightforward circuits, embodying high-frequency amplification either by transformer coupling, by the tuned anode, or on the reactance capacity coupled system, all of which are described in this Encyclopedia. Other sets, are, however, available which embody dual amplification principles and the reflex system. In these one valve performs the work of two.

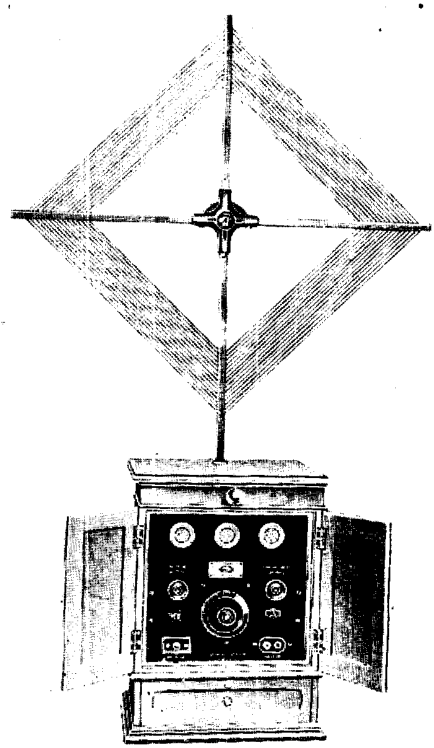
In many cases a crystal detector is used for rectification purposes, and the valve or valves for amplification. One example of a single-valve set with a dual amplification circuit, using a frame aerial, Fig. 8, picks up practically all the B.B.C. stations at headphone strength, and brings in local stations at loud-speaker strength. The frame aerial is made collapsible, as in Fig. 9, and the whole is readily portable. Some of these sets are more difficult to



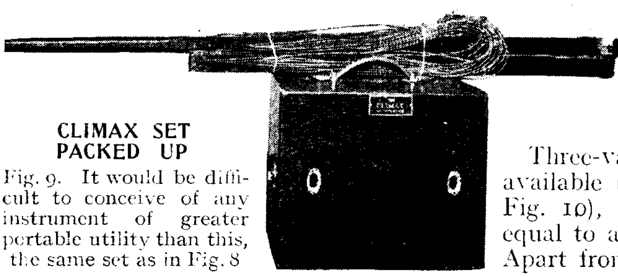
CLIMAX SET AND FRAME AERIAL
Fig. 8. A dual amplification circuit is employed in this most compact instrument

tune and handle than some of the straightforward circuits, but they possess the merits of economy, as fewer valves give an equivalent result, battery power is less, and consequently replacements of dry batteries and recharging accumulators is correspondingly reduced.

Similar principles are adapted for multi-valve sets. In one combination two valves are used, each of which performs the duties of the high- and low-frequency amplifier, and a crystal detector is used for rectification purposes. The results obtained, while seldom being quite equivalent to a four-valve set, are extremely good. Perhaps a fair average would be to take a two-valve dual amplification set as about equal to a three-valve straightforward circuit set. But this can only be in any case a general statement, as comparison between individual sets and the results obtained from them depend on the efficiency of the aerial, the quality of the workmanship on the set itself, and the skill with which it is handled. This latter point is important, as many experimenters fail to get the full value out of a circuit from not studying the tuning carefully.

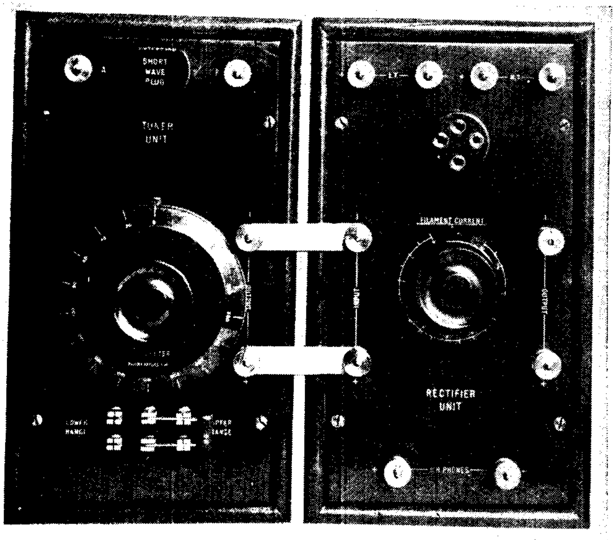


THREE-VALVE CABINET
Fig. 10. The Sterling "Threeflex," employing dual amplification, gives results equal to an ordinary four- or five-valve set



CLIMAX SET PACKED UP
Fig. 9. It would be difficult to conceive of any instrument of greater portable utility than this, the same set as in Fig. 8

Three-valve dual amplification sets are available (an example is illustrated in Fig. 10), and these give results about equal to a four- or five-valve normal set. Apart from the utility, range and power



BUILDING UP A SET BY UNITS

Fig. 11. Various stages of amplification can be added to the detector unit, as in this McMichael set

with doors to them, as in Fig. 12, are the best of all these kinds. Moreover, the doors can be closed and locked to prevent the set being tampered with.

When the set is intended for loud-speaker work a separate loud speaker is often used, but if at the outset it is desired to use a loud speaker, it is better to obtain a pattern in which the loud speaker is incorporated within the cabinet itself, such as in Fig. 13.

Of these some fine examples are on sale, and are worthy of being considered as musical instruments. The patterns illustrated are typical of this class. The Aristocrat receiver in Figs. 14 and 15 has the loud-speaker trumpet concealed behind a pierced panel covered with silk; folding doors cover the controls when the set is not in use, and a hinged panel, Fig. 15, provides for inspection of the interior.

The choice of this class of instrument should be to a large extent governed by the character of the furnishing of the room in which it will be used.

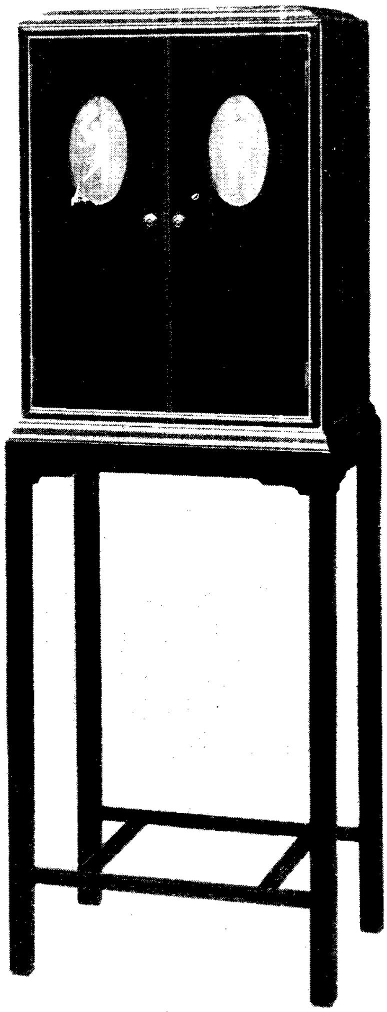
Should the reception desired be from many different stations during the evening's performance, a set that is quickly tunable is desirable, and also one that will tune with certainty. This is done in most sets by tabulating the various dial readings, and noting the positions of the various controls so that any station can be tuned in as quickly as possible. Some sets, such as the Polar seven-valve in Fig. 16, embody tuning scales which are calibrated. A movement of the control knobs actuates a pointer which moves across the calibrated scale, so that it is merely necessary to set the various controls so that the pointers are in corresponding positions, or at their proper setting on the tuning scales, to enable the desired stations or a required wave-length to be picked up. Other sets may incorporate a wave meter, which, by directly indicating the wave-length, enables the particular stations to be picked up without delay.

If the presence of an external aerial be objected to, a multi-valve set capable of giving good results on a frame or indoor

of the set, there are other points worthy of consideration. These include the general style and appearance of the set. This choice commences with the unit sets, of which a variety of types are on the market. In these each essential component, such as the tuning element, as in Fig. 11, and detector unit, and the various stages of amplification and so forth, are obtainable in the form of small self-contained units, which can be purchased independently. When properly connected one to the other they enable a variety of different circuits to be formed, and also enable the amateur to obtain progressively a multi-valve set by commencing first with the tuning unit and ordinary detector, and adding stages of amplification to it from time to time.

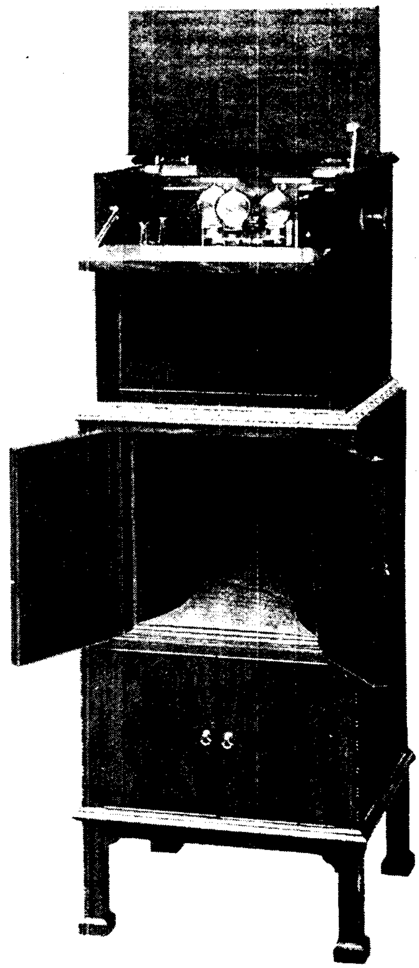
Necessarily, these sets occupy considerable space. Self-contained sets are preferable on this account, and those which are entirely enclosed with only the control knobs, switch handles, and the like exposed on the outside of the panel are to be preferred to the more open patterns, as the accumulation of dust and dirt upon the surface of the panel, particularly in the case of the horizontal panels, results in a loss of signal strength, and oftentimes in setting up parasitic or crackling noises in the headphones. Sets that embody a vertical panel or one slightly inclined are to be preferred, while those aerial should be chosen. Generally, such sets require at least three stages of high-frequency amplification, or their equivalent in a dual amplification circuit.

Apart from purchasing a ready-made or commercial set, which, of course, should be licensed for use by the British Broadcasting Company, the experimenter can obtain a constructor's licence from the Post Office and build up a set in his own workshop. This offers endless scope and provides a most fascinating hobby.



WIRELESS RECEPTION DE LUXE

Fig. 12. Hinged doors conceal the operating knobs and controls of this entirely enclosed Marconi four-valve set



THREE-VALVE MARCONI SET

Fig. 13. Incorporated in the cabinet of this three-valve set is a concealed loud speaker

In the pages of this Encyclopedia detailed instructions are given for the construction of all classes of receiving sets. The illustrations Figs. 17 to 19 show a home-made four-valve receiver constructed throughout by an amateur, with the exception of the purchase of a few commercial components. In this case tuning is effected with the aid of independent plug-in coils, which enable the ordinary broadcast stations to be heard. The changing of these coils for others of appropriate value allows the long-wave transmissions of the Eiffel Tower, as well as the Morse signals on the longer wavelengths, to be heard.

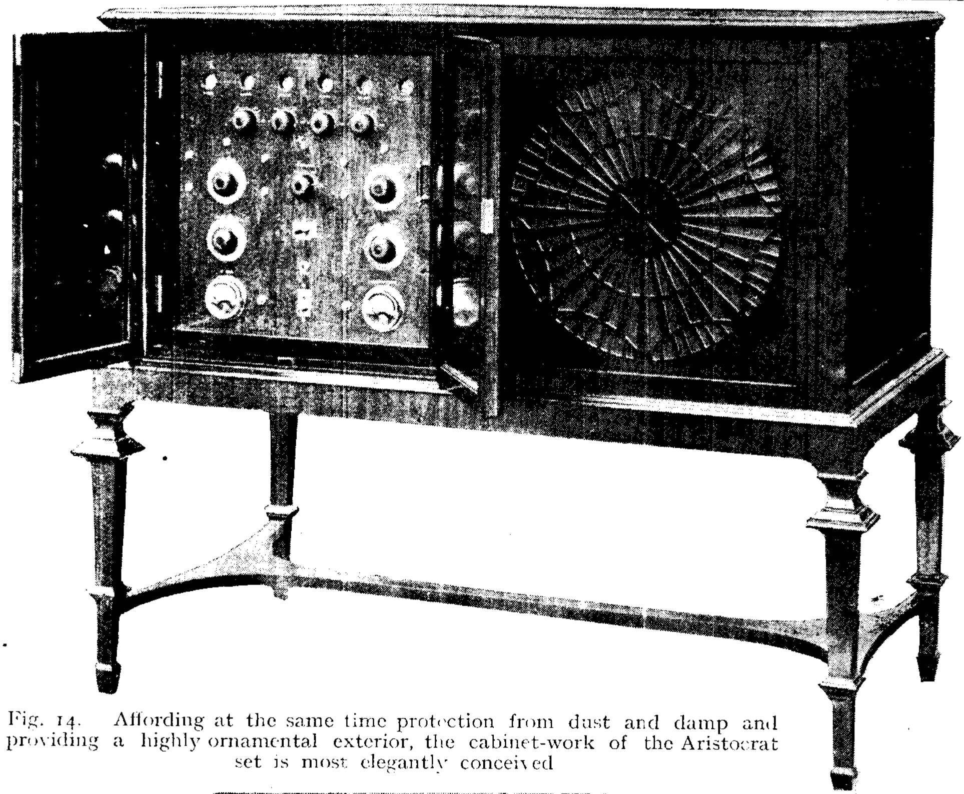


Fig. 14. Affording at the same time protection from dust and damp and providing a highly ornamental exterior, the cabinet-work of the Aristocrat set is most elegantly conceived

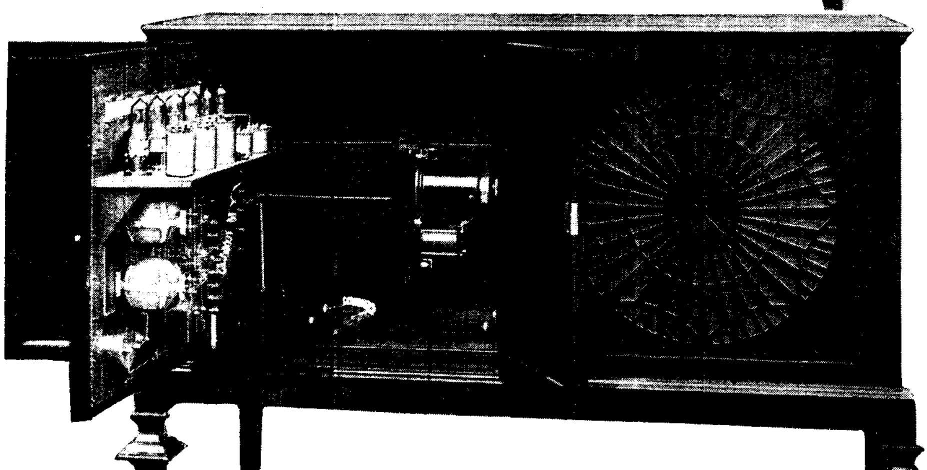


Fig. 15. Mounted as it is on hinges, the whole panel moves outward to allow of inspection of the interior of this receiving set at any moment

Courtesy General Radio Co., Ltd.

ARISTOCRAT SIX-VALVE SET AND LOUD SPEAKER

This feature is incorporated in many commercial sets, and should be borne in mind when making a choice should similar reception be desired. The circuit diagram for the amateur-made set is given in Fig. 20, and by comparing it with the various components and the internal views of the set some comprehension of the connexions and the details of the receiving set are obtainable.

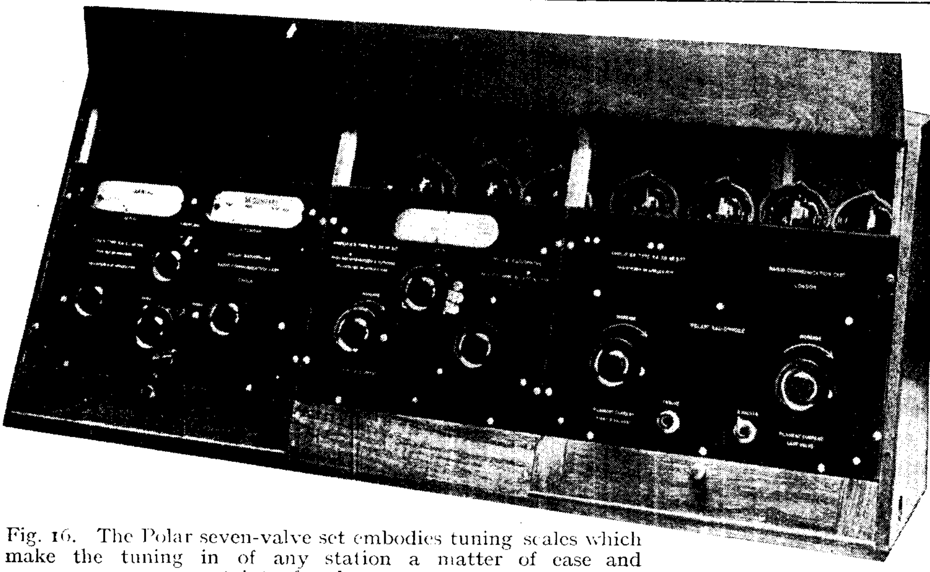


Fig. 16. The Polar seven-valve set embodies tuning scales which make the tuning in of any station a matter of ease and certainty for the amateur

Courtesy Radio Communication Co., Ltd.

