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HARMSWORTH'S WIRELESS ENCYCLOPEDIA

For Amateur & Experimenter

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MARCONIPHONE RECEIVING AND AMPLIFYING SETS

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MAGNETISM EXPLAINED

FINE PHOTOGRAVURE PLATE:
A NOVEL LOOSE COUPLER

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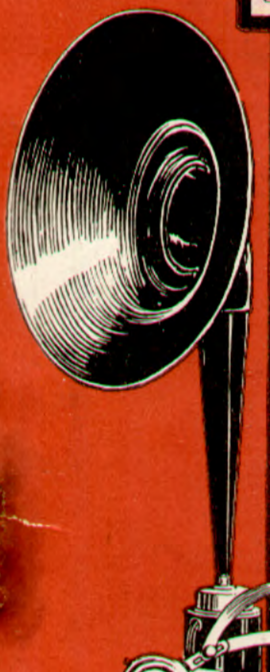

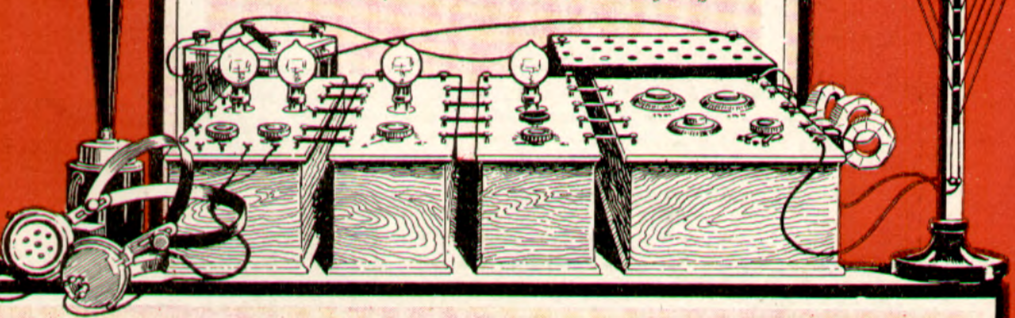

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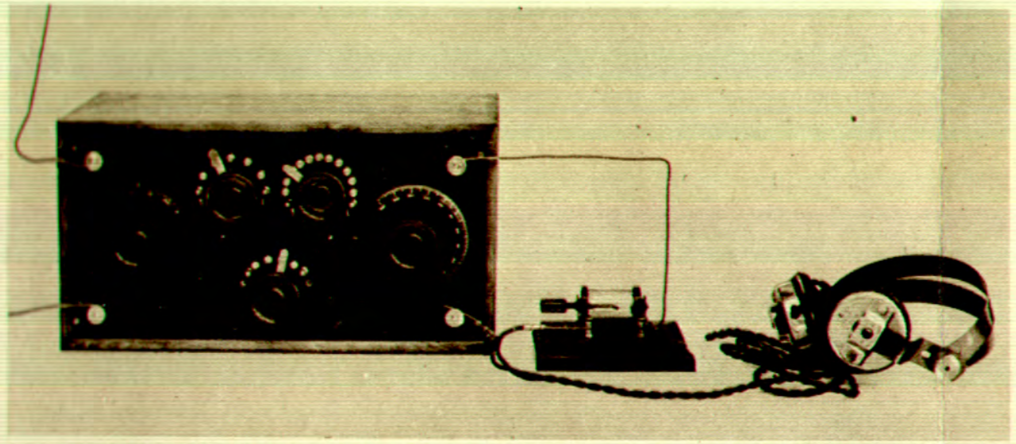

Fig. 10. Home-made loose coupler complete in its dust-proof cabinet, wired up to a crystal set

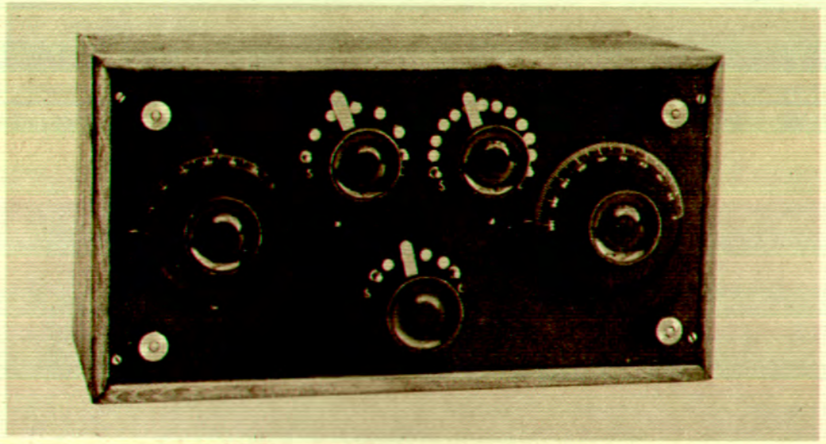

Fig. 11. Front of panel with stud-switches and rotor controls. Studs marked S and L indicate short and long waves

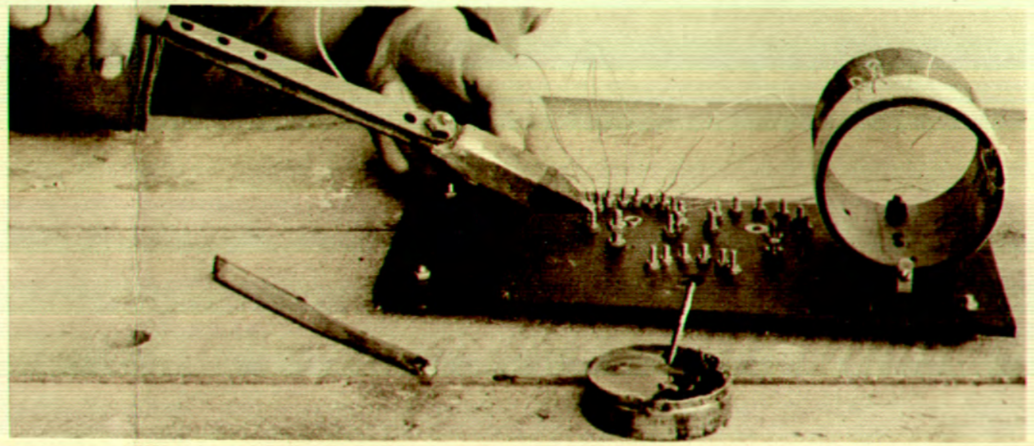

Fig. 12. Lengths of wire are soldered on to the contact studs before the second coil is mounted, so making connexions easy

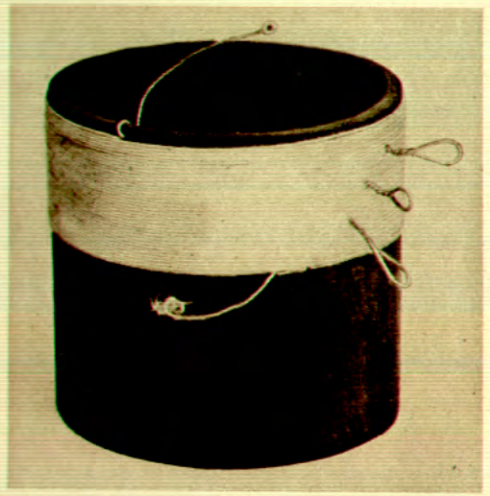

Fig. 13. Secondary coil and its tappings, showing hole for rotor shaft

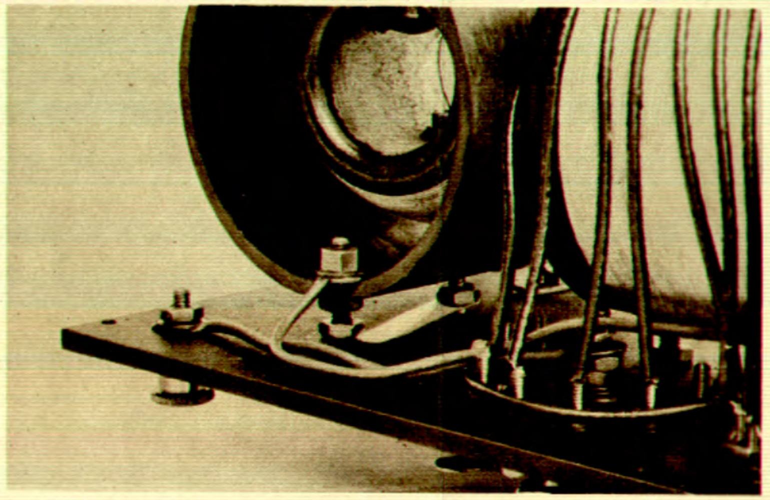

Fig. 14. How the secondary coil of the loose coupler is mounted on a 2 B.A. rod

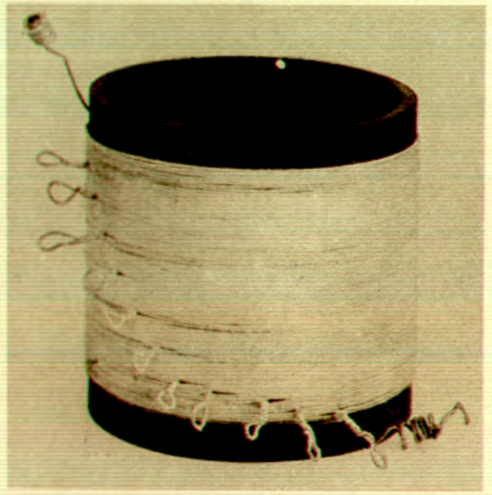

Fig. 15. Primary coil and its tappings. This should be compared with Fig. 13

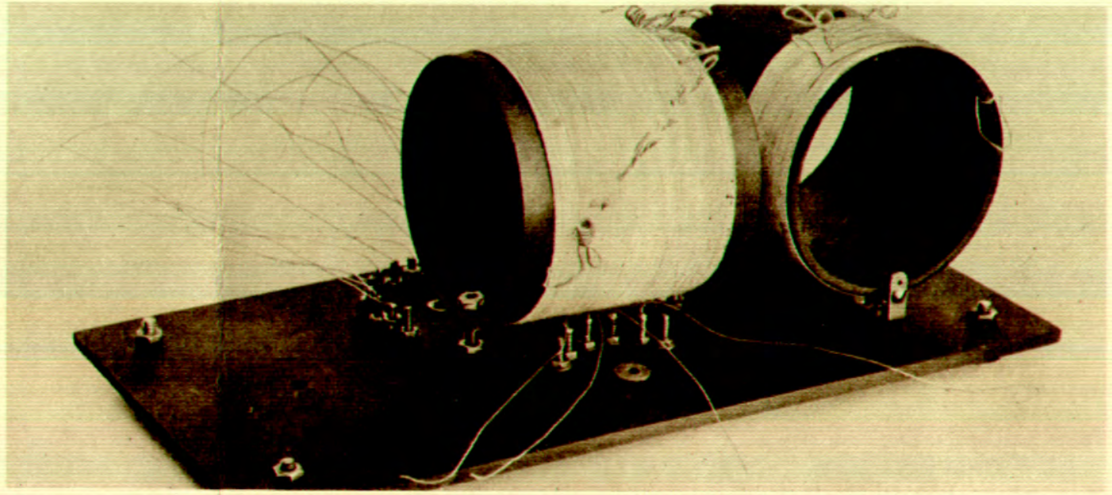

Fig. 16. Mounted on the back of the panel are the two coils in position ready to be connected to their switch-studs