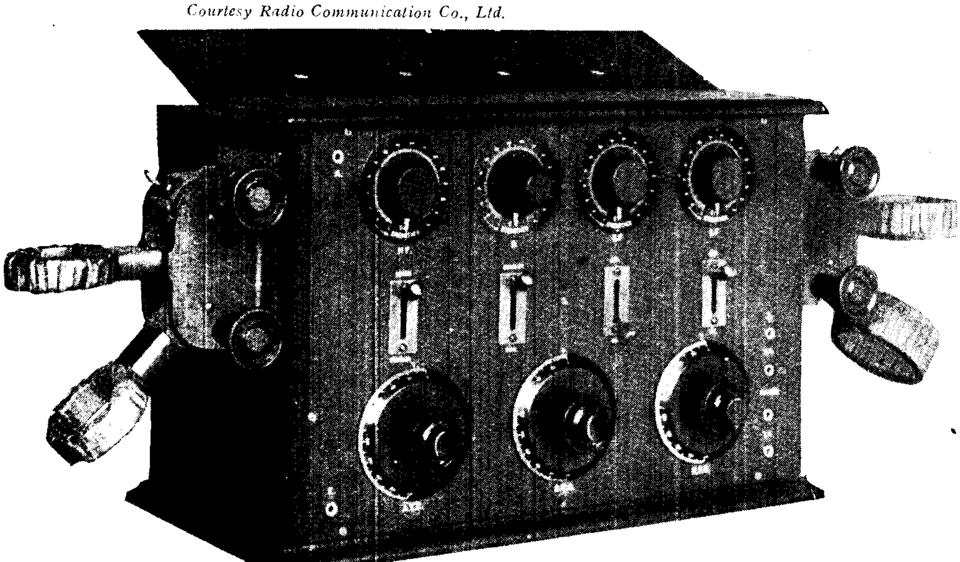


Fig. 17. A four-valve enclosed receiving set for home construction. Tuning coils are used to increase the wave-length range as required

FOUR- AND SEVEN-VALVE SETS FOR BROADCAST RECEPTION

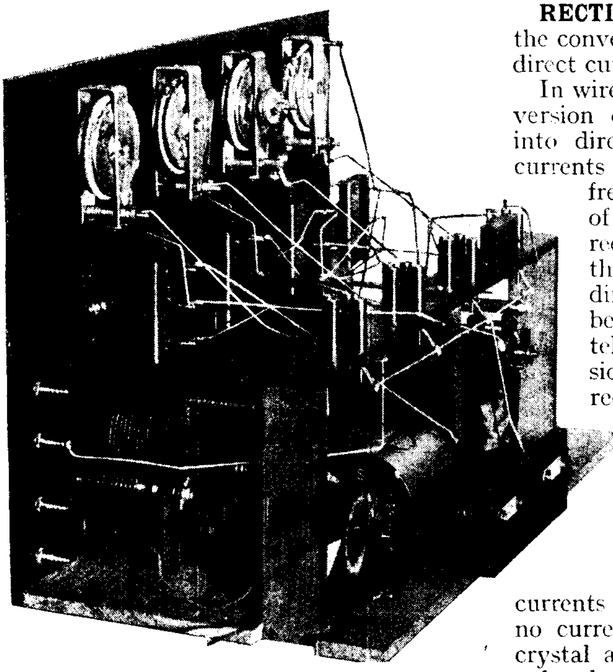
The purchaser of a commercial set should endeavour to listen on the set before completing the purchase. The home constructor should familiarize himself with reading the theoretical diagrams and choose circuits most likely to meet individual requirements. Thereafter he should build the set with as much care and ability as possible, adhering rigidly to the circuit selected and finishing it throughout in a proper manner. Finally, he should spend the time necessary in tuning the set to become thoroughly familiar with the inevitable peculiarities inherent in any receiving set. Until this be appreciated and understood no set will yield its full measure of enjoyment in the form of clear speech and the true tonal qualities of music and concerts, and the results will be disappointing.

RECTIFICATION. General term for the conversion of alternating current into direct current.

In wireless the term is used for the conversion of the high-frequency currents into direct currents. The alternating currents used in wireless have such a high frequency that they are incapable of working a telegraph or telephone receiver in the normal way, and they have to be converted into direct currents before signals can be read by the vibration of the telephone diaphragm. The conversion is carried out by means of a rectifier.

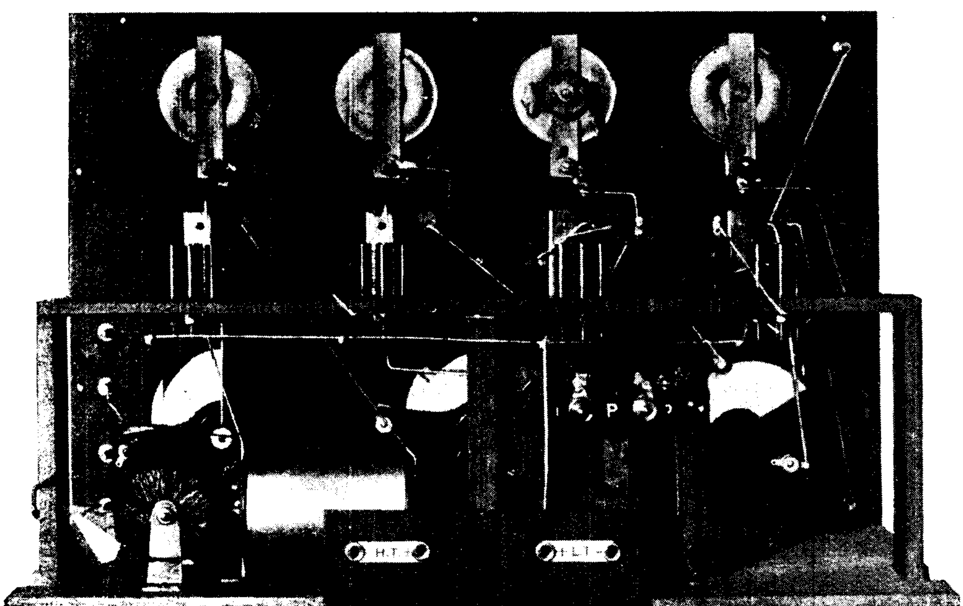
In wireless two general types of rectifiers are used, the crystal and the valve. The crystal detector has the property of allowing a much larger current to pass in one direction than in another. With the very feeble currents obtained in reception practically no current passes one way, so that the crystal acts as an ordinary air or water valve does, the current only being allowed to flow in one direction. The alternating current is thereby converted into direct current.

The same process takes place in the



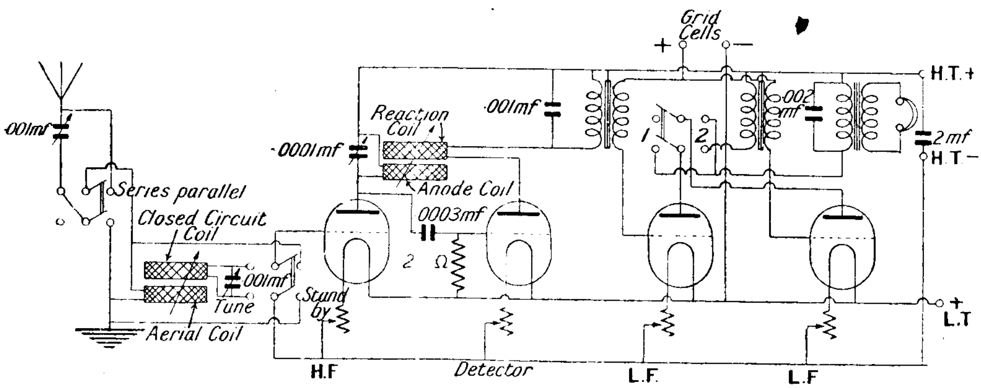
DETAILS OF THE AMATEUR-MADE SET

Fig. 18. Transformers, valve platform, switches and other details of the set in Fig. 17 are seen here. The construction of this efficient set may be carried out at home



REAR VIEW OF THE FOUR-VALVE PANEL

Fig. 19. A striking feature of this home-constructed instrument is the very neat way in which the components and wiring have been arranged



THEORETICAL CIRCUIT OF FOUR-VALVE SET

Fig. 20. The wiring of the set illustrated in Figs. 17, 18 and 19 is shown here

two- and three-electrode thermionic valve. The exact action is explained under the heading Valve, and the reader should also consult the entry Fleming Valve.

Alternating currents for power and lighting purposes and accumulator charging are rectified by special apparatus. The rectification of alternating currents for accumulator charging is explained under the heading Accumulator. *See* also Alternating Current; Crystal; Direct Current; Electrolytic Rectifier; Noden Valve; Tungar Rectifier; Valve.

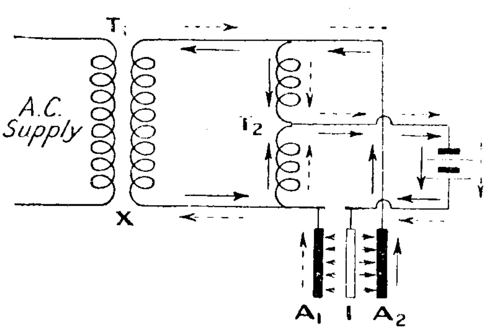
RECTIFIER. Any device for converting alternating current into direct current. In wireless, the term rectifier includes crystal detectors and the two-, three- and four-electrode valves. In alternating current work generally, alternating current is converted into direct current in one of the following ways: (1) By the rectifying commutator; (2) by the aluminium valve rectifier; (3) by the mercury vapour rectifier; (4) by the rotary or synchronous converter; (5) by the motor generator.

The rectifying commutator is a commutator driven at a speed synchronous with the alternating current supplied to its brushes, and it reverses the connexions of the armature windings as a whole. Alternate half-waves of the current are reversed from the alternator, so delivering a direct current to the receiver. This type of rectifier is only used for the rectification of comparatively small currents at fairly low pressure on account of the heavy sparking which occurs at the brushes at high voltages.

The aluminium valve rectifier is a chemical rectifier. It is an electrolytic cell which depends upon the property of aluminium electrodes to let electric current pass in one direction, when the aluminium electrode is the cathode, but not in the other. In page 16 is given a circuit diagram of the way four such cells are connected together for converting alternating current into direct current for charging an accumulator.

The figure shows the connexions for charging a battery or accumulator, using one cell only. The cell has two aluminium electrodes, A_1 and A_2, and one iron electrode, I. The current can flow in the cell from the iron electrode to either of the aluminium electrodes, but not from the aluminium electrodes to the iron electrode. The current in this latter direction is stopped by the formation of a thin insulating film of aluminium oxide over the aluminium plate. The electrolyte used is generally ammonium phosphate or sodium phosphate.

T_1 is the supply transformer. The secondary of this transformer is connected



ONE-CELL ALUMINIUM RECTIFIER

Thick arrows show the direction of the current when the terminal X is positive, and the dotted ones its direction when negative to the aluminium electrodes of the rectifier and is shunted by the auto-transformer T_2. This latter transformer is tapped at its middle point and connected to one terminal of the battery being charged. The other terminal of the battery is connected to the iron electrode of the rectifier.

The action is as follows, and for simplicity of explanation it is assumed that at the moment the terminal X of the secondary of the transformer is positive. The current attempts to flow from this terminal to the cell, but is prevented from going through the cell, since the current cannot go from the aluminium electrode to the iron one, as already explained. It passes therefore to the coil T_2 and out through the middle tapping to the accumulator, and through the latter to the iron plate of the rectifier, from there to the plate A_2, and up from there to the other terminal of the transformer secondary.

It will be noted that the tapping of the auto-transformer T_2 is at its middle point. The energy delivered to its lower half acting as a primary coil is transferred to its upper half by the transformer action, so that a direct pulsating current of twice the amperage of the current of either half of the coil is delivered to the accumulator, though the voltage is halved.

On the reversal of the alternating current the current follows the direction of the dotted arrows. The aluminium electrodes change over, A_1 becoming the active electrode instead of A_2, the electrodes alternating in activity with every alternation of current. But, as will be noticed, the direction of flow of current into the accumulator is unchanged.

This type of rectifier has the great advantage over others that it is cheap and simple, but it suffers from the disadvantage that it is not very efficient, being of the order of about fifty to sixty per cent, while the cell has a strong tendency to heat up, and should be kept continually cooled to give the best results.

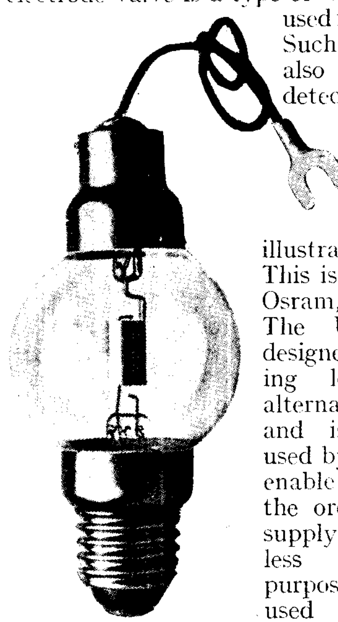
The mercury vapour rectifier works by means of an exhausted glass bulb, which is fitted with carbon electrodes and has a small quantity of mercury sealed in its base. Its action is more fully explained under the heading Mercury Valve Rectifier.

The fourth type of rectifier, the rotary or synchronous converter, is a machine for converting A.C. to D.C., or vice versa. It is chiefly used to convert polyphase alternating currents into direct currents on a large scale, and it has little interest to the wireless experimenter. It is a continuous current dynamo provided with slip rings at the opposite end of the shaft to the commutator. Current supplied to the commutator drives the machine as a motor. As the armature revolves in its magnetic field, A.C. current is generated and collected by the slip rings. Rotary converters are used on board ship in connexion with ships' transmitting sets, and fuller information on the subject will be found in Hawkhead and Dowsett's "Handbook for Wireless Telegraphists." Refer also to the heading Converter in this Encyclopedia.

The fifth way noted for obtaining direct current from alternating current is by means of the motor generator. For its action the reader is referred to the article on Generators in this Encyclopedia. *See also* Accumulator; Charging Board; Crystal; Electrolytic Rectifier; Noden Valve; Valve.

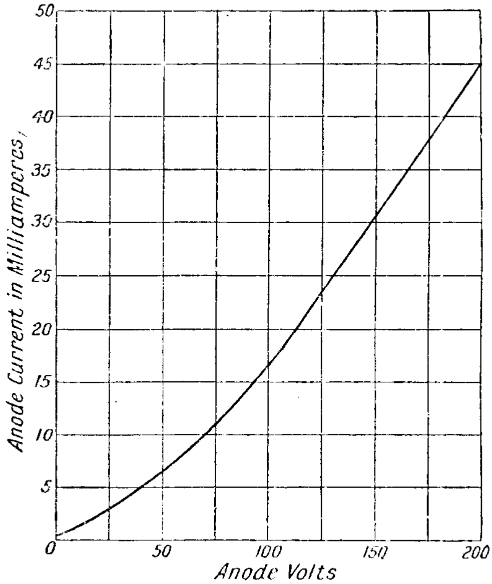
RECTIFYING VALVE. Name given to types of valves. One is the ordinary three-electrode valve, and the other is the two-electrode valve used for the rectification of alternating current. The Fleming two-electrode valve is a type of valve which is used for rectifying. Such valves may also be used as detector valves.

A typical two-electrode valve for low power is illustrated in Fig. 1. This is the Marconi-Osram, type U3. The U3 valve is designed for rectifying low-frequency alternating currents, and is frequently used by amateurs to enable them to use the ordinary house supply A.C. for wireless transmission purposes. When used for this, a smoothing circuit is necessary. It will be seen that the U3 valve has an Edison screw cap at one



U3 VALVE

Fig. 1. Two-electrode rectifying valve for low power. This may be used with the A.C. house current



AMPERAGE AND VOLTAGE CURVE

Fig. 2. Above is given the characteristic curve of the Marconi-Osram U3 rectifying valve

end, which fits into a standard socket. The other end has a plain brass cap with a flexible lead attached. This combination of contacts makes for convenience in fitting in a circuit.

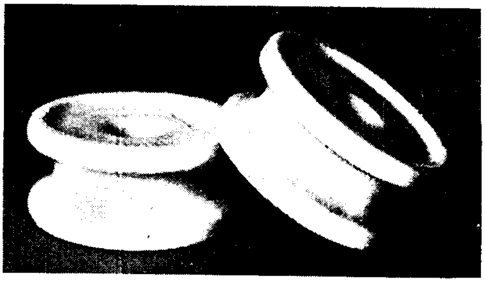
The filament is of the spiral type, which is said to make for better emission. It requires 5·5 volts and takes a current of 1·5 amperes. The total watts dissipated under normal conditions are 15, while an emission of 80 milliamperes is obtained. The impedance is approximately 4,500 ohms. Fig. 2 is a characteristic curve for this valve. *See* Valves for Transmission; Fleming Valve.

RED LEAD. Name given to a scarlet oxide of lead, obtained by heating finely divided white lead in a reverberatory furnace. Red lead is extensively used in wireless work, although its presence may not be particularly apparent. It forms one of the ingredients in the preparation of the paste with which accumulator plates are filled. While the plates are being formed, however, its properties undergo a change in the process.

Red lead also forms one of the constituents of many paints for the preservation of wood and metal structures used in wireless work. As, however, such paints have a metallic base, they are conductors of electricity, and should not be used under any conditions where they might cause loss of signal strength, or in some cases complete failure of the apparatus, owing to the path which they provide for leakage of current.

An effective use for red lead, purchased in the form of a tube, is as a means of making oil-tight joints between parts of machines. In this case the red lead is mixed with gold size or linseed oil, to render it paste-like in form, when it can be applied with a brush to the parts to be united.

REEL INSULATOR. Name given to a type of insulator characterized by its shape. In form it is circular in plan, and has a groove in the rim, as may be seen from the illustration. These insulators have a central hole, and are usually recessed on each flat face. The material mostly used in their manufacture is a form of china or porcelain, with a hard, glossy face. Their uses include the isolation of wooden and other bases from a wall or other support, and the insulation of aerial guy-wires. In this class of work one wire is spliced around the rim and the other passes through the central hole, and is spliced or whipped to prevent it pulling out. *See* Insulator.



CIRCULAR OR REEL INSULATORS

Circular insulators of the reel type are employed for insulating aerial guy-wires. They are both economical and effective in use

REFLECTION. In physics a phenomenon occurring in all kinds of wave motion. Like refraction (*q.v.*) it is most noticeable with a ray of light. If a ray of light strikes a reflecting surface at an angle it is bent back in a direction which can be determined by the two laws of reflection. These laws are: (1) The incident ray, that is, the original ray, the perpendicular to the surface and the reflected ray are each in the same plane; (2) the angle of reflection is equal to the angle of incidence.

Electric rays may be reflected in a way exactly similar to light waves. Hertz showed how electric waves could be reflected by a metal plate. This fact is becoming of increasing importance in the study of short waves, for by suitably arranged reflectors Marconi has shown that a beam of electric waves may be directed like the beam of a searchlight. This obviously leads to the immensely important result that secret wireless conversations are possible.

If a parabolic metal mirror is constructed and a Hertzian linear oscillator is placed on the focal line of the mirror, a beam of electric radiation may be projected parallel to the axis of the mirror, provided the dimensions of the mirror are not small compared with the wave-length. Unless such reflecting mirrors are to become unwieldy it is clear that the wave-lengths of the rays must be small; and in fact the experiments have been carried out with waves only a few metres in length. The dimensions of the mirror should be at least twice the wave-length, so with a wave-length of, say, only a dozen metres, the size of the mirror must be at least twenty-four metres. And the difficulty occurs that it is not easy to produce electro-magnetic waves of short length for wireless telephony.

The actual mirrors used for reflection are not solid metal ones, for not only would they be extremely heavy and difficult to construct, but they would be difficult to erect in position to withstand heavy winds. A number of wires placed so that they form a parabolic surface are used in place of the solid metal sheet, and these wires offer far fewer mechanical difficulties in erection, and are, of course, of much less weight. Moreover it is clear that they can be constructed of much greater dimensions with safety, so allowing longer waves to be used.

Many experiments have been carried out by C. S. Franklin, of Marconi's Wireless Telegraph Co., in connexion with the reflection of short wireless waves in this way. Such wireless beams have been directed over distances of a hundred miles between two definite stations, and those out of line between the stations have not been able to pick up the telephony. *See* Heaviside Layer ; Short Wave.

REFLEX RECEIVERS AND HOW TO BUILD THEM

Single and Multi-valve Sets Using the Dual Amplification Principle

Considerable economy in construction and upkeep of a receiving set can be achieved by the use of circuits in which each valve does the work of two, as described here. Detailed instructions for making both one-valve and three-valve receivers are given.
See also Crystal Receiver ; Dual Amplification ; Regeneration

A reflex receiver is a set in which the valve or valves used serve a double purpose in amplifying at both radio- and audio-frequency at the same time. This property of the thermionic valve has been known for a long time, but the inefficiency of the valve and coupling transformers did not allow this property of the valve to be utilized until comparatively recently.

It may be for this reason that the reflex receiver is still regarded by many as in a purely experimental state, and not a receiver that can be relied upon for successful reception.

This impression is not justified, however, for if the principles of this receiver are well understood and care taken in the construction and disposition of the components, extremely satisfactory results may be obtained.

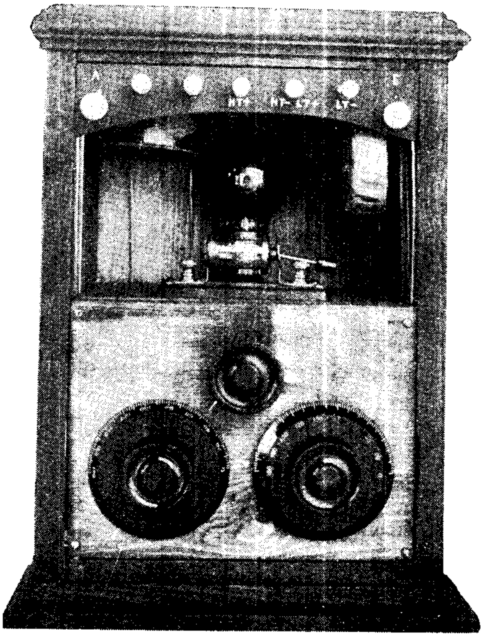
The attraction of the reflex receiver lies in its economy, both in first cost and in its upkeep, as half the number of valves are required to give the same results as a set where the valves serve only a single purpose.

In principle the reflex receiver is quite simple, and consists of applying to the grid of the valves currents of both radio- and audio-frequency, which are amplified in the same valve without interfering with each other. In effect, it will be seen that two superimposed currents operate within a single circuit.

The application of the reflex principle to a receiving circuit can be effected in a variety of different ways, but a valve used for a double purpose is restricted to amplification, a separate means being required for rectification. This may be effected by either a valve or a crystal.

A single-valve reflex receiver employing a crystal rectifier is shown in Fig. 1. Amplification by the valve is effected at both radio- and audio-frequency, the results being equivalent to those given by a straightforward two- or three-valve set.

The set shown in Fig. 1 gives a very good reception when it is in use within 100 miles of a broadcasting station, while stations within 25 miles are received so as to give good results on a loud speaker.



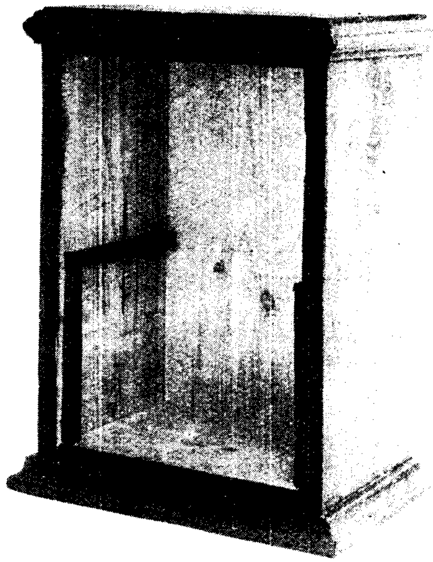
SIMPLE REFLEX RECEIVER

Fig. 1. Here is shown the completed single-valve reflex set. The instrument is capable of headphone reception within a radius of 100 miles

The circuit diagram for this receiver is shown in Fig. 8. The aerial oscillations impressed on the grid of the valve are amplified in the normal way in the tuned anode circuit. The amplified oscillations are now rectified in the crystal detector circuit. This circuit includes the primary of the low-frequency transformer, and the rectified pulses of current are induced at higher amplitude into the grid circuit, where they undergo the normal process of low-frequency amplification. These amplified current pulses actuate the telephones, which are in the anode circuit.

In the construction of this set a cabinet is required measuring $10\frac{1}{2}$ in. by $7\frac{1}{4}$ in. in height and width, while the depth from back to front is $5\frac{1}{2}$ in. These measurements are taken inside the case, and allow any thickness of timber to be used without throwing them out. An ornamental moulding is fixed to the top and bottom of the cabinet, and takes away from its otherwise somewhat plain appearance.

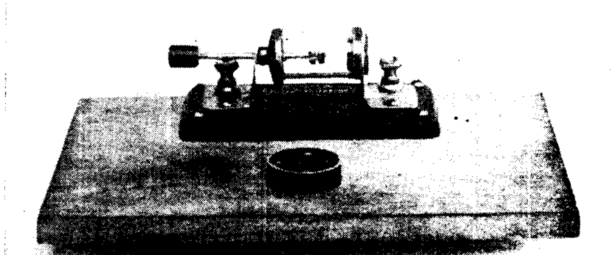
It will be seen from the illustration in Fig. 1 of the completed set that the top half of the cabinet is open and forms a receptacle for the valve and crystal detector and two plug-in honeycomb inductances. The two former components are mounted on a wooden panel screwed to fillets of wood 5 in. up from the base.



COMPLETED CABINET

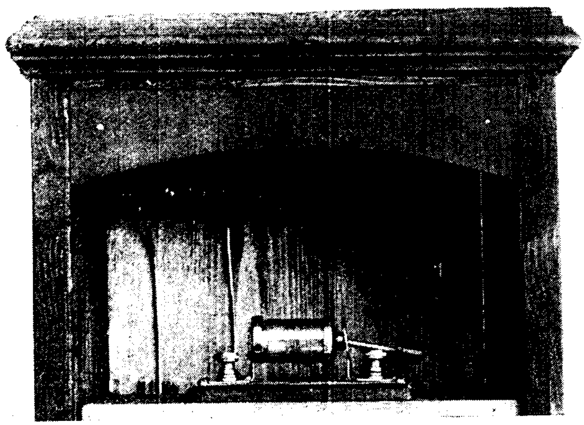
Fig. 2. The fillets seen on the sides of the cabinet support the valve platform and front panel

A flanged ebonite valve holder is employed, and secured to the inside of the platform with wood screws. A hole of suitable diameter is made in the platform through which the top of the valve holder is pushed. This is seen in Fig. 3, which also shows the crystal detector mounted in position. Two fillets are also required



VALVE PLATFORM WITH CRYSTAL DETECTOR

Fig. 3. Illustrated above is the horizontal platform to which are attached the crystal detector and the valve holder



COIL HOLDERS ABOVE PLATFORM

Fig. 4. Situated at right angles to each other, the coil holders are fitted with terminals and baseboard for easy connexion

$1\frac{7}{8}$ in. from the left side of the panel and $1\frac{7}{8}$ in. from the bottom. The smaller condenser is wired across the tuned anode coil, which is placed on the same side of the cabinet. The smaller condenser is placed in relatively the same position on the right of the case as the larger one. It is important to maintain efficient insulation throughout the construction of the set, and to this end all current-carrying material should be insulated with ebonite. The condenser spindles require bushing to prevent contact with the surface of the wood, and the same applies to the wires connecting to the tuning coils.

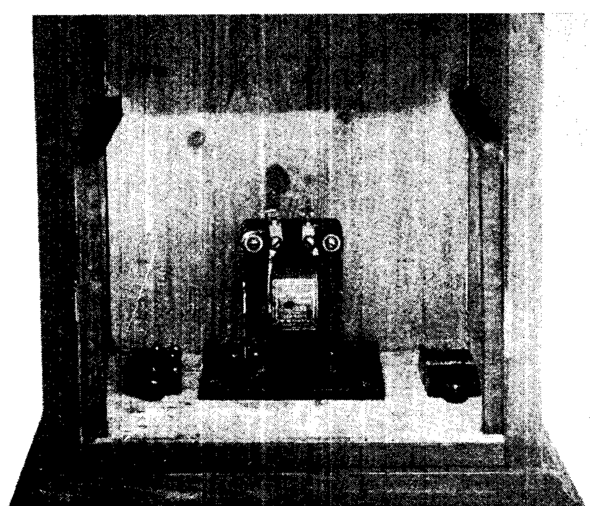
for support of the front panel. This is also of wood, and measures $7\frac{1}{4}$ by $5\frac{1}{2}$ in.

To the back of the panel are screwed two coil holders arranged at right angles to each other to avoid interaction. The coil holders are shown in Fig. 4, and are fitted with terminals and baseboard, which facilitates connexion of wires and their mounting. These components may be purchased, but if difficulty is experienced in this direction the ordinary type of plug-in coil holder may be adapted to suit the purpose.

The low-frequency transformer used in the set is mounted on a small base of ebonite and placed to the back of the base. A fixed condenser of ·001 mfd. capacity, which is shunted across the telephones and high-tension battery, is attached to the base, and is seen to the left of the transformer. To the right of this unit is placed a fixed condenser of ·0003 mfd. capacity, which is wired across the secondary of the transformer. These condensers are seen in Fig. 5 on either side of the transformer.

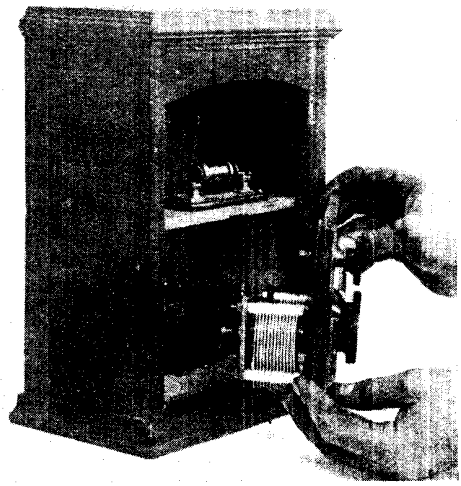
To the front panel are attached two variable condensers of ·0005 mfd. and ·0003 mfd., and a filament resistance, which is centrally placed at a distance of $1\frac{1}{2}$ in. from the top of the panel. The larger condenser is situated

Fig. 6 shows the front panel being offered up to the cabinet. This illustration also shows an ebonite terminal board cut to fit the top of the cabinet and curved at its lower end, to which the aerial and earth terminals and also the battery and telephone terminals are fixed. The terminal to the left is for connexion to the aerial, and is followed by a pair of telephone terminals. These are followed by the high-tension positive, a common high- and low-tension negative, and the low-tension positive terminal, while the earth terminal



LOW-FREQUENCY TRANSFORMER

Fig. 5. On the bottom of the cabinet is fixed the low-frequency transformer with the fixed condensers on either side



FITTING THE PANEL

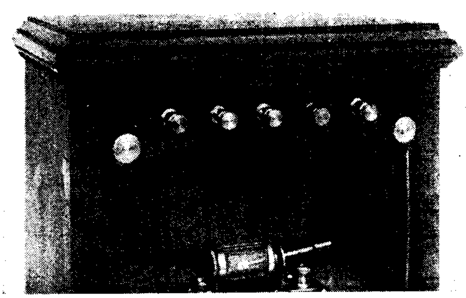
Fig. 6. To ensure an easy fit, and also to avoid fouling of the transformer by the condenser, careful experiment is necessary before fitting the panel

is to the extreme right. A close-up of the terminal board is given in Fig. 7.

The wiring may now be carried out according to the wiring diagram given in Fig. 8. The completed set fitted up ready for operation is shown in Fig. 9. In order to avoid the possibility of wrongly connecting up the battery leads, the terminals may be lettered with white paint applied with a fine brush.

For broadcast wave-lengths a No. 35 Igranic coil or No. $2\frac{1}{2}$ circuit coil is recommended in the aerial tuning circuit, and a No. 75 coil of the same make in the tuned anode circuit.

Fig. 16 on the photogravure plate shows a three-valve reflex receiving set complete in a cabinet.

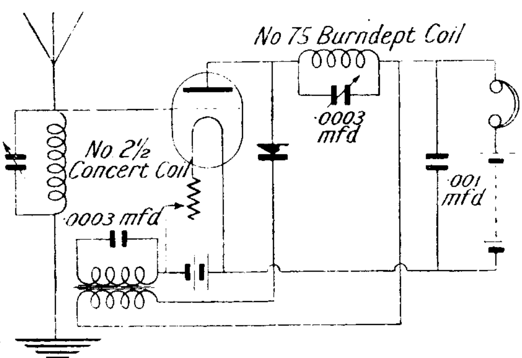


TERMINAL BOARD

Fig. 7. Every connexion to the set is made to these terminals arranged along the top of the cabinet

The cabinet, although large, is not difficult to construct. A plain box is required, measuring 24 in. long by 7 in. high on the inside. The width from back to front is $8\frac{1}{2}$ in., which measurement is also taken from the inside. The corners are preferably mitred or tongued and grooved, but an overlap joint will be found quite satisfactory if well screwed and glued. The wood selected for the case may be left to the constructor's choice, but it should be at least $\frac{3}{8}$ in. in substance. Fig. 10 gives a good idea of the construction of the cabinet.

When the set is finished and in the cabinet an ornamental beading is tacked to the inside of the case and, as shown in Fig. 16, gives a very finished appearance. The moulding makes the panel a fixture inside the set, and means must therefore be allowed for obtaining access to the interior. One method is to screw the back only to the case, so that if it is required to change the valves or to make any adjustment, the removal of the back

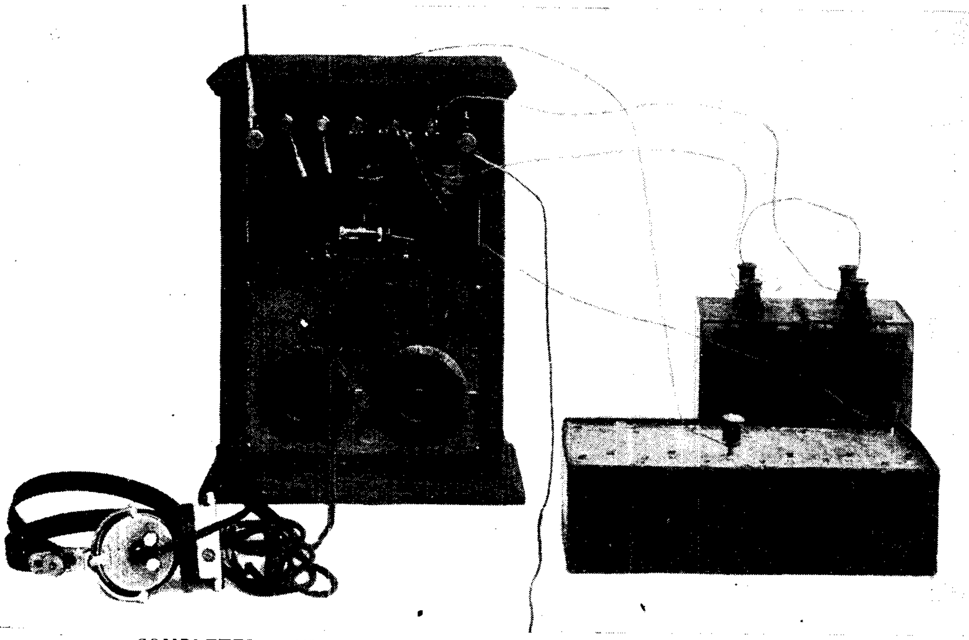


WIRING DIAGRAM

Fig. 8. The wiring of the one-valve reflex set is carried out according to this circuit

may be easily accomplished. An alternative plan is to hinge the right-hand portion of the case. The panel is secured on its inside by fillets of wood $\frac{1}{4}$ in. square, which are tacked to the inside of the cabinet all round, $\frac{3}{8}$ in. from the front edges.

A 9 in. length of the bottom fillet is cut off at the right-hand side to allow an ebonite platform, shown in subsequent illustrations, to be fitted. Before the cabinet is finished a slot is required for access to the terminal board. This slot measures 8 in. in length and $\frac{3}{4}$ in. in depth, and is cut 1 in. from the inside of the right-hand side of the case. The bottom of the slot

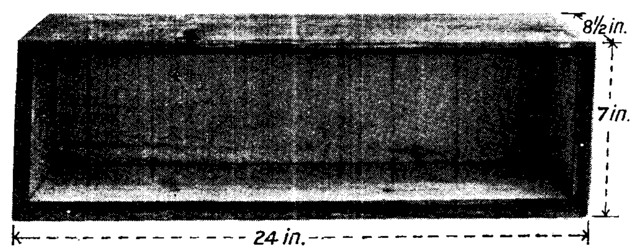


COMPLETED AND CONNECTED: THE ONE-VALVE REFLEX SET

Fig. 9. Aerial, earth, H.T. and L.T. and telephone connexions are complete, and the set is ready for use. The possibility of confusion is avoided by lettering the terminals in white

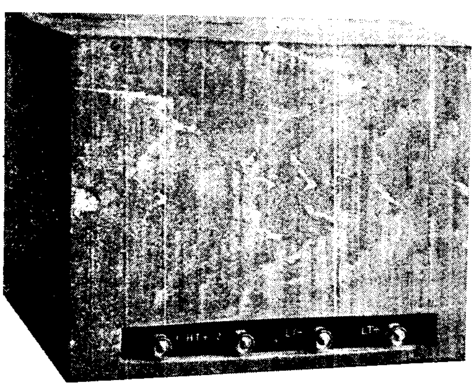
comes flush with the inside of the bottom. Fig. 11 gives a good indication of the position and purpose of the slot.