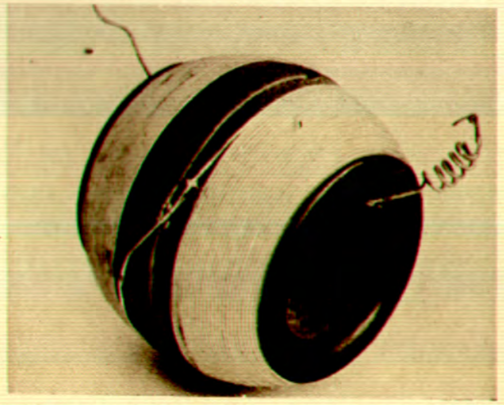

Fig. 17. Rotor used for tuning in short wave-lengths shown complete

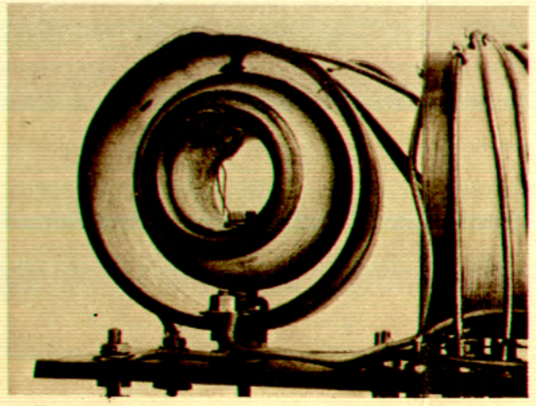

Fig. 18. The rotor of the primary coil in position showing connexions

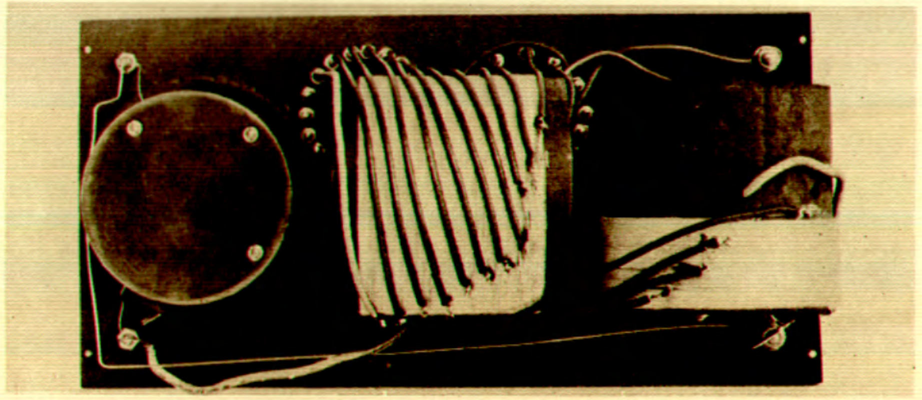

Fig. 19. This is a view of the back of the panel of the complete loose coupler showing the coils with their tappings and the condenser

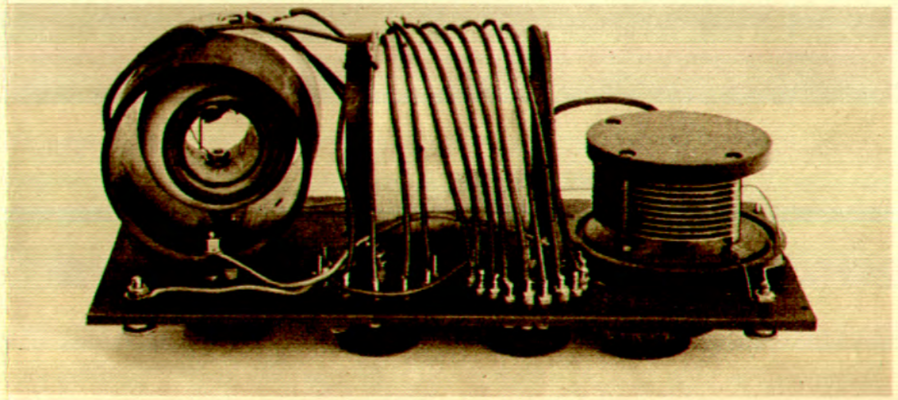

Fig. 20. Another view of the loose coupler panel in which may be seen the arrangement of the complete instrument

LOOSE COUPLER: HOW TO CONSTRUCT A LOOSE COUPLER CONTAINED IN A CABINET AND FORMING A HIGHLY SELECTIVE TUNING UNIT WHICH MAY BE USED WITH ANY RECEIVER

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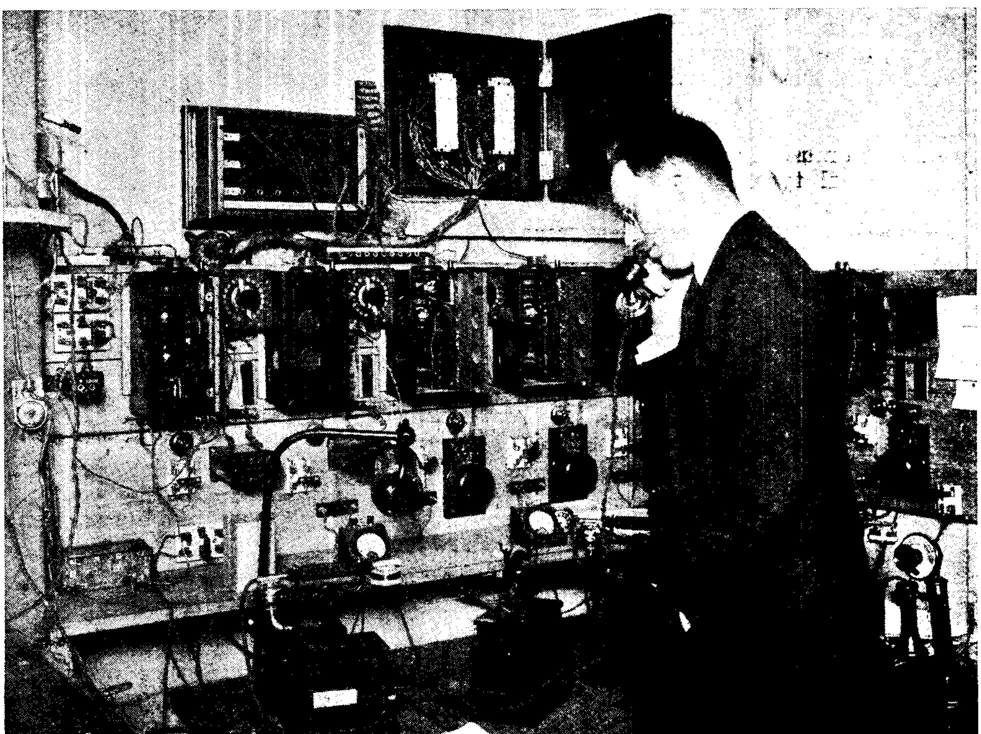
From photographs of an instrument specially constructed for HARMSWORTH'S WIRELESS ENCYCLOPEDIA

degree, his blasting meter, however, making it a matter of direct observation to measure actual over-control. In passing, it may be noted that experience shows that meters to indicate degree of control, blasting, quality, and so forth are essential; the personal equation cannot be relied upon for really accurate judgment.