The main panel is cut from $\frac{1}{4}$ in. ebonite, and is made to fit the cabinet. Only the best quality ebonite should be used, and is chosen with a matt surface on both sides. When cut to the required



CABINET FOR THREE-VALVE SET

Fig. 10. Above is the case for the three-valve set with dimensions, before the slot is made in the back



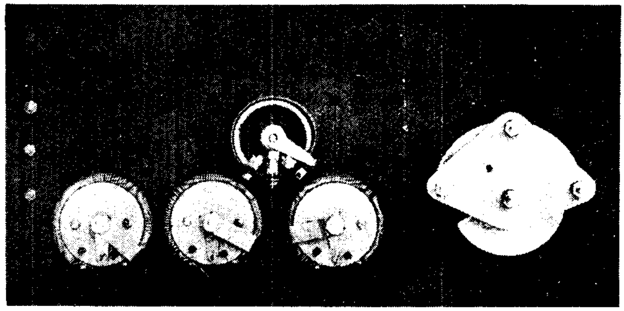
REFLEX SET TERMINAL BOARD

Fig. 11. A slot is cut in the back of the cabinet to admit the terminal panel by which the battery leads are taken through

size, the panel is marked out according to the dimensions and sizes given in Fig. 13. The sizes of the holes given will be found correct for probably the majority of components, but some of the holes will necessarily vary with different makes of components. A safe plan is to drill the panel to the particular instrument purchased. The experimenter is recommended to choose all fittings, as far as possible, having one central fixing, as this type is particularly easy to assemble.

Care should be taken in drilling out the holes for the contact studs to ensure that the spacing is uniform.

The best plan is to step out the radius of the line of studs with the position of the spindle hole as centre. Setting the divider legs at 1½ in. radius, the location of each hole is made from a point on the radius directly above the centre point. In this way an equal number of stud holes is marked on either side and a balanced effect is obtained which goes a long way to giving a neat appearance to the workmanship of the set.



REAR VIEW OF PART OF THE PANEL

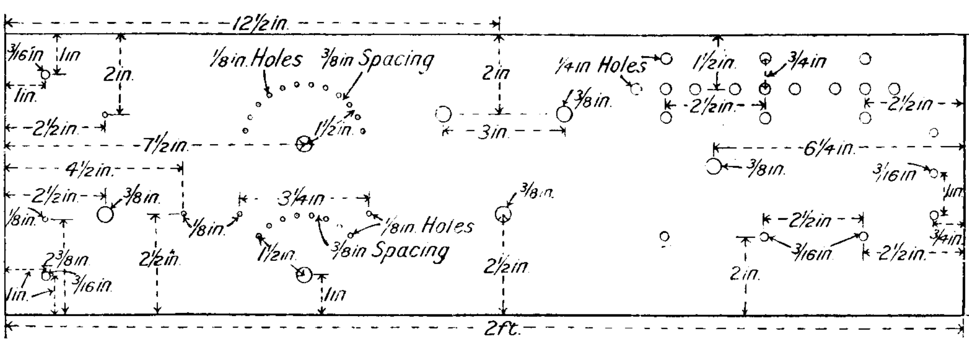
Fig. 12. The three filament resistances and the potentiometer are mounted in the above order

Before drilling the holes for the contact studs, the panel should be laid on a flat table and the position for the holes made more definite by means of a centre punch. Fig. 14 (on the plate) shows the assembly of a typical filament resistance with a set of its parts in the foreground. This illustration indicates the best way of mounting the resistances. If not properly assembled, trouble will be experienced later, when it is very difficult to rectify, as the wiring comes in the way of any repair work to the panel.

When the resistances are disassembled ready for mounting, the parts should be laid out in order to ensure their correct assembly. The resistance former and wire is mounted to the panel, after which the knob pointer, locking nut and spindle are added, the spindle being inserted from the outside. It is important at this stage to see that the spindle is locked rigidly to the controlling knob. After mounting the remainder of the parts in position, the locking nut is very tightly screwed to the contact arm.

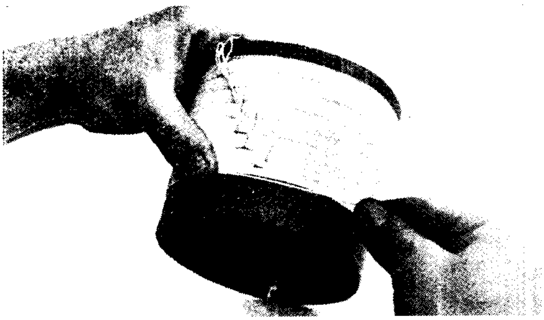
The potentiometer has a resistance of about 240 ohms, and is of the rotary, panel-mounting type. Its position on the panel is above and between the first and second filament resistance. It is seen in Fig. 12, which gives a rear view of the right half of the panel. In this illustration the valve peep-holes are seen to the top of the panel, under which are the potentiometer and the filament resistances, the latter being in line with each other. The back of the telephone terminals are to the extreme left, and to the right is seen the variable condenser, which has a maximum capacity of ·00025 mfd.

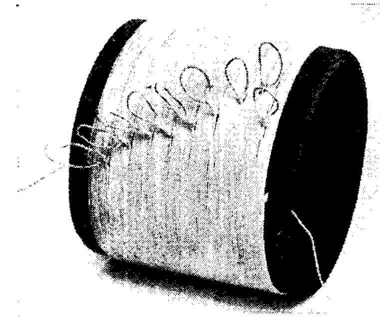
The primary inductance consists of 48 turns of No. 24 D.C.C. wire tapped at every ten turns. The secondary is wound with the same gauge wire, and having 100 turns, tapped at every ten turns. The formers on which these inductances are wound are cut from ebonite tube of 4 in. extreme diameter. A length of 3 in. is required for the primary and 4 in. for the secondary inductance. If ebonite tube is not readily obtainable, cardboard formers of the correct length and diameter will be found quite suitable if they are thoroughly impregnated with paraffin wax.



PANEL OF THE THREE-VALVE REFLEX SET

Fig. 13. When the ebonite for the panel has been cut to the required size it is marked out according to these dimensions for purposes of drilling



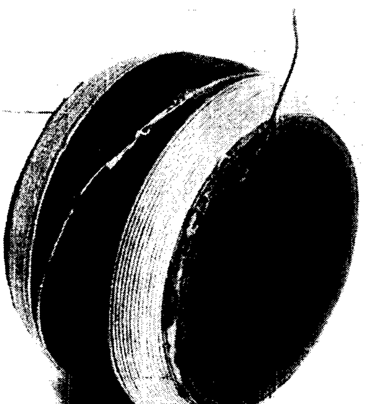


INDUCTANCE IN PREPARATION AND COMPLETED

Fig. 25 illustrates the method of holding the inductance while the hand winding is being carried out. Fig. 26. The completed secondary inductance ready for mounting to the panel. Notice the loops for tappings

Winding is commenced in the primary coil at a distance of ½ in. from the edge, and if the gauge of wire used is correct and the turns closely spaced, a margin of ½ in. is left at the other edge of the tube. The secondary coil has a margin of ½ in. at either end. The best and quickest method is to wind the inductances in a lathe, but if wound by hand, care should be taken to ensure that the wire is tightly drawn and that no gaps between adjacent wires are permitted. A convenient method of holding the inductance former and the wire is shown in Fig. 25, where the winding of the secondary coil is in progress. Fig. 26 illustrates the completed secondary coil.

The method of making the taps should be noted, as it allows easy connexion of the wires to the switch studs. At the point where a tap is required, three or four turns of wire are made, which form the tapping into a small loop. When soldering the connected wires the loop is cut off to within a distance of ¼ in. from the tube and the insulation stripped off with a sharp knife.



WIRING OF THE ROTOR

Fig. 27. An illustration of the wound rotor which forms part of the secondary circuit. Note how the halves of the winding are joined

The secondary coil is mounted to the panel by means of valve sockets. The socket hole is tapped out 4 B.A. and the socket attached to the inside of the panel by means of countersunk screws. The holes for these screws are given in the panel lay-out in Fig. 13, and are seen in Fig 33 on either side of the six-stud primary switch. This illustration makes the method of attachment quite clear.

The primary coil after winding is shown in Fig. 33. The rotor is fitted to the inside of the coil, and for this purpose two holes of $\frac{3}{16}$ in. diameter are drilled ¼ in. from one edge of the inductance former. The holes are arranged on either side of the former, so that when a spindle is inserted through both holes an equal amount of tube is seen on either side.

The rotor is of the variometer ball type and has a diameter of 3½ in. This may either be purchased or made according to the instructions given under the heading Variometer in this Encyclopedia.

Fifteen turns of No. 24 D.C.C. wire are wound on either side of the rotor and the inside ends are soldered together to form one inductance. Care must be taken to ensure that the wire runs in the same direction on both sides of the rotor. Fig. 27 shows the wound rotor and clearly illustrates the method of joining the two halves of the windings.

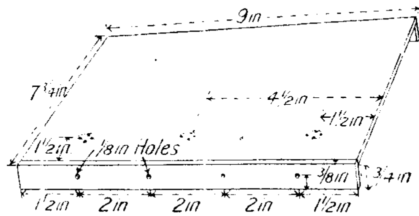
The rotor is mounted on a spindle consisting of a $5\frac{1}{2}$ length of 2 B.A. screwed rod, locking nuts being used to secure it rigidly to the rotor. One end of the rotor wire is soldered to the spindle on the inside of the rotor. Connexion is taken from the spindle by means of a brass strip slipped over the spindle and the other end bent round the edge of the inductance coil before a spring washer, flat washer and locking nuts are added. A short length of insulating flex wire is loosely tied round the spindle and one end of it soldered to the remaining free end of the inductance. The object of tying the connecting wire to the spindle is to take the strain of a pull off the soldered joint.

These details of the rotor assembly and its connexions are shown in a close-up view in Fig. 18 on the plate.

The primary coil is secured to the panel at the top end by means of a 4 B.A. countersunk screw, the head of which is flush with the outside of the panel. Several flat washers are used as packing, to keep the inductance a little away from the panel. At its lower end the inductance is secured with two 3 in. brass strips, which are bolted to the panel.

The next item for construction is the platform attached to the back of the panel at the right-hand side. On the platform are mounted two low-frequency transformers and three valve holders. At the back edge a terminal board is fixed for connexion of high- and low-tension batteries.

The platform is cut from $\frac{3}{16}$ in. ebonite measuring 9 in. in length with a width of $7\frac{3}{4}$ in. The terminal board is 9 in.



PLATFORM OF THE CABINET

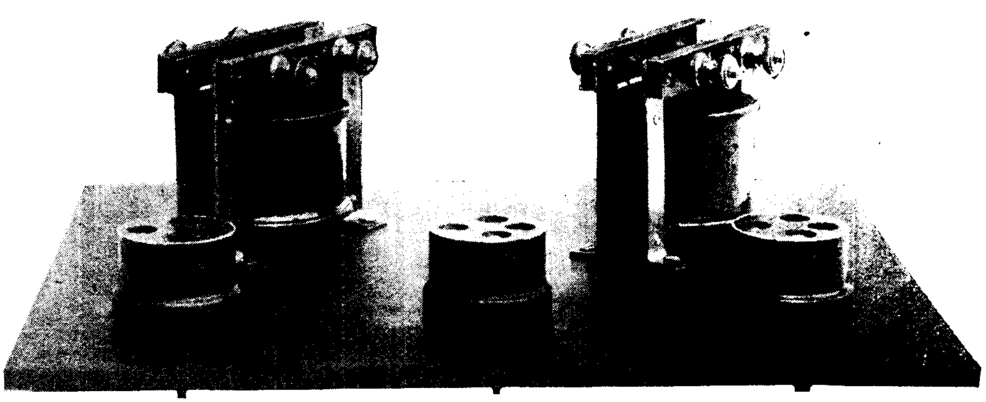
Fig. 28. The main dimensions are given in this diagram of the platform which supports the valves

in length and $\frac{3}{4}$ in. deep, and is secured to the platform so that its top edge comes flush with the top of the platform by means of right-angle brackets. The platform is attached to the panel in a similar way, the top of the platform being $\frac{3}{4}$ in. from the bottom of the panel. Fig. 28 gives a dimensioned perspective drawing of the platform and terminal board.

Any good make of low-frequency transformer having a ratio of about $4\frac{1}{2}$ to 1 will be suitable, and the transformers should be mounted sideways to each other, as shown in Fig. 29, in order to lessen the possibility of interaction between them.

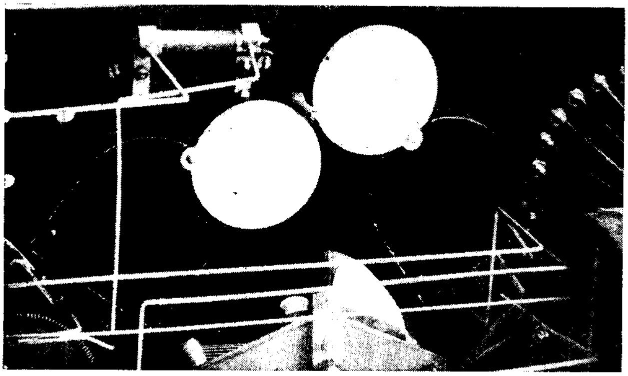
The platform is more rigidly secured to the panel by a brass strip bolted to the panel just below the centre valve peep-holes and to the platform close to the centre valve holder. Figs. 28 and 34 give a good idea of the platform part of the construction.

Fig. 30 clearly shows the positions of the high-frequency transformers. The type chosen for the set is the Sterling high-frequency transformer designed for broadcast wave-lengths. A feature of this



VALVE HOLDERS AND TRANSFORMERS IN POSITION

Fig. 29. A view of the platform, showing the transformers in position behind the valve holders, before the terminal board has been fitted



DETAIL OF THE DAMPING PLATES STOP

Fig. 30. To prevent contact between the transformer damping plates a stop is inserted between them

transformer is the novel method of obtaining a tuning effect, which consists of a metal damping plate secured to a spindle fitting at the centre of the curved portion of the transformer casing. A small ebonite knob is employed to operate this damping plate from the outside of the panel of the set.

Two $\frac{3}{8}$ in. holes are shown above the variable condenser in Fig. 13, through which the knobs of the damping plates are passed. Each high-frequency transformer is held in position by two 6 B.A. $\frac{3}{4}$ in. countersunk screws, which screw up from the outside of the panel into tapped holes drilled at the two corners of the transformers. If desired, a screw hole in the centre of the transformer may be made, through which a screw may be passed from the outside of the panel, a nut being used on the inside to bolt the transformer up tightly. This centre screw, however, is optional, and the transformers shown in Fig. 19 are fitted to the panel without them.

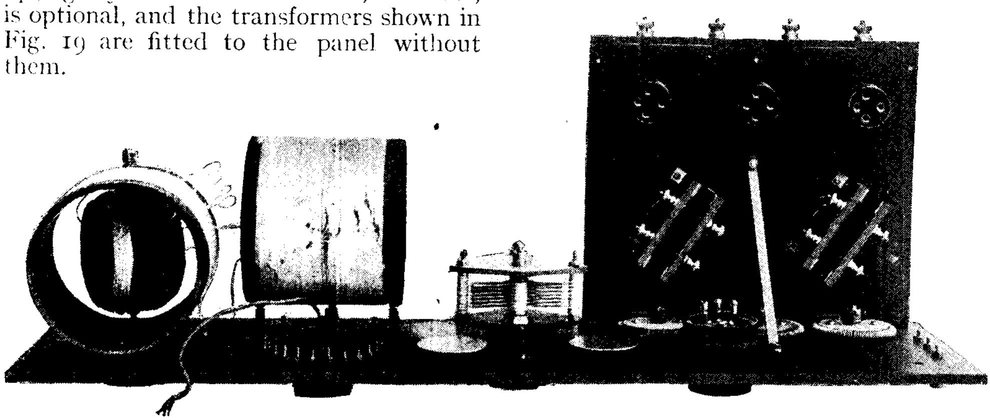
On no account whatever should a hole be drilled near the edge of these components, as this would result in cutting the wires of the inductances of which the transformer is built up.

In the positions that the high-frequency transformers occupy on the panel there is a possibility of the damping plates touching each other. This is prevented by screwing a valve leg covered with a piece of cycle valve rubber between the two plates. This stop is also useful in indicating the positions of the damping plates relative to the transformers. A close-up of this stop is shown in Fig. 30.

A plan view of the general lay-out of the main components is shown in Fig. 31, and clearly indicates the position of the valve platform and the strengthening strip.

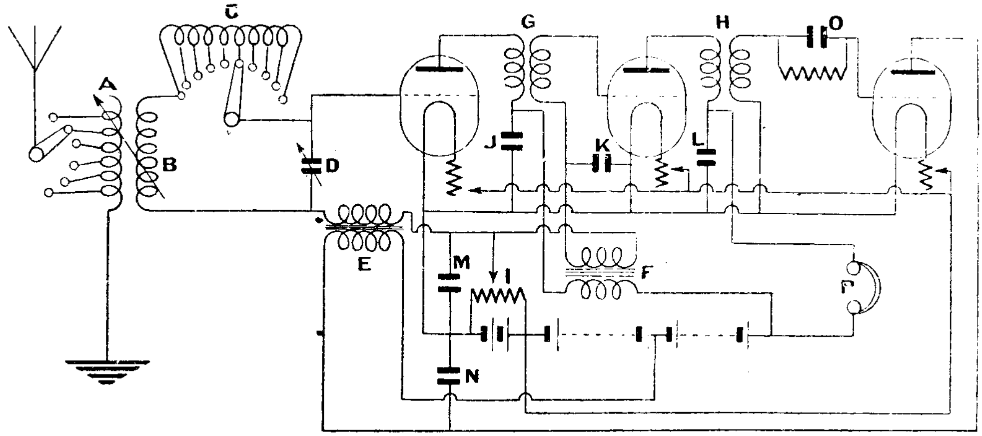
Connexion from the stud switch spindles is made by flexible insulated wires soldered to the spindles. To ensure a minimum amount of bending to the ends of the flexible wires, they are wound round the spindles two or three times before the free ends are taken to their points of connexion. This arrangement is important for forestalling wear. A close-up of this is shown in Fig. 33.

The wiring of the set is carried out with $\frac{1}{16}$ in. square tinned wire, and if care is taken, a very fine appearance is obtainable.



THREE-VALVE REFLEX SET READY FOR WIRING

Fig. 31. One cannot but be attracted by the neat appearance of the assembled components set up ready for wiring. Square tinned copper wire is used for this purpose



THEORETICAL CIRCUIT FOR THE THREE-VALVE REFLEX SET

Fig. 32. Details of wiring, which should begin at the aerial circuit, are given above. For explanation of the lettering see the list of components in the text

In order to free the wire from any trace of bends or kinks, one end is held in the vice while a length of about 30 in. is pulled straight. This length of straightened wire is cut off and laid flat on a bench until required. Considerable practice is required before perfection is reached with wiring of this nature. As far as possible, one circuit should be wired at a time, as this considerably assists the experimenter in following the wiring diagram. The wiring diagram is given in Fig. 32, and in Fig. 20 (on the plate) is seen the underneath of the platform with the low-tension circuit completed.

It is advisable to put the valves in their positions and to test the wiring of the low-tension circuit with the filament lighting battery, as a fault discovered at this stage is much more quickly rectified than if left until all the wiring is completed.

The aerial primary inductance is now wired. This is greatly facilitated if the secondary coil is removed during this operation.

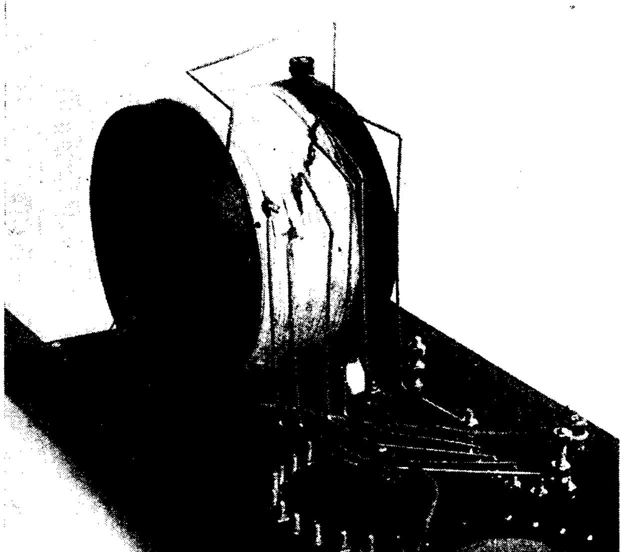
The wiring of the primary inductance is seen in Fig. 33.

The secondary inductance is now wired to the ten-stud switch similarly to the primary. The fixed condensers are attached to the panel and the platform, where their position gives the shortest wiring leads. Their positions in the circuit are shown in the wiring diagram, Fig. 32, and the list of parts required is to be found at the end of the article.

The wiring of the underneath of the platform is shown in Fig. 20 on the plate.

It will be seen that wires connecting to the anode and grid legs of the valve holders are taken through small holes adjacent to their respective points of connexion.

A close-up view of the wiring at the platform end of the set is seen in Fig. 34.



REAR OF PANEL

Fig. 33. Here is illustrated the wiring of the primary coil to the six-stud switch

From the illustrations of the completed wiring considerable assistance may be gathered regarding the best way to take the wires from point to point, and also which wires to leave to the last. It follows that the most accessible wires are the last to be attached.

An elevation view of the right-hand side of the interior of the set is given in Fig. 34, and a plan view in Fig. 35.

The back elevation with the valves in position is shown in Fig. 21. Figs. 24 and 23 give respectively an underneath view of the set and a slanting view taken from the right side.

Before the set is wired to the batteries it is advisable to look over the wiring to make certain that there is no possibility of two wires touching, and that all connexions are correctly made. The first test may be made before the set is fitted permanently to the cabinet, and the usual precautions applied to ensure the safety of the valves.

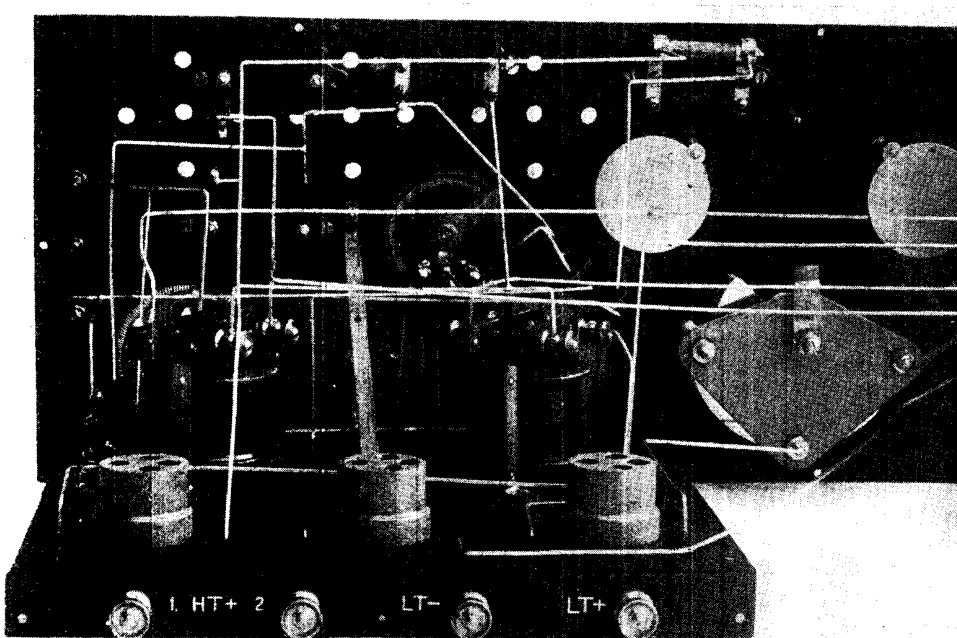
If no response is heard in the telephones when the aerial and earth and telephones are connected, the potentiometer knob should be rotated until a rushing noise is heard.

The potentiometer plays an important part in the operation of the set, and the experimenter will find that successful reception depends very largely on its correct adjustment.

The part of the secondary circuit comprising the rotor serves a very useful purpose in the elimination of interference, and in the preliminary test should be closely coupled to the primary circuit. If interference from another station is experienced the rotor should be tuned until the interference is eliminated. This will probably result in a loss of strength of the signal being received. Readjustment of the tuning elements will enable the signal to be increased to its original strength while the interfering station is entirely suppressed.

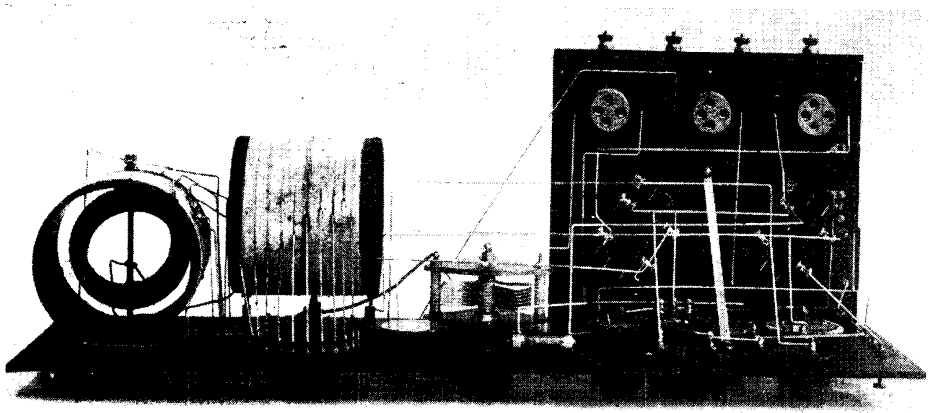
The condenser is extremely critical in tuning, and the use of a vernier attachment is recommended. The set is unusually free from the effect of body capacity, but it may be found that extension arms to the damping plates will effect an improvement, as they are very close up to the transformers.

The set is one that requires to be understood before it can be worked at its best efficiency, but in this connexion it should be stated that all the British broadcasting stations were heard perfectly clearly



WIRING COMPLETED: RIGHT SIDE OF THE SET

Fig. 34. Close-up view of the wiring at the valve-platform end of the set, showing also the terminal board. Square tinned copper wire is used throughout



PLAN VIEW OF COMPLETED THREE-VALVE SET

Fig. 35. The disposition of components, their relative situation and their easy accessibility are clearly demonstrated in this photograph. The experimenter will observe the method of connecting many of the wires in the circuit. This should be carefully studied

within half an hour of the completion of the construction, loud-speaker strength being available on stations up to 100 miles.

The components required are :—

A—Aerial primary inductance.

B—$3\frac{1}{2}$ in. diameter rotor.

C—Aerial tuning secondary.

D—Variable condenser, ·00025 mfd.

E and F—Good quality low-frequency transformers.

G and H—Sterling high-frequency transformers.

I—Potentiometer, 240 ohms.

J, K and L—Mica condensers, ·001 mfd.

M—Mica condenser, ·002 mfd.

N—Mica condensers, ·005 mfd.

O—Combined grid leak and condenser of 2 megohm resistance and ·0003 mfd. capacity.

P—Telephones of 4,000 ohms resistance. —*W. W. Whiffin.*

REFRACTION. Bending of electromagnetic waves as they pass from one medium to another. The phenomenon is most easily noticeable when rays of light pass from one medium to another, as, for example, when they pass from air to glass. The phenomenon of refraction is important in wireless, as it is in optics. It is, in fact, probably due to refraction that wireless waves are able to travel round the earth.

Marconi noticed during his early attempts at transmission that it was much easier to transmit at night than during the day, and that with a given power the wireless waves travelled farther. The velocity of the wireless waves varies inversely as the density of the atmosphere, so that the tops of the waves move faster than the bottom, since the atmosphere is less dense high above the earth than it is at ground level. This normal refraction effect, however, is small, and does not account for all the movement of the waves round the earth.

In 1912 Dr. Eccles suggested another cause for refraction. He showed that when an ether wave passed through a gas containing ions the velocity of the wave front increased. During the day the atmosphere is more evenly ionized than during the night, when a high ionized layer of the atmosphere is more sharply defined. This causes the tops of the waves to travel faster than the feet, and the wave front is accordingly tilted forward so that the strain energy follows the curvature of the earth. This effect is called ionic refraction.

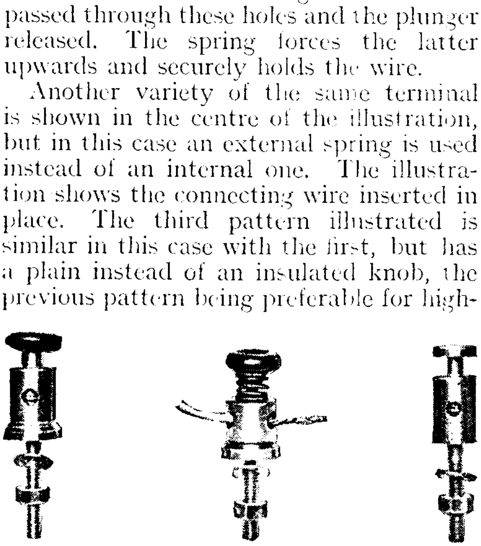
This ionic refraction accounts for many of the curious freaks of transmission. When the whole atmosphere is highly ionized, due to a clear sunny day, the effect of the ionic refraction on the bottom of a wireless wave is very nearly the same as on the top of the wave. The wave is not so bent forward, therefore, and there is less inclination for it to follow the curvature of the earth. If the day has been cloudy, however, the ionic layer is well defined and the lower regions of the atmosphere have not been ionized, so that reception during and after a cloudy day is usually much better than during a day of brilliant sunshine. That is why, on the whole, one expects better reception during the winter days than during the summer ones. In the same way reception becomes worse when thunder is in the air, because the whole atmosphere is in a highly ionized condition and the ionic refraction is not so noticeable.

The refraction of electric waves was demonstrated by Hertz by means of parabolic mirrors and a prism of pitch. He obtained radiations from an oscillator fitted into one mirror, which passed through the prism and were refracted by it like rays of light, the refracted radiations being received by a second oscillator fitted into the other mirror. *See* Fading; Electrolines; Heaviside Layer; Short Wave.

REFTY TERMINAL. Name given to a patented terminal, a special feature of which is the celerity with which connexions can be made or severed. Three patterns are illustrated. That on the left shows the ordinary terminal, which is generally of the telephone type.

It is secured by means of a screwed shank, nut and washer. The upper part of the terminal is occupied by a small spring-pressed plunger terminating in a small ebonite knob. The spring is located beneath this plunger and presses it upwards. When the knob is depressed, a hole drilled through the plunger registers with a hole drilled through the top of the terminal. The connecting wire is then passed through these holes and the plunger released. The spring forces the latter upwards and securely holds the wire.

Another variety of the same terminal is shown in the centre of the illustration, but in this case an external spring is used instead of an internal one. The illustration shows the connecting wire inserted in place. The third pattern illustrated is similar in this case with the first, but has a plain instead of an insulated knob, the previous pattern being preferable for high-tension circuits and the latter for low-tension connexions.



REFTY TERMINALS

Here are three patterns of the well-known Refty terminals. A special feature is the quickness with which connexions can be made or broken by spring plungers

The use of Refty terminals is a great saving in time and trouble for the experimenter who is limited for time in effecting changes in circuits or in making additions or alterations to them. It is but the work of a moment to effect connexions where these terminals are fitted to the set. *See* Terminal; Wiring.

REGENERATION. Since the three-electrode valve has the ability to operate as an amplifier, it follows that the energy in the output circuit is greater than that in the input circuit. If part of the output, therefore, is returned to the input side, there will be a further amplification of energy, and if this is returned in sufficient amount and in correct phase relationship there must be a constant re-amplification or "feeding back" of energy from the output to the input side. Sustained oscillations will then be produced, without the need for supplying an alternating potential to the valve grid from an external source, and the valve then acts as an oscillation generator.

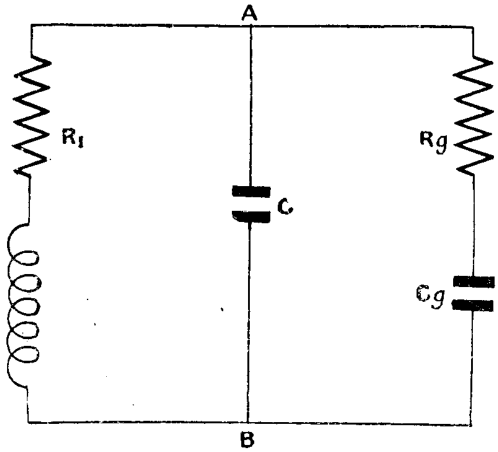
The frequency of these oscillations will depend upon the constants of the circuit, and their intensity upon the amount of self-oscillation or feeding back of output to the input side.

The effect of inter-electrode capacity may cause a valve to produce oscillations also, even when there is no mutual inductance between the output and the input coils. Such capacity gives rise to an effective impedance between filament and grid when the oscillation frequency is sufficiently high, and this impedance can be represented by a resistance, Rg, and a reactance due to the effective input capacity Cg, in Fig. 1.

The total resistance of the circuit approximates closely to

$$R_1 + \left(\frac{Cg}{C + Cg}\right)^2 Rg$$

If oscillations are impressed on this circuit, the rate at which they would die out would naturally depend upon the value of the total resistance. If Rg is negative, the total resistance will be reduced, there will be a smaller consumption of power in the input circuit, and the valve will give a greater amount of amplification. If, however, Rg has a negative value and the effective resistance to the right of A B in Fig. 1 is equal to resistance R_1, that is, the total resistance of the



FILAMENT-GRID IMPEDANCE

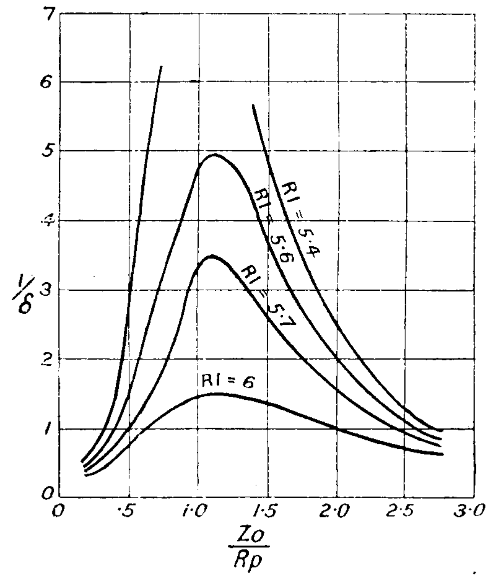
Fig. 1. How the impedance between filament and grid may be represented by a resistance, Rg, and a reactance, Cg

circuit is zero, it will produce sustained oscillations.

In fact the formula may be taken as a measure of the damping due to the total resistance of the circuit. It may be stated, in fact, that regeneration is actually the increase in amplification due to a reduction in circuit resistance arising from the causes explained above. The regeneration effect is measured as a reciprocal of the damping, namely, $\frac{1}{\delta}$.

The value Rg is positive whenever the external plate circuit is non-reactive, or only contains capacitative resistance. If, on the other hand, the reactance in the plate circuit is inductive, and the angle of impedance in the plate circuit is large enough, Rg has a negative value.