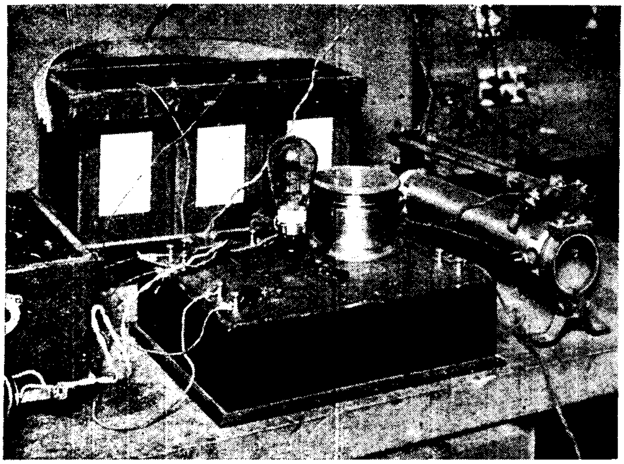
The procedure for ordinary studio broadcast is as follows. The announcer, when ready to start a programme, presses a bell-push in the studio—the signal that he requires the microphone sensitized. (It is assumed that some five minutes before an engineer's test proves that all is ready, magnetizing current on quality correct, batteries charged, and so on.) Immediately the push is worked in the studio a buzzer is energized above the appropriate amplifier, the operator brings the control to medium, the announcer announces, and the item is then given. After the song the announcer asks for a minute's pause, and the control engineer brings his controls quietly back to zero sensitivity. The engineer, furthermore, has a switch handy which controls the lighting of red lights over the studio doors, inside and out. When the microphone is sensitive the red lights are on; when the lights are off all and sundry may move in and out of the studio, laugh and talk. Thus there is no noisy mechanical switching, and the broadcast comes on without warning and fades out as it finishes; the illusion of air-borne sound mysteriously conveyed to listeners' homes is thus more nearly achieved.

A switch cuts off the output from the amplifier to the transmitter, and thus tests may be made without radiating rehearsals from the aerial. To this end 'phones are tapped off the amplifier, and wires are run right back to the little room just off the studio. This room has a small window giving a view into the studio, and thus a broadcast producer may rehearse his performers and keep an eye on their movements, opening the window and issuing his instructions therefrom.



CONTROL APPARATUS FOR SIMULTANEOUS BROADCASTING AT 2 LO

Fig. 3. Lines from the seven principal provincial stations terminate at this point, and when simultaneous transmission is in progress each of these lines is fed from a common source. When the London station is simultaneously broadcasting the operator controls the seven lines at once, while the output for the London area is being broadcast at the same time



APPARATUS FOR BROADCASTING TIME SIGNALS

Fig. 4. Greenwich time signals are broadcast direct from the Observatory, without any relaying, via the London Broadcasting Station by means of the apparatus seen in this photograph

(A precursor of television and an uncanny feeling, I may assure you; it is frequently impossible not to imagine oneself in the room.)

It has been found that the engineer is, perhaps, not the person of best mentality to control; someone of more artistic and musical make-up probably fills this post better. Thus ideally (the controls being so simple) a musical and artistic controller is more ideal for the job, the engineer standing by in case anything goes wrong. Of course the "musical engineer" fulfils in one man all the essentials, but he, unhappily, is rare.

It is part of the controller's functions to judge balance as between instruments, or accompanist and performer, and thus if he judges a band to be incorrectly balanced, he telephones through to the announcer, giving his recommendations. This point becomes less and less important with our bigger studio, where performers are frequently 15 and 20 ft. from the microphone, and the announcer more used to placing as a result of accumulated experience.

I have spoken of two amplifiers in the same room, but this is looking ahead to the time when we have two stations—one for the "highbrow" and one for the "low-brow" concert.

In the same room as the amplifiers will be found the "simultaneous board" (Fig. 3.), by means of which the broadcast can be distributed all over the country to our various main stations. There is a large terminal board on which terminate the lines from our seven provincial stations; there are also blanks ready for such relay stations as may be fed from London. Each line terminates on the simultaneous board proper. This consists of a large vertical panel with female jacks in long rows vertically downwards. There are drop indicators above every line to give a visual signal when any provincial station rings London. Switches on each line serve to switch over each or every pair to the ordinary exchange board, so that the office telephones may be connected to the private trunks. This is, of course, useful when the lines are not being used for broadcast, and ordinary company's business is facilitated by direct 'phone connexion. On a vertical desk-like portion of the board will be found the line amplifiers, one for each line. Each of these amplifiers has its input and output terminals connected to a female jack, the cords of these jacks being concealed below the vertical portion and held in place by pulley weights. The arrangement is, in fact, similar to that at any private branch telephone exchange and works in a very similar way.

If it is desired to broadcast from London outwards, the London input wire, with its row of vertical parallel female jacks, is connected to each of the inputs of each of the amplifiers, the output of these amplifiers being taken to one of the female jacks of the provincial station line.

If, say, Newcastle is giving its broadcast to all other stations, then all the inputs of the amplifiers are put into the Newcastle row of parallel females, the outputs of each individual amplifier going to each of the other provincial lines, and through a special connexion circuit amplifier to London. The correction amplifier raises the pitch of the incoming broadcast from the distant station, the pitch having being lowered by the capacity effect of the long trunk line. This is a point which always has to be borne in mind in relaying operations.