The ratio between the regenerative effect and the ratio of the external impedance in the anode circuit to the anode resistance is shown by the curves drawn in Fig. 2. These curves are of interest in eliciting the fact that the maximum regenerative effect is obtained when the external resistance in the anode circuit is

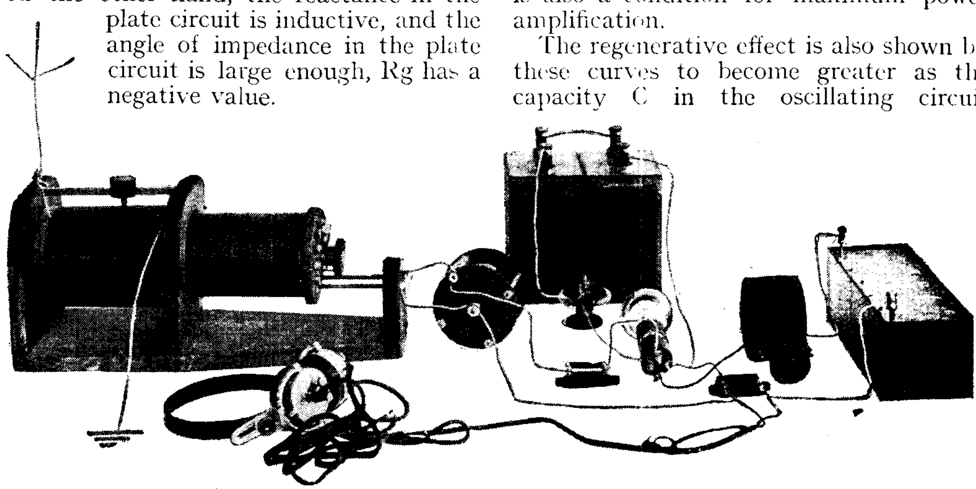


CURVES SHOWING REGENERATION EFFECTS

Fig. 2. Curves showing ratio between the regenerative effect and the ratio of the external impedance in the anode circuit to the anode resistance : *Zo* is the external impedance ; *Rp* the resistance

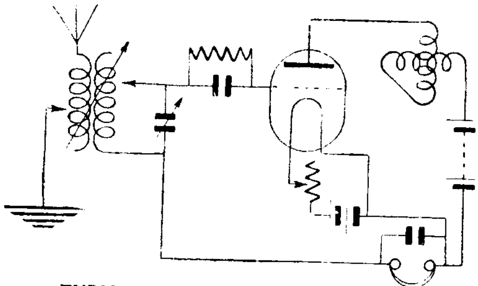
equal to the anode resistance itself. This is also a condition for maximum power amplification.

The regenerative effect is also shown by these curves to become greater as the capacity C in the oscillating circuit



REGENERATION APPLIED TO SINGLE-VALVE CIRCUIT

Fig. 3. Above is given an illustration of the disposition of components in a typical single-valve regenerative lay-out. This should be studied with the diagram in Fig. 4



TYPICAL REGENERATIVE CIRCUIT

Fig. 4. A loose coupler with tapped secondary is used for aerial tuning. The secondary circuit has a condenser shunted across its coil

diminishes. *Zo* is the external impedance in the plate or anode and *Rp* the resistance in the circuit.

The practical application of regeneration to a simple single-valve receiving circuit is illustrated in Fig. 3, which shows the disposition of ordinary components needed to build up a single-valve regenerative receiver. The theoretical circuit diagram, Fig. 4, shows that a loose coupler with a tapped secondary is employed for aerial tuning purposes. The secondary circuit is tuned by a variable condenser shunted across the secondary coil.

Regeneration is obtained from a variometer in the anode circuit, which, when tuned in sympathy with the aerial circuit, hands on a fluctuating current impulse to the grid circuit and thereby increases the signal strength. There are numerous other ways of accomplishing the same result, dealt with under the titles Regenerative Circuits; Regenerative Set.

REGENERATIVE CIRCUITS: EXAMPLES AND ACTION

Effects Obtained by Coupling Grid Circuits with Plate Circuits

This important article deals with the principles of regeneration. It should be read in conjunction with such articles as Armstrong Circuits; Cascade Amplification; High-frequency Amplifier; Reaction; Reflex Circuit, etc. Under the heading Regenerative Set is described the making of sets employing such circuits

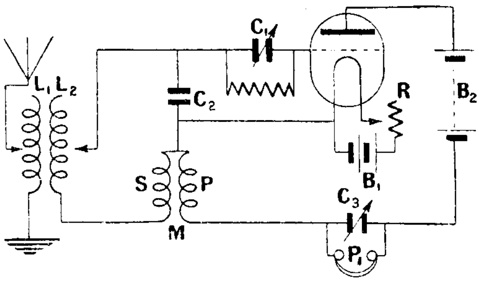
Regenerative circuits are those in which the grid and anode circuits are coupled, it may be inductively, conductively or electrostatically. Not uncommonly regenerative circuits are also spoken of as "reaction" circuits, but in either case it covers a regenerative system of amplification by which the strength of the incoming radio signal is amplified and increased within the same valve, as distinct from "cascade" amplification. In the latter the radio- or audio-frequency component of one valve anode current is impressed upon the grid and filament of a second valve, that is, the output circuit of the first valve is coupled to the input circuit of the second valve, up to several stages if necessary.

Regenerative systems were first disclosed by Captain E. H. Armstrong, and have been elaborated from time to time under more or less fanciful names as "super-regenerative" circuits. The object is to reinforce the main signal within the same valve without employing external stages of amplification, and whether described as reaction, regeneration or super-regeneration matters but little.

The three-electrode valve, as is well known, acts as a repeater of radio-frequency currents; that is, if an oscillating voltage is applied to the grid and filament the anode current will oscillate at the same frequency. The use of a grid condenser during the reception of damped waves causes the anode current to vary simultaneously; also by the employment of a grid battery the grid potential can be so adjusted that the increase of anode current for each incoming first half-wave will exceed the decrease for the other half-wave (or vice versa), and, in effect, what is a more or less rectified current results. With a proper valve characteristic a very slight change in grid potential is sufficient to cause a relatively large change in the anode current. If by some means the grid potential were to be reinforced above and below the maximum values due to the radio signal alone, an increased effect would immediately result in the telephone current.

During the reception of radio signals the anode current varies at the frequency of the incoming oscillations. Therefore if this radio-frequency component of the anode current can be impressed upon the grid circuit in synchronism with the signals being received, the energy of the original signal will be increased, and the result is regeneration.

How this amplification of the incoming signals is obtained may be explained in the following manner. A very small amount of energy applied to the grid circuit will release a considerably greater

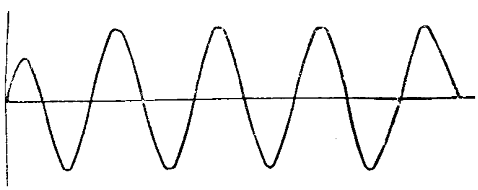


REGENERATIVE CIRCUIT PRINCIPLES

Fig. 1. Tuning in this method of regeneration is effected partly by the variable inductances L_1, L_2. The variable condenser, C_1, should be of as small a capacity as possible. Regenerative transformer M is adjusted until maximum signal strength is secured

amount of energy in the anode circuit. A part of the energy so liberated is then impressed upon the grid circuit through the coupling transformer M, seen in Fig. 1, and the difference between points of maximum and minimum potential between grid and filament is accordingly increased.

This liberates increased energy in the anode circuit, but reaction cannot continue indefinitely, for the final amplitude of the regenerated current is limited by the saturation characteristic of the valve itself; the limitations are due first to the electronic emission arising from filament temperature, which cannot be raised beyond a certain point, and secondly to the space-charge within the valve, which restricts the anode current for a given anode voltage. The electrons flowing between filament and anode constitute a negative electric charge in space which repels the electrons escaping from the filament, causing a proportion of them to return to the filament instead of reaching the anode.



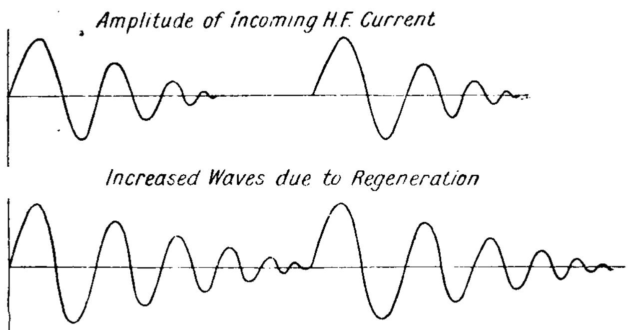
EFFECTS OF TOO CLOSE COUPLING

Fig. 3. Continuous oscillation, as represented above, arises from the too close coupling of grid and plate circuits

To illustrate the practical effects of regenerative coupling reference should be made to Fig. 2. The upper part of this figure shows the amplitude of the incoming radio-frequency currents, while the lower part represents the increased number of waves due to regeneration.

It is essential that the coupling of the transformer M, in Fig. 1, should be very carefully adjusted, as if the coupling is very close the system may be set into self-oscillation; the oscillations due to each spark at the transmission station may then merge together into a form represented by Fig. 3, instead of each train of oscillations dying away before the next is originated. Since it is the variation in the strength of current and not the total amount itself which gives rise to the audible signals in the telephone, the result in such cases would be unsatisfactory.

The complete functioning of a regenerative circuit, such as in Fig. 1, may be stated as follows: The incoming oscillations are first repeated in the anode or plate circuit;

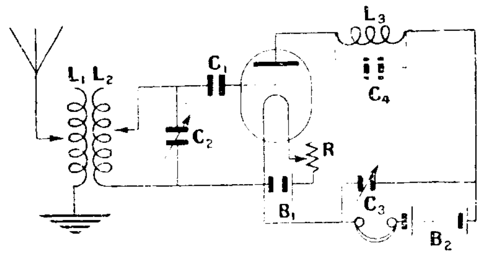


EFFECTS OF REGENERATIVE COUPLING

Fig. 2. Upper diagram shows the amplitude of the incoming radio-frequency currents; below is shown the increased number of waves due to regeneration

they are reinforced through coupling to the grid circuit, thus causing still greater variation in the grid potential. During this time the rectified charge accumulates in the grid condenser, which is negative on the grid side, and this partially obstructs the flow of electrons to the plate, thereby reducing the strength of the plate current. At the termination of the wave train the charge in the grid condenser leaks through the grid resistance, the grid returns to normal potential, and the plate current falls to its normal value.

To operate a circuit such as the above, the following is the best procedure. First close the circuit from B_1 to filament,

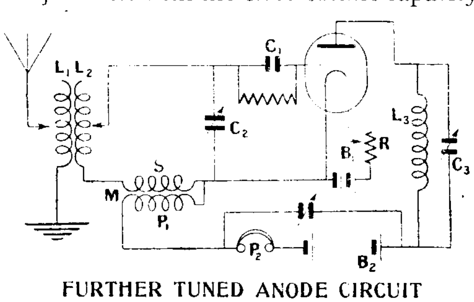


TUNED ANODE REGENERATION

Fig. 4. Amplification here is by tuned anode circuit. Apparatus is as in Fig. 1, with a plate circuit inductance L_3 and condenser C_4. Condenser C_2 acts as a by-pass for the radio-frequency of the plate round the telephones and battery B_2

adjusting the current by means of the filament resistance R. Next adjust the electro-motive force of battery B_2 to the degree necessary for the correct operating characteristic of the valve. Tune in by the variable inductances L_1 and L_2, using as small values of C_1 as possible and relatively large values of L_2 to maintain a high potential difference. Lastly adjust the coupling of the regenerative transformer M until maximum strength of signals is secured. The condenser C_2 is for the purpose of by-passing the radio-frequency component of the plate current round the telephones; its capacity is generally fixed.

Regeneration by tuned anode or plate circuits can be accomplished in at least four different ways. The simple tuned anode circuit is shown in Fig. 4. In addition to the apparatus shown in Fig. 1, this includes a plate circuit inductance, L_3, and a condenser, C_4. The inductance coil, L_3, in conjunction with the electrostatic capacity

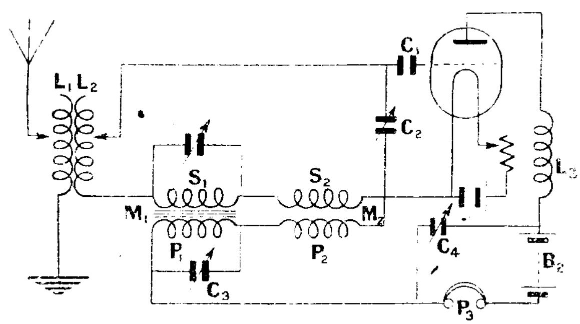


FURTHER TUNED ANODE CIRCUIT

Fig. 5. Resonance is secured by variable inductance L_3 which at low oscillations is shunted by condenser C_3. Here primary coil P_1 becomes part of the tuning circuit

of the valve itself between filament and plate, constitutes an oscillation circuit of variable frequency. The condenser C_2 acts as a by-pass for the radio-frequency component of the plate current round the telephones and battery B_2.

The condenser C_4 is of fixed capacity. As the incoming radio-frequency oscillations are repeated in the plate circuit, the counter electro-motive force of coil L_3 either assists or opposes the plate circuit battery. The effect is alternately to decrease and increase the potential difference between the filament and plate, and since the space between these two constitutes a small capacity the charge accumulated is varied as a consequence. This self-capacity of the valve acts as a coupling to transfer energy from the plate circuit to the grid circuit, energy being supplied by the reactance voltage of the coil L_3. Consequently a marked degree



AUDIO- AND RADIO-FREQUENCY COMBINED

Fig. 6. Radio-frequency transformer is shown at M_2. M_1 is an iron-core coupling amplifying the audio-frequency component of the anode current

of amplification is thus secured, and either the radio- or the audio-frequency of the plate current component may be amplified by proper tuning.

Captain Armstrong has given the following explanation of the phenomenon. When the grid circuit is not in a state of oscillation, the potential difference between plate and filament will be nearly that of the battery B_2 in Fig. 4. But during the reception of waves the potential difference will vary, according as the reactance voltage of coil L_3 assists or opposes the voltage of the local battery B_2. If, then, the current in the plate circuit decreases, the reactance voltage will be in the same direction as the voltage of B_2, and therefore an increase of potential will result between plate and filament. If, on the other hand, the current from B_2 is increasing, the reactance voltage of L_3 will oppose that of the battery, decreasing the resulting potential difference between plate and filament.

When a negative charge is impressed upon the grid, the plate current decreases, but when a positive charge is applied to it the plate current will increase. Hence when filament and grid are connected to a source of radio-frequency oscillations the current in the plate circuit will vary as the applied frequency. When a negative charge, therefore, is imparted to the grid, the plate current is reduced and the reactance voltage of L_3 acts in the same direction as B_2, increasing the potential difference between plate and filament and drawing more electrons out on the grid. This increases the charge in the condenser formed by the plate and grid, and the energy for this increased charge is furnished by the inductance L_3 as the current from battery B_2 decreases.

This increased negative charge on the grid tends to produce a still further decrease in the plate current, which causes a further discharge of energy from the plate inductance L_3 into the grid circuit.

The Critical Moment in the Operations

When, however, a positive charge is manifested on the grid, the plate current is increased, and the reactance voltage of L_3 consequently opposes the voltage of battery B_2. This reduces the potential difference between grid and plate, and therefore part of the energy stored up in the condenser formed by the grid and plate is given back to the plate inductance.

This is the moment at which electrons will be drawn into the grid in accordance with the valve action, and during a group of incoming oscillations a charge is gradually trapped in condenser C_1, which at the termination of a wave train leaks away from the grid, exerting the usual relaying action on the plate circuit. This relay action occurs at audio-frequency.

The necessity for resonance, therefore, between the plate and the grid circuits is obvious. In order that transference of energy from plate to grid circuit may take place in synchronism with the wave received, circuit L_3 and the condenser formed by the self-capacity of the valve must possess the same natural frequency. Then energy will be transferred from the plate to the grid circuit at the proper moment to increase the final amplitude of the waves; regeneration thus results.

It may be necessary to shunt coil L_3 with a condenser C_4, shown by the dotted lines in Fig. 4, in order that the circuit may function on the longer wave-lengths.

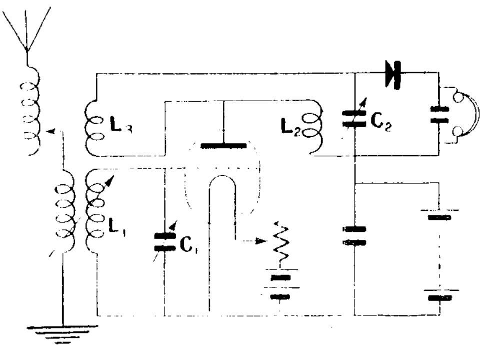
Another method for obtaining a tuned plate circuit is shown in Fig. 5. Here resonance is secured by the variable inductance L_3, which at lower oscillation frequencies may be shunted by the condenser C_3. Condenser C_2 acts as the by-pass for radio-frequency current round the telephone circuit. The primary coil P_1 of the regenerative coupler becomes part of the tuning circuit.

A System Giving Great Amplification

A circuit in which both radio- and audio-frequency components of the plate current can be amplified through the same valve appears in the diagram, Fig. 6. The radio-frequency transformer is shown at M_2, and through this the radio-frequency component of the plate current is reinforced through the valve grid. The other transformer, M_1, is an iron-core audio-frequency coupling for amplifying the audio-frequency component of the plate current, its primary, P_1, being shunted by a condenser C_3 and the secondary, S_1, by another condenser. Condenser C_3 tunes the circuit P_1C_3 to the desired audio-frequency, and the secondary condenser performs the double function of providing a path for the radio-frequency current through the grid circuit and tuning circuit to the audio-frequency component. Condenser C_4 provides a path for the radio-frequency current round the headphones, P_3. Inductance L_3 tunes the plate circuit to the incoming signal. This system is difficult to keep in stable operation, but great amplification is claimed to result.

Additional circuits have been developed by Armstrong, Franklin, Marconi and others, mainly electrostatic, some of which combine the regenerative amplifier and the cascade principle in addition.

With all the regenerative circuits the great difficulty facing the experimenter is that of tuning. In some circuits the regenerative effect is not obtained, indeed, without correct tuning, and the circuit may act as a straightforward detector and amplifier, giving results far below expectations. The reader should study carefully the methods of tuning given in this Encyclopedia under the various regenerative



REGENERATIVE COUPLING

Through the back-coupling coil L_3, circuit L_1C_1 is coupled to L_2C_2. Pulsations in L_1C_1 cause radio-frequency current changes through L_3, with a self-oscillation in L_1C_1

circuits, and also such cognate headings as Tuning, in order to obtain the proper effects from his set.—*A. H. Avery.*

REGENERATIVE COUPLING. The use of regeneration, reaction, or back-coupling is illustrated in the diagram. Circuit L_1C_1 is coupled with L_2C_2 through the back-coupling coil L_3. Any pulsations set up in L_2C_2 will also cause radio-frequency changes of current through L_3, maintaining a self-oscillation in the circuit L_1C_1 if the coupling is sufficiently tight.

Such an arrangement would be used in heterodyning and amplifying a continuous wave signal. For receiving spark signals, however, the coupling would require to be looser until heterodyne oscillation just ceases. *See* Reaction; Regenerative Circuits.