The simultaneous board operator is given a telephone magneto ringing instrument terminating on a female jack, and he can thus communicate with the local transmitting station or any provincial station or a place of outside broadcast and such other points as are found desirable.

One man operates the whole system, and being in the same room as the studio amplifier controllers, can give his instructions to them direct. The simultaneous board operator is considered as in charge of all arrangements.

Outside Broadcast

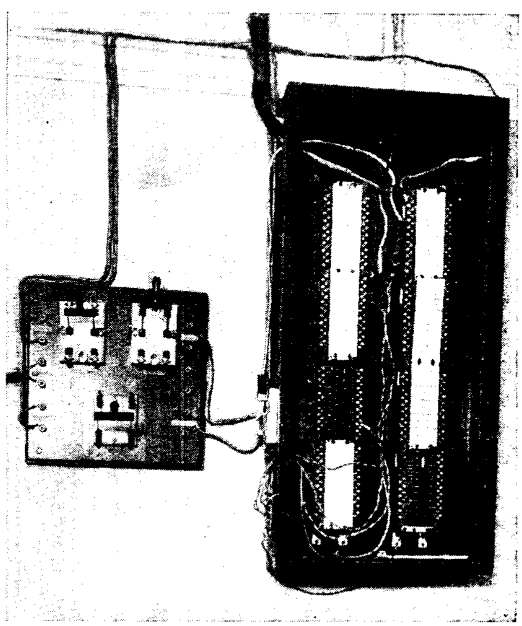
A special section of three or four men is in charge of all outside broadcast work. Their equipment consists of a number of spare microphones and portable amplifiers exactly similar to the first-stage amplifier for the studio work. Their job is to go to the place (banqueting hall, ballroom, concert hall, or whatever it may be), and there instal the amplifier and microphone. A special wire is laid between the place of outside broadcast and a special terminal board in the amplifier room. To one end of this line is connected the output terminals of the first-stage amplifier at the place of outside broadcast; the other end terminates on the input side of the main studio amplifier. A second line for ordinary telephone communication terminates on a hand telephone conveniently placed for the amplifier control engineer.

Thus before the show begins the outside broadcast engineer gets in touch with headquarters, and at the word go, switches through the broadcast. The control engineer accepts this, switches it through his amplifier, brings it up to the desired strength, and carries on controlling just as if the broadcast were coming from the studio. Should anything go wrong, this is immediately apparent to the outside broadcast engineer at the far end of the line, who is using a portable wireless receiver to check outgoing broadcast.

Late in 1923 the wireless link was developed. It dispenses with the necessity for land lines between Savoy Hill and the place of outside broadcast. In this case the microphone equipment is the same as before, but the output terminals of the first-stage amplifier are placed across the input terminals of a small 30 watt wireless transmitter working on a low wave-length. The radiations from this transmitter are received at Savoy Hill on a specially selective receiver. The output terminals of this receiver terminate upon the input of the main amplifier, thus forming a link, without the need of wires, between headquarters and the place of outside broadcast.

A further combination can be used in which the wireless receiver can be several miles from London, a wire between receiver and headquarters forming the link. The wireless receiver then serves to pick up any wireless emissions that it may be desired to broadcast. In the relaying of American transmissions at the end of 1923 we received the American emissions at a point high on the North Downs; the output of the receiver was put to a land-line which ran to Savoy Hill, and was there paralleled through suitable amplifiers to London, the provinces, and the Sheffield relay station.

It is by combining wire and wireless that sounds may be distributed all over the kingdom, the simplest receivers sufficing for reception of the weakest arriving signals, which could otherwise only be apprehended by the most complex apparatus.



LONDON THEATRE TRANSMITTING BOARD

Fig. 5. This is known as the theatre line board at the London station. When transmissions from the theatres connected to the broadcasting station are being sent out this apparatus switches on or off, but the control of the actual transmission is similar to the ordinary transmissions from the studios

The transmitter at the London station is of standard design, but some discussion of its properties may be interesting.

In the main the circuits are of straightforward design—in fact, one may say that for broadcasting it is far better to use the simple, straightforward circuits, both in transmitting and reception, if good quality is to be maintained.

Thus the 2 LO arrangement embodies a simple choke control system of modulation with a sub-control valve for amplification. The high-frequency circuits are only peculiar inasmuch as the ordinary reaction system is abandoned and instead a master oscillator applies a fluctuating potential between grid and filament of the main oscillating valve, so that absolute wave constancy is assured.

Modulation at the London Studio

Dealing with these points in detail, let us first examine the modulation system. The wires from the studio terminate on a transformer which has its secondary connected across grid and filament of the sub-control valve. This valve is treated so as to avoid distortion, and negative bias is applied to the grid. The impulses arriving from the studio are magnified by this valve by a resistance-capacity arrangement, and the magnified impulses are passed on to the main control valves. These valves, four in number in parallel, dissipate 1½ kilowatts in the steady state. The anodes are of the molybdenum type and run at red heat continuously. The choke is of closed iron construction, and is arranged to deal with the full magnetizing current without saturation. Across the choke is connected an electrostatic voltmeter reading up to 10,000 volts, and this voltmeter naturally measures the R.M.S. value of the modulation. In the grids of the main control valves is connected a grid-meter for registering grid current, and this, as has been pointed out before, is calibrated against a similar meter in the studio.

Thus the engineer on duty at the transmitting station, although he does not control the broadcast, can at any rate watch the volume-meter, which is an indication of whether the whole set is working, and can also at times give information over the telephone to the control people in the studio as to the amount of modulation being registered.

The ideal arrangement would be for the control engineer at the studio to be able to read the electrostatic-meter, and an aperiodic volume-meter should be arranged in the studio, but this is a somewhat difficult matter if it is to give an adequate indication, and thus the dual control with the volume-meter in the transmitting-room is a practical compromise.

The master oscillator is driven from the same high-tension supply, 10,000 volts, as the modulators, as well as the main oscillator. The condenser for the master oscillator is of the air type, and is specially constructed to avoid brushing or dielectric losses. The filaments are lighted one and all from direct current in order to avoid any hum that might be occasioned were they fed from transformers and alternating current. The power supply, however, is from alternating current at the beginning, and a 500 volt, 300 cycle alternator is paralleled across the primary of the main input power transformer. The secondary of this transformer gives power at 10,000 volts, and the two outers of the transformer are connected across the anodes of a bank of rectifiers whose filaments form the positive supply to the main set. In order to smooth the unidirectional impulses to direct current, large chokes and condensers are used, and these are arranged to overcome any alternating current hum.

Ideals and a Big Safety Factor

The interesting point about the whole set is that it is designed with an enormous factor of safety, whereas in a commercial design it would be necessary to sacrifice certain ideals. Every circuit is equipped with instruments to read feed currents and voltages, as it is found that it is absolutely necessary to measure every quantity to keep a constancy of adjustment.

The aerial is of the twin-sausage type, and is slung some 70 ft. above the roof of Marconi House. It is intended to move the station elsewhere, probably to the roof of a large building in Oxford Street, where it is contemplated that the aerial will be 150 ft. from the level of the roof and slung on steel lattice towers.

It is interesting to note that probably far more radiation is obtained from a roof aerial than from a ground aerial; that, in fact, the building helps to radiate and adds to the effective height. Thus one cannot say that the height of the aerial at Marconi House is only 70 ft., because in some experiments that were carried out with an earth screen to cut out the building, although the aerial amperes were increased, radiation was no better.

LONG-WAVE RECEIVER AND HOW TO MAKE IT

A Simple but Very Efficient One-valve Receiver for Wave-lengths over 2,000 Metres

If an ordinary short-wave or broadcast receiver is loaded for the reception of long-wave signals its efficiency is considerably reduced. Here is described an easily constructed instrument of high efficiency for such work which may be coupled to any amplifier. **See also High Frequency; Short Wave**

A long-wave receiver is an apparatus designed for the reception of signals transmitted on long wave-lengths, in contradistinction to broadcast or others which are known as short-wave receivers. It is found that the efficiency of a receiving set of short-wave type is considerably reduced when called upon to receive signals on a long wave-length. An example of this is found in a set using the tuned anode method of high-frequency amplification, where the efficiency of the amplifying valve is very considerably reduced on wave-lengths over 2,000 metres. Above this wave-length resistance-coupled high-frequency amplifiers are recommended.

It does not follow that a long-wave receiver need be a multi-valve set of high power, which is often assumed by the uninitiated. The set described herewith, and illustrated in Fig. 1, will bring in long-wave signals at very considerable strength.

A.T.I. with Fixed Reaction

The principal feature in its construction is the aerial tuning inductance with fixed reaction coupling. This is shown completed in Fig. 2, and a view of the rear, showing the position of the reaction coil, in Fig. 3. It consists essentially of six basket coils mounted on a common spindle, the ends of the coils being brought to a stud switch, enabling any number of the coils to be included in the aerial tuning circuit at will. Another and smaller coil is inductively coupled to these coils to obtain a reaction effect from the anode to the grid circuit.

The remainder of the components, as seen in Fig. 1, comprise a ·001 mfd. variable condenser, which is wired across the aerial tuning coils, and the essential features of a single valve detector. For the sake of simplicity the components are mounted on a common baseboard. In the construction of this receiver the experimenter is at liberty to choose any components suitable for the valve detector, as this follows standard practice. The value recommended for the grid condenser is ·0003 mfd., used with a grid leak of 2 megohms. Any type of receiving valve may be used. In the illustration, in Fig. 4, of the set wired up ready for use a soft Dutch valve is used, and this is well suited to purposes of rectification. If this type of valve is used, care must be taken not to exceed the plate voltage of the valve, which has a maximum efficiency at about 30 volts.

For the tuner two pieces of $\frac{1}{4}$ in. ebonite are required, cut to squares of 3 in. One of these forms the base and the other the vertical face, on which is mounted the stud switch and the arm supporting the basket coils. Any convenient size of switch may be used having six studs. Two extra studs of greater height, one at either end, act as stop pegs and prevent the contact arm from being turned too far. The hole for the spindle of the contact arm is drilled centrally on the square of ebonite intended for the vertical face.

Having made the switch and a free, smooth action being obtained on the moving arm, the vertical piece of ebonite is mounted to the base piece. For this purpose a 3 in. length of $\frac{1}{2}$ in. angle brass is required. The back of the ebonite to which the switch is mounted is arranged against the edge of one of the ends of the base. This gives an unbroken front to the ebonite, the joining of the two pieces being at the back. Fig. 5 shows the assembled switch and squares of ebonite joined at right angles with the brass strip. As will be seen from this and other illustrations of the tuner, three countersunk screws are used on each panel for fixing the brass right-angle strip.

How to Build up the Tuner

A different view of the tuner in the present state of assembly is shown in Fig. 6. A hole of 2 B.A. tapping size is drilled $\frac{3}{8}$ in. from the top of the vertical panel and equidistant from the sides. The hole is tapped 2 B.A. and a 3 in. length of screwed rod screwed in until one end comes flush with the outside of the panel. In order to secure a good appearance this end should be first ground off and slightly rounded. A piece of ebonite tube of ⅜ in. external diameter is now cut off and slipped over the rod so that sufficient of the latter projects to enable a 2 B.A. nut to fix the tube rigidly in position.

Too much force should not be brought to bear upon this nut, as it may result in pulling the rod through the ebonite face. If this mistake is inadvertently made the trouble may be overcome by cutting another length of 2 B.A. tube and fixing a nut to the outside of the panel. This will make one end of it a secure fixing to the tube at the expense of the good appearance of the instrument. The assembly of the ebonite tube is shown in Fig. 7. The terminals are required on the base, and the holes for these may be drilled before the assembly of the coils. The holes are considerably counterbored on the underside to take a nut to be fitted to the terminal stems so that both lie below the level of the base. The terminals may be placed on the front panel or at either of the corners at the rear of the base as individual requirements suggest.