REGENERATIVE SETS & HOW TO MAKE THEM

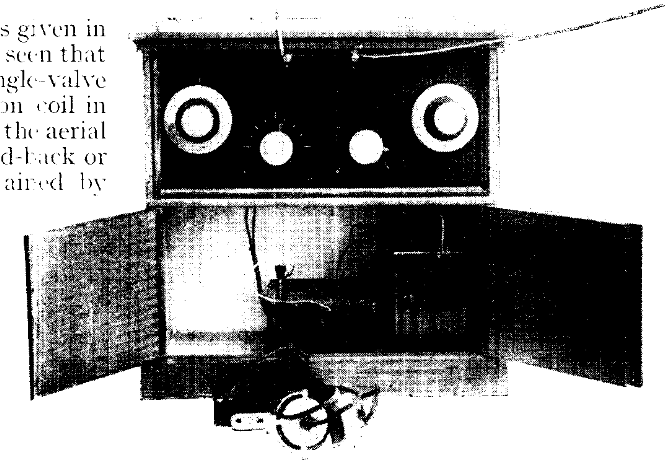
Two Easily Built and Effective Receivers Employing Regeneration

Here are described single-valve receiving sets, which, by means of regeneration, develop considerable range and power, and possess other good qualities. The description of the second set includes a photogravure plate; at moderate distances from a station this set will receive well even without an aerial. See also related headings, as Amplifier; Reaction; Regeneration; Super-regeneration, etc.

A single-valve receiving set embodying a simple circuit operating on the regenerative system is illustrated in Fig. 1. This is a self-contained set, and for a single-valve receiver has an extraordinary range and power. At 30 miles from London it brings in 2 LO at moderate loud-speaker strength, tunes sharply and brings in most of the other B.B.C. stations, as well as the concerts broadcast from L'Ecole Supérieure des postes et télégraphes.

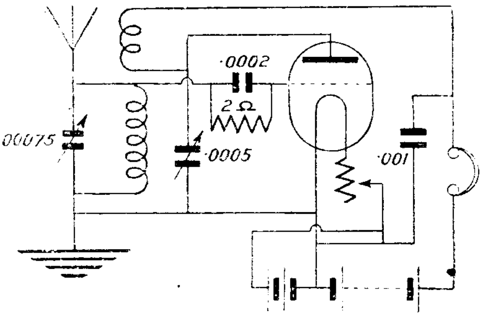
The circuit for this set is given in Fig. 2, from which it will be seen that it comprises an ordinary single-valve receiving set with a reaction coil in the plate circuit coupled to the aerial tuning inductance. The feed-back or regenerative effect is obtained by means of a variable condenser between the plate or anode terminal of the valve and the earth side of the aerial inductance. The set is stable, reliable in use and gives remarkably clear reproduction.

As with any set embodying aerial reaction, the greatest care must be taken in handling it not to cause annoyance to near-by listeners. This is best accomplished by very loosely coupling the anode inductance coil to the aerial coil, tuning in the desired station on the aerial tuning condenser, building it up to maximum strength by careful adjustment of the regenerative condenser, and finally making critical adjustment with the filament resistance and both tuning condensers. There should then be no troublesome reaction or interference caused to anyone.



HOME-MADE REGENERATIVE SET

Fig. 1. Of extraordinary power and range, this amateur-built self-contained regenerative set will work a loud speaker from twenty to thirty miles from the broadcasting station



THEORETICAL CIRCUIT DIAGRAM

Fig. 2. In the plate circuit is the reaction coil, which is coupled to the aerial tuning inductance. The values of the condensers are all given

The case, illustrated in Fig. 4, is of ample proportions. This is to enable the components to be widely separated to avoid interference, and also to provide a storage place for the telephones and high- and low-tension batteries. The case is simply constructed from ordinary deal, stained a nut-brown colour and wax-polished. The constructive details may follow those described under the heading Cabinets in this Encyclopedia.

It should be noted that the case comprises, as it were, three parts. First the outer case, consisting of the two sides, bottom and top with their mouldings, the central shelf or division, and the back. The upper half of the back is hinged, as in Fig. 5, to provide access to the valve and other components, while the lower half is rigid. The upper front of the case is filled in by an ebonite panel, and the lower part, beneath the panel at the front, by two small hinged doors ornamented by simple mouldings.

The lower part of the back is fixed to the sides and to the shelf.

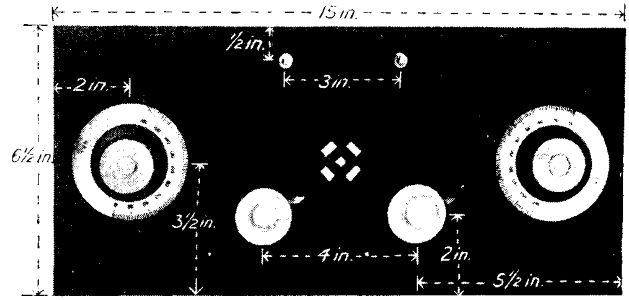
Having prepared the case the ebonite panel is then cut to fit it, and the dimensions for this and the centres for the various components are given in Fig. 3. The next step is to prepare the small valve platform and attach this to the back of the panel by means of a strip of angle brass, or other secure attachment. This is clearly shown in Fig. 6 and several of the other illustrations.

The two condensers can be purchased ready for use. Those with aluminium or ebonite end plates are equally serviceable, but are preferably of the single hole fixing, as this saves the trouble of drilling and tapping small screw holes for fixing purposes. The condensers should be fixed, and dials and knobs attached to the spindles, tested for accuracy of movement; if desired these may be removed until a later part of the construction.

The two-coil holder is of somewhat novel construction, as it incorporates a reduction gear between the control spindle and the moving part of the holder. The gears actually used in the holder as illustrated were taken from a Meccano set, but any other brass gear wheels, respectively about $\frac{5}{8}$ in. and $1\frac{3}{4}$ in. in diameter and $\frac{1}{8}$ in. or $\frac{3}{16}$ in. wide on the face, will be suitable. The smaller gear should be mounted on a plain brass spindle, as is clearly illustrated in Fig. 7. The larger gear wheel is mounted on to the spindle of the coil holder, and both these gears should run perfectly true on their spindles.

A support for the small gear shaft is made from a piece of flat brass plate about $\frac{3}{4}$ in in width and $1\frac{1}{2}$ in. in length. This has a hole drilled in its upper end to receive the shouldering end of the spindle. The plate is attached to the sides of the coil holder by means of two countersunk screws and is so placed that the two wheels engage or mesh with each other properly, this feature being clearly illustrated in Fig. 8.

A distance piece, cut from brass tube, is soldered on between the face and the small gear and bears against a brass washer on the inner side of the panel. The panel is best bushed with brass, and the whereabouts of this hole must be accurately determined, so that when the knob is rotated the small gear rotates the larger one without any suggestion of jerkiness or



PANEL DIMENSIONS

Fig. 3. Overall measurements are given here, and the relative positions on the panel of the chief components

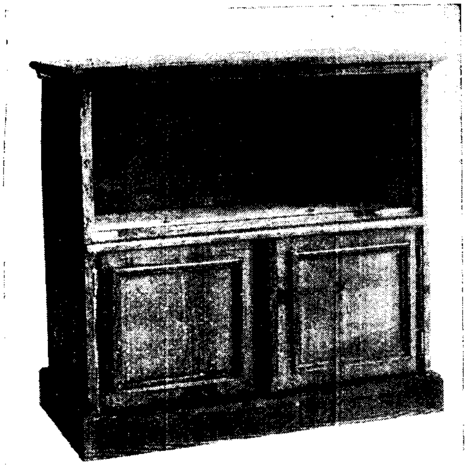


Fig. 4. With batteries and telephones enclosed in the lower compartments, the set is entirely protected from dust

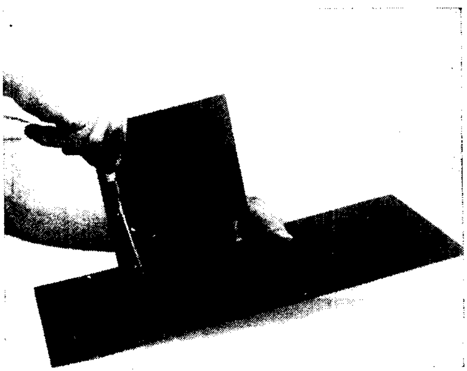


Fig. 6. How the valve panel is fitted to the front of the set by means of two strips of angle brass

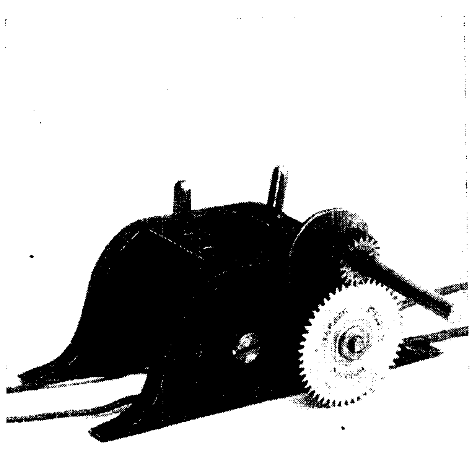


Fig. 8. A slow, even movement of the reaction coil is obtained when gearing is employed

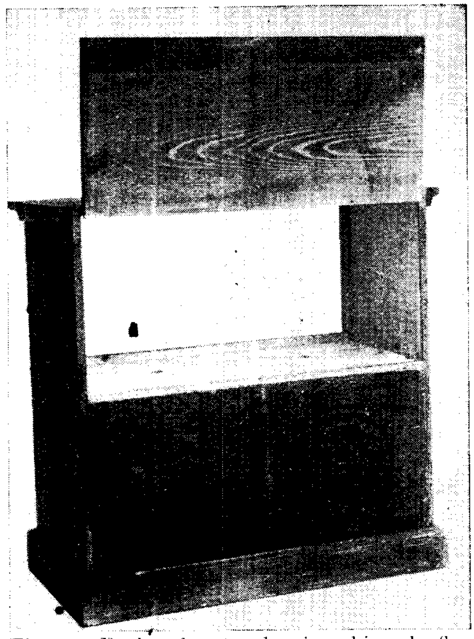


Fig. 5. Back of set, showing hinged flap providing access to the valve and wiring behind the ebonite panel

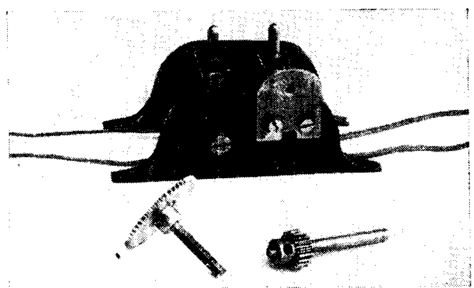


Fig. 7. Geared coil holder for the set, showing the small spindle and gear detached

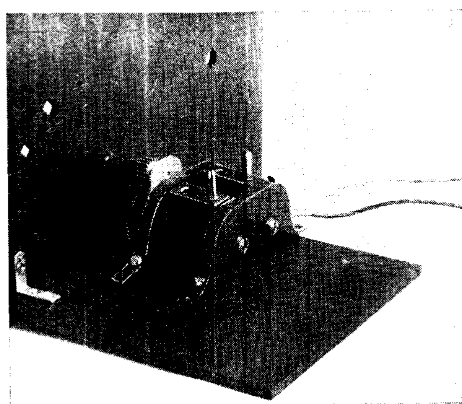


Fig. 9. Here is shown the method of fitting the coil holder behind the panel, with the gearing in its proper position

CABINET AND COIL-HOLDER ARRANGEMENTS OF THE REGENERATIVE SET

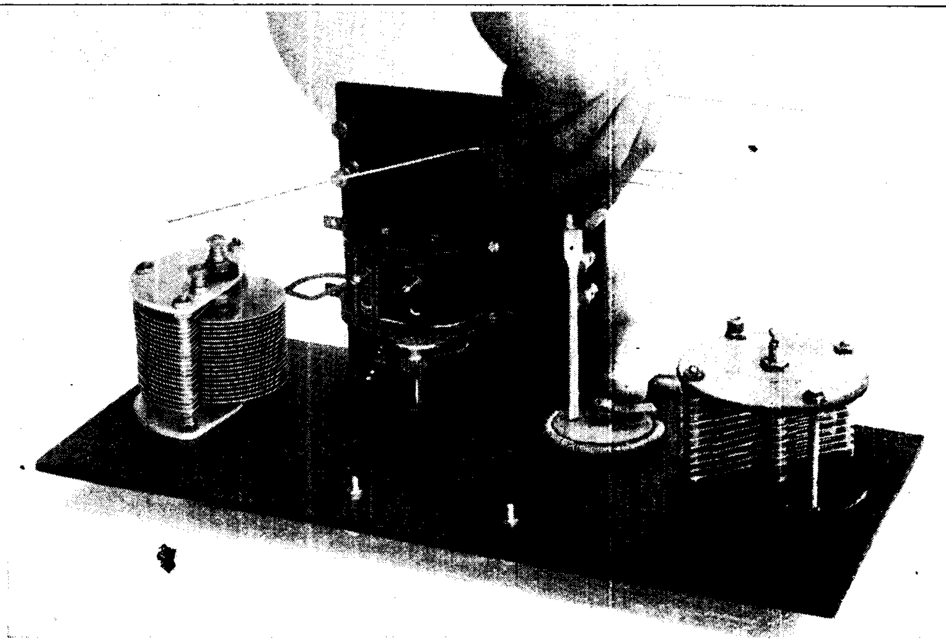


Fig. 10. The location of the coil holder, valve holder, rheostat and variable condensers. The valve holder is so placed as to ensure clearance of the moving coil

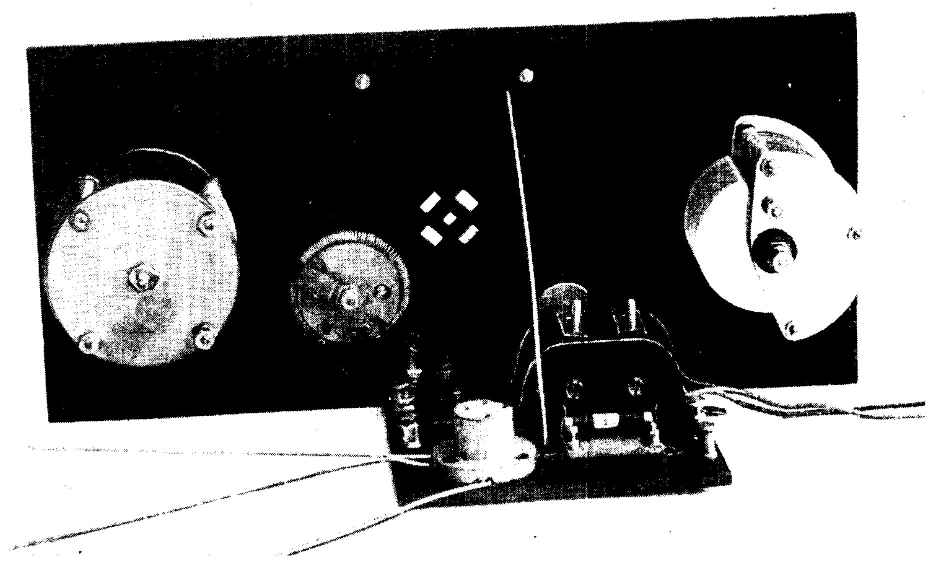
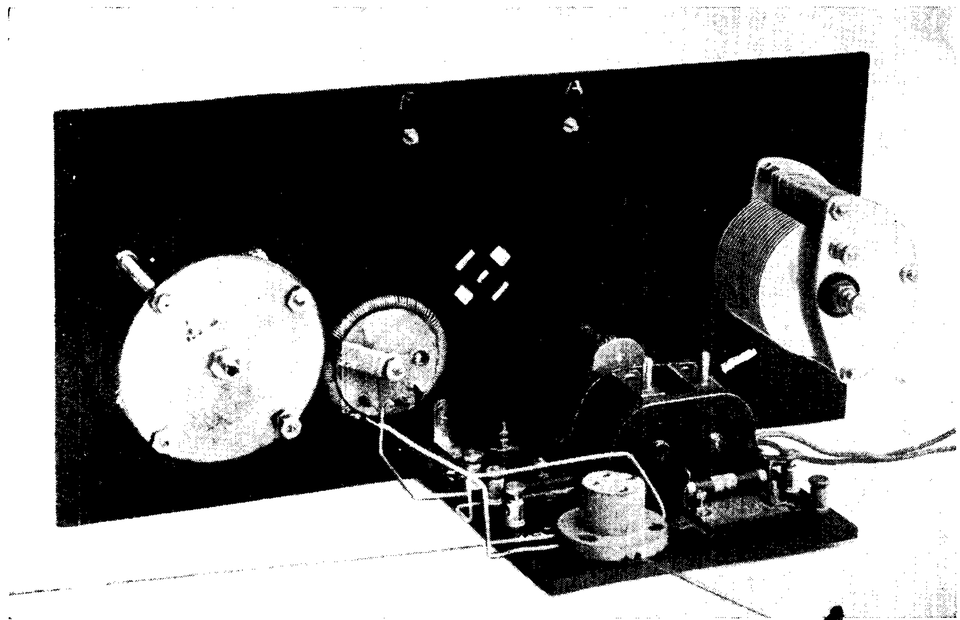


Fig. 11. In wiring, the first step is to connect the leads from valve holder and coil holder

EARLY STAGES IN THE ASSEMBLING OF THE SET

any tendency to jam. The coil holder itself may be any of the sound commercial patterns or built up from ebonite, as described under the headings Coils and Coil Holders.

When completed, this part of the apparatus is secured to the valve platform, as shown in Fig. 9, by four brass screws tapped into holes in the platform. Care must be taken to allow sufficient space for the movement of the anode coil and for the insertion of the aerial tuning coil.



FURTHER STAGE IN WIRING THE REGENERATIVE SET

Fig. 12. Terminals are shown fixed to the valve platform for high- and low-tension battery leads and the filament circuit is shown wired up

A flanged valve holder is then secured to the back of the valve platform in such a position that movement of the anode coil will not be impeded by the presence of the valve, and the filament rheostat fixed in place, as in Fig. 10.

Terminals are fixed to the valve platform for the high- and low-tension battery leads, and for the telephone connexions. The grid leak and condenser are then secured in their place, as is visible in Fig. 11 and several of the illustrations, and the wiring commences. Various stages are illustrated in Figs. 10 to 14. The work should be carried out progressively and each connexion thoroughly well made, either by terminal nuts or by soldering, taking care in the latter case to clean off all traces of soldering acid or flux.