The next item in the construction of the tuner is the making of six identical basket coils. For this purpose 15 nails are pushed into holes in a wooden cotton reel drilled to receive them so that the nails project radially in the same plane at equal distances. The reel chosen should be small in diameter, a suitable size being ¾ in. diameter. If a reel of this diameter cannot be procured little difficulty should be experienced in turning or cutting down the end of a large reel.

Winding the Special Coils

Ordinary iron box nails of 1½ in. length are used. Having made this coil former, winding the basket coils may be commenced. The wire used is No. 24 gauge D.C.C., and in winding one or two turns are taken around any one nail and winding commenced by spacing round the wire on alternate sides of the former.

This operation is clearly shown in Fig. 8, which illustrates the coil half finished. The wire should be pressed down every half a dozen complete turns and no slackness in it should be allowed, as this tends to weaken materially the coil. Winding in the manner described is continued until the coil measures 3 in. in diameter. The free outer end of wire is secured by taking one or two turns round the coil. A better plan, which helps to strengthen the coil, is to bind it all round with cotton.

Should any difficulty arise in any part of the winding processes, fuller instructions and suggestions will be found under Basket Coils, which will help with the coils under construction. Fig. 9 shows a finished coil, from which the nails are being removed. After each coil has been finished and before the nails are removed the complete coil is immersed in a bath of melted paraffin wax. The first coil is now put aside and the remaining five finished. While the paraffin bath is still hot six circular washers of stout cardboard are cut, having a central hole of ⅜ in. diameter and an external diameter of 2 in. These are waxed in the same way as the coils, and placed on one side to dry.

The Inductance and Its Reaction Coil

For mounting the coils two pieces of ebonite tube of ⅜ in. internal diameter and any convenient external diameter, the thicker the better, are each cut to a length of ½ in. One is slipped over the ebonite rod fixed to the front of the instrument. After this a cardboard washer is added, followed by one of the coils. Alternate washers and coils are added until six are on. A 4 B.A. screw is inserted in a tapped hole in the remaining ebonite bush, which is now pushed along the rod and clamped tightly in position by means of the screw.

Fig. 10 shows the front of the instrument at this stage of the construction. The beginning of the winding of the first coil is taken to the aerial terminal. The end of the first coil is cleared of insulation and joined to the bare wire of the beginning of the second coil. This process of joining the end of one coil to the beginning of the next is carried on until the end of the last coil remains. Short lengths of 24 gauge tinned wire are now soldered to the six contact studs. With care this operation may be performed with the coils in position. Should there be any difficulty with the soldering, however, the coils may be slipped along the ebonite rod to allow more room for soldering connecting wires to the stud stems.

The six wires from the contact studs are covered with insulated sleeving and soldered in turn to the coils. The earth terminal is joined to the arm of the switch by connecting wire. Fig. 11 shows the tuner after connecting up the wires to the

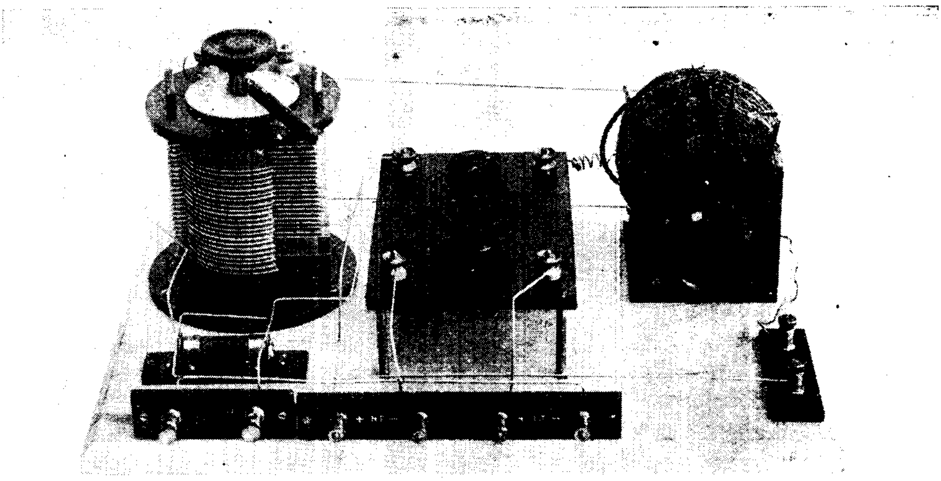


Fig. 1. Illustrated above is a receiver which will bring in long-wave signals at considerable strength. The principal features are the aerial tuning inductance with fixed reaction coupling

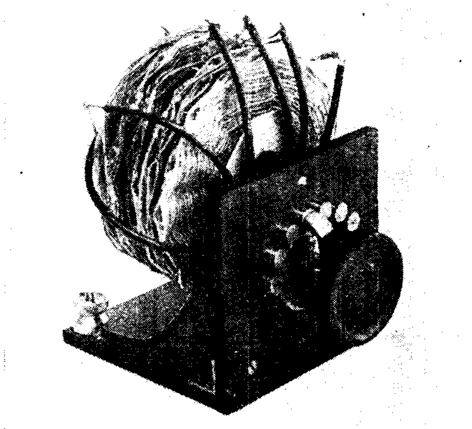


Fig. 2. Six basket coils mounted on a common spindle form the aerial tuning inductance

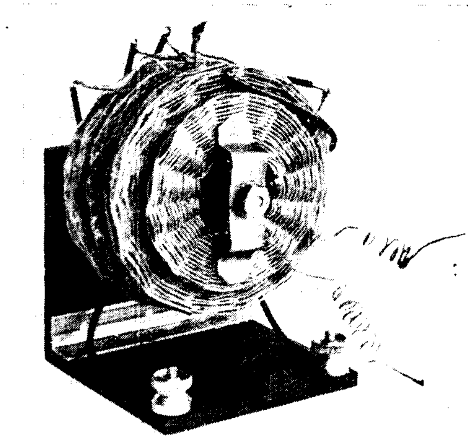


Fig. 3. Another view of the aerial tuning inductance showing the six reaction basket coils

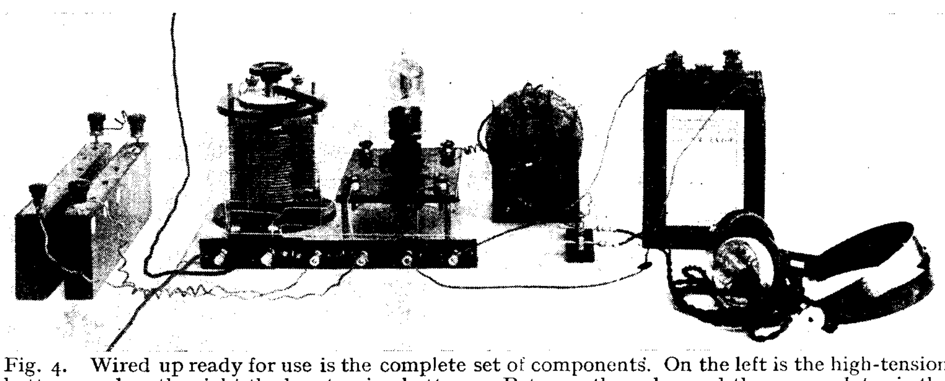


Fig. 4. Wired up ready for use is the complete set of components. On the left is the high-tension battery, and on the right the low-tension battery. Between the valve and the accumulator is the inductance unit, which, as will be seen in Fig. 2, is operated by a stud switch

LONG-WAVE RECEIVER AND ITS COMPONENTS

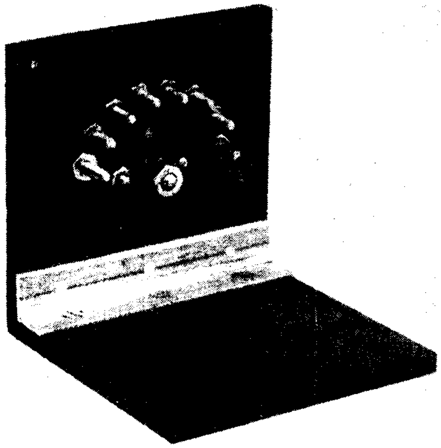


Fig. 5. A brass angle piece and screws hold the switch panel and base of ebonite together. The backs of the studs and spindle are shown

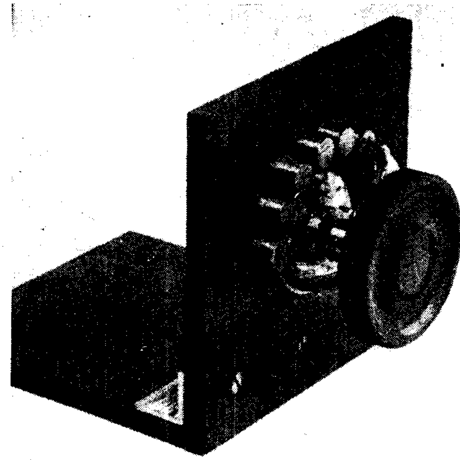


Fig. 6. Screws holding the panel to the brass angle piece should be countersunk, as shown. The studs and contact arm are also seen

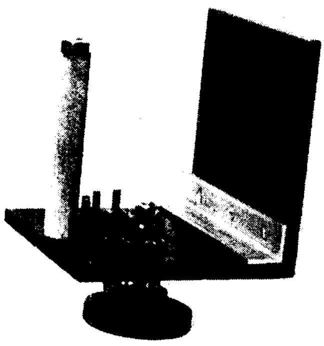


Fig. 7. An ebonite tube is mounted on the vertical panel to act as an insulated support for the coils

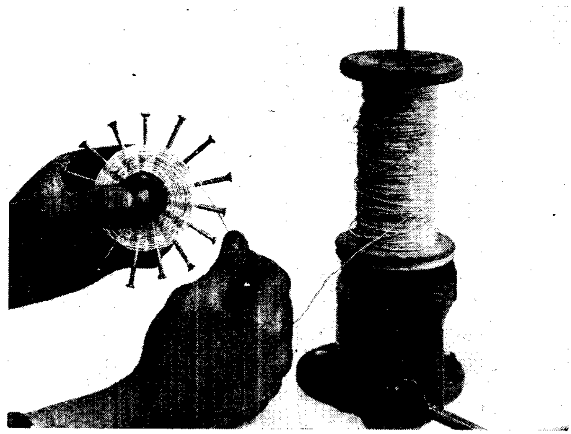


Fig. 8. Basket coils for the aerial tuning inductance are easily wound by hand on a home-made former comprising a wooden hub and long nails

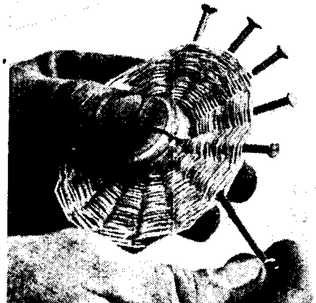


Fig. 9. When the coil is complete the nails are removed from the hub of the former

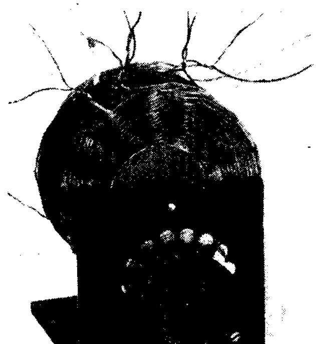


Fig. 10. Basket coils are fixed on the ebonite tube. This shows a front view

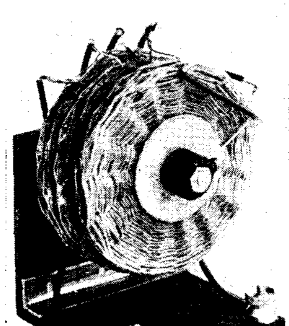