The wiring is then carried out from the five terminals on the valve platform, care being taken to connect one side of the regenerative condenser to the anode terminal of the valve, as the set will not function properly if this connexion is made to the opposite side of the anode inductance coil. When the wiring is completed each part of the circuit should be tested for continuity, and when all is in order, flexible wires are attached to the terminals and connected to the high- and low-tension batteries respectively, and to the telephones, these wires passing through circular holes drilled through the shelf.

The panel is then inserted from the back of the case, as in Fig. 15, and bears against fillets or moulded pieces in the front of the case. It is secured by small fillets screwed to the case at the back of the panel after the latter is in its place. Connexions to the batteries are best effected with wander plugs or spade terminals, according to the nature of the battery. The latter will depend upon the type of valve used, that shown in the illustration Fig. 16 being the Marconi-Osram R type. The telephones used with this set should be of high resistance, at least 2,000 ohms, unless a telephone transformer be incorporated with the set, in which case those of low resistance may be employed.

If greater signal strength is needed, this set can be used in conjunction with a one- or two-valve low-frequency amplifier, which can, if desired, be incorporated in the space beneath the set for the batteries and telephones, and these accommodated elsewhere. Thus the set can be developed from a single-valve receiver, as shown complete in Fig. 18, to one of two or three valves, with power for operating

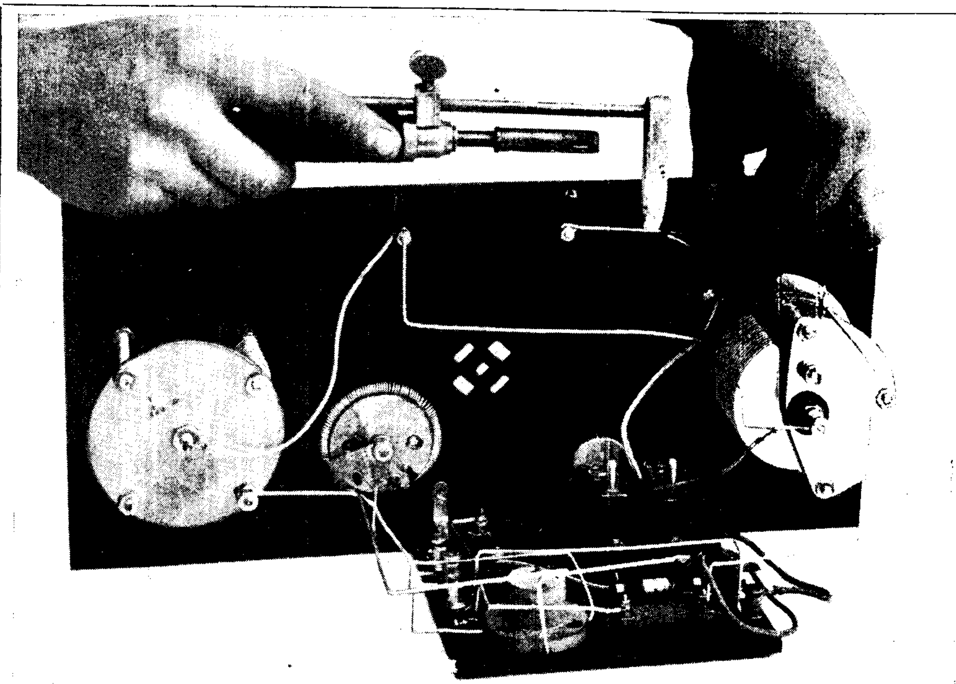


Fig. 13. The aerial circuit is now being wired up, the filament circuit having already been entirely connected as shown in Fig. 12

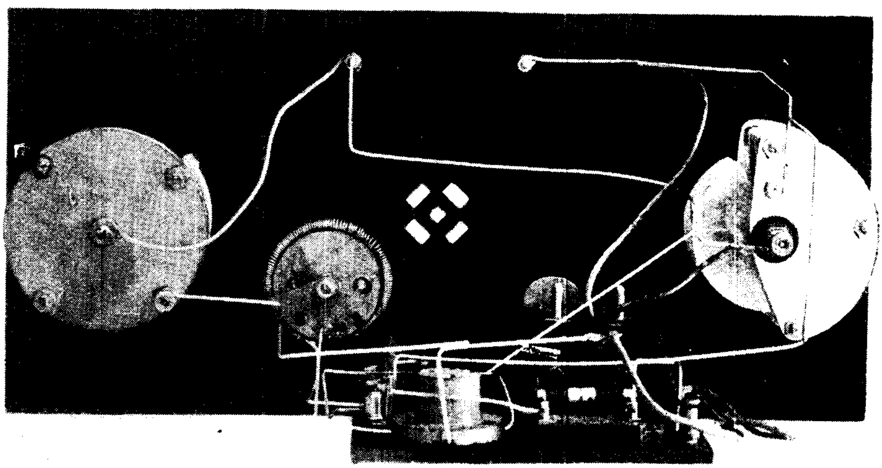
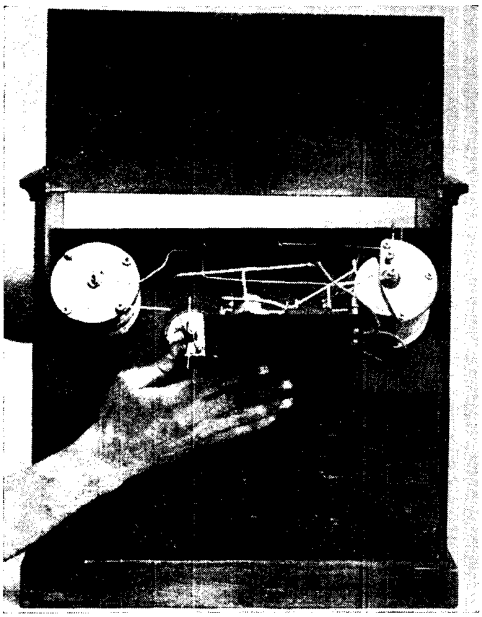


Fig. 14. Perhaps the leading impression that one gathers from the completed wiring is its simple appearance. The back of the panel is neat and compact

REGENERATIVE SET: FINAL STAGES IN THE WIRING

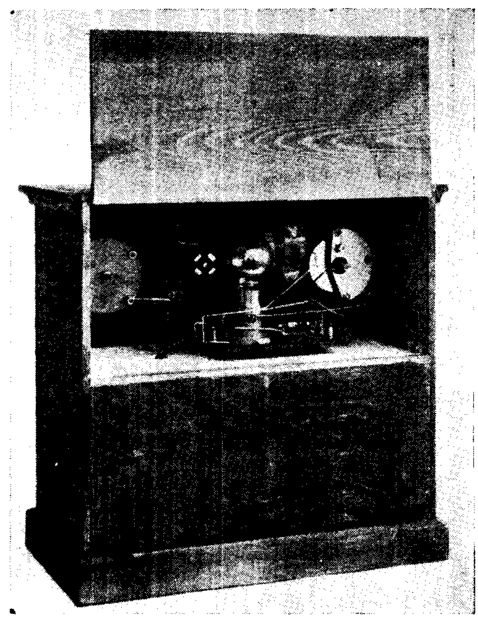
a loud speaker up to, say, 50 or 60 miles from the broadcast station.

At the first attempt to tune the set, place a No. 35 honeycomb coil or a No. 2½ Burndept in the aerial coil holder, and a No. 75 coil in the reaction coil holder. Adjust the latter until it is about half-way from the aerial coil, doing this by rotation of the left-hand knob towards the left. Turn the filament current on until it is nearly full on, and rotate the aerial tuning condenser. The regeneration



FITTING THE PANEL

Fig. 15. How the panel is inserted in the cabinet from behind. Fillets prevent it from moving when in position

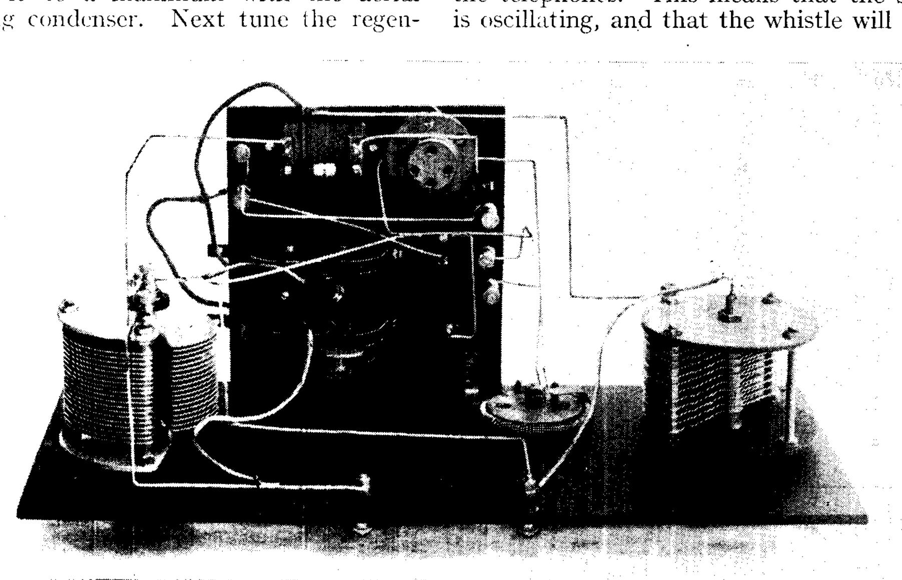


NEARING COMPLETION

Fig. 16. The panel is now in situ inside the case and the front panel fixed into position. A Marconi-Osram R valve is used

condenser should meanwhile be at zero coupling.

As soon as a signal is heard, carefully tune it to a maximum with the aerial tuning condenser. Next tune the regeneration condenser until the maximum signal strength is obtained. At this stage there may be a shrill whistling sound in the telephones. This means that the set is oscillating, and that the whistle will be



WIRING OF THE COMPLETED PANEL

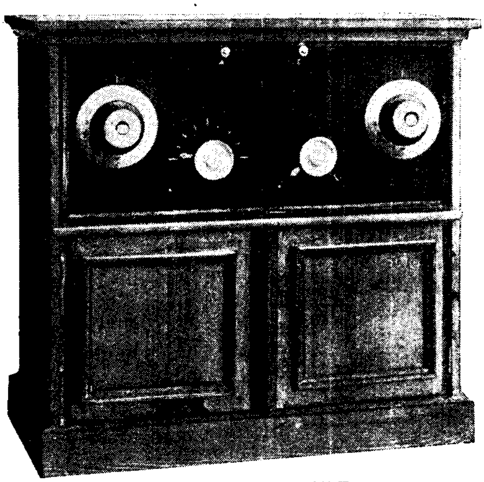
Fig. 17. Seen thus in plan, an excellent idea of the wiring system may be gathered. The constructor is recommended to study this photograph in conjunction with the wiring diagram, and along with Figs. 9 to 14

heard by all the listeners for a mile or more around. Check this instantly by detuning with the regeneration condenser, by reducing the filament brightness, or by loosening the coupling between the reaction and aerial coils. The best results are given from a loose coupling between these coils, especially for the near-by stations.

There is one critical position where the regeneration condenser and the degree of coupling between the reaction and aerial coils give very loud and stable signals notably free from distortion. The filament adjustment is very critical for the best results, the slightest movement making all the difference between harsh and pure reproduction. The signals are, however, quite easily picked up when the reaction coil is loosely coupled; there is therefore no reason for the set to oscillate or cause any annoyance while searching for a station. When a carrier-wave whistle is heard in the telephones from a distant station, the aerial condenser should be left at that setting, the coupling tightened, and the regeneration condenser adjusted to give the loudest signals, completing the tuning by a fine adjustment of all the controls.

In general, the more distant the station the tighter the coupling may be before the set will oscillate or howl.—*Edward St. John.*

A set which has several advantages for both the dweller in the country and the town resident is shown in the illustration,



SET READY FOR USE

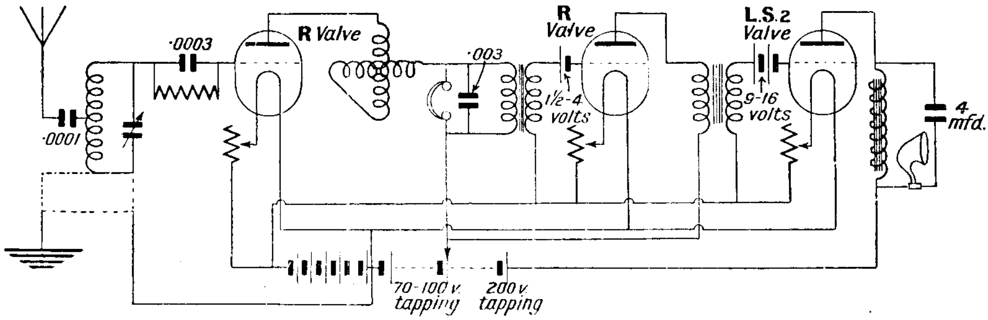
Fig. 18. One of the outstanding merits of the set whose evolution has been traced is that with comparative ease it can be converted from a single-valve to a two- or three-valve set

Fig. 22, on the photogravure plate. The set is a one-valve regenerative receiver to which a two-valve low-frequency amplifier has been added. Although the receiver as photographed has been included in one cabinet, it is best regarded as being in two distinct parts, which may be constructed separately or together, according to the conditions which it is required to meet. Reference to the circuit diagram (Fig. 19) will make this clear. The one-valve regenerative receiver can be constructed as far as the telephones, and will then be complete in itself. It will give good results ten miles or so from any B.B.C. station if connected to a large frame aerial or to a gas pipe or water pipe without an earth lead. It will, of course, give excellent results on an ordinary outdoor aerial; but if it is so connected very great care must be exercised in its use, as, since reaction is given by coupling on the aerial tuning inductance, there is a risk of re-radiation, particularly if an earth lead is also used.

When used on a fair outdoor aerial 30 miles from London, badly shielded by trees, 2 LO and 6 BM are brought in at good loud-speaker strength with the addition of the two-valve L.F. amplifier. Without the amplifier, London, Bournemouth, Newcastle and Birmingham are brought in on the telephones.

The circuit is based on an American design, its special points consisting of an inductance coil tapped at the centre, to which the aerial or gas-pipe lead is connected, with a ·0001 mfd. fixed condenser in series. The effect of the series condenser with the centre tapping is to make the tuning aperiodic, so that practically no variation in tuning occurs whatever the wave-length of the aerial, gas pipe, or other receiving arrangement. Reaction is provided by means of a good quality variometer with fairly heavy gauge windings, which is partly inserted in the inductance coil former, as seen in Fig. 27 on the plate.

It is essential that this variometer should be of high efficiency and minimum capacity. That seen in the photograph is a General Radio Co.'s instrument, in which the stator and rotor are not only extremely close together, but are so wound that formers are altogether dispensed with. Any other good quality condenser, such as the Edison-Bell, Bowyer-Lowe, Igranic, or E.E.C., may be used.



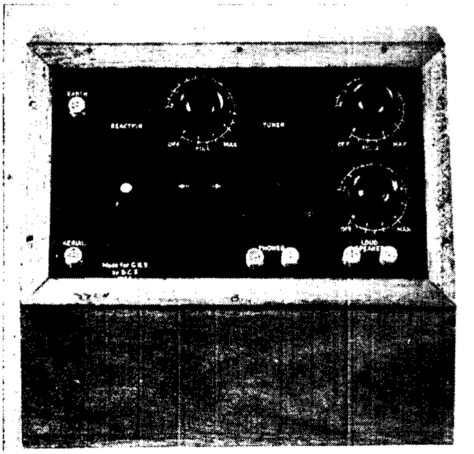
AMPLIFIED REGENERATIVE CIRCUIT DIAGRAM

Fig. 19. Two valves, one an R and the other an L.S.2, form the amplification, for loud-speaker purposes, of the single-valve regenerative circuit

The photograph of the complete set, Fig. 22, shows the general features of the receiver. The variometer dial on the left governs the reaction, and once it is set it hardly requires any alteration. All the tuning, which is quite sharp, is effected by the condenser dial in the centre, half a revolution of the vernier knob being sufficient to cut a station out completely.

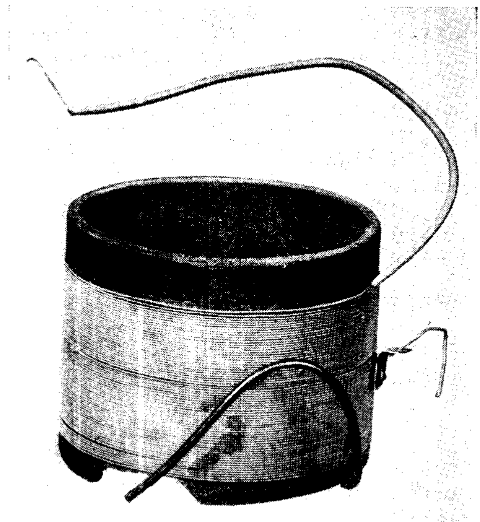
This condenser should have a maximum value of ·00025 mfd. If this capacity is exceeded it will be impossible to tune in the lower wave-lengths in the B.B.C. band. Above the tuner are two neat opaline valve windows; the other three controls are the valve rheostats. Separate terminals are provided for telephones and loud speaker, a switch on the case cutting out the L.F. valves when not required. All battery leads, five in number, are brought to a valve holder which plugs into a hole cut into the side of the cabinet, as seen on the right in Fig. 22, the corresponding ebonite bracket carrying the valve legs being seen in Figs. 25 and 27.

An interior view of the cabinet showing the wiring completed and the valves in place is given in Fig. 23. Exact dimensions for the cabinet and the panel, which is seen more clearly in Fig. 20, are not given, as the experimenter will find it best to suit both the size of his cabinet and the dimensions of the panel to the actual components which he uses. It is better to err on the side of generosity in dimensions, since crowding is dangerous in regenerative circuits. The series of photographs will show clearly the disposition of the various parts, and it is sufficient to say that the



THREE-VALVE REGENERATIVE SET

Fig. 20. The disposition of components is obvious. Rheostats here are in position and holes have been drilled for variometer and condenser



INDUCTANCE COIL

Fig. 21. Aperiodic tuning is given by central tapping for aerial lead. The former is cut roughly to fit over the reaction variometer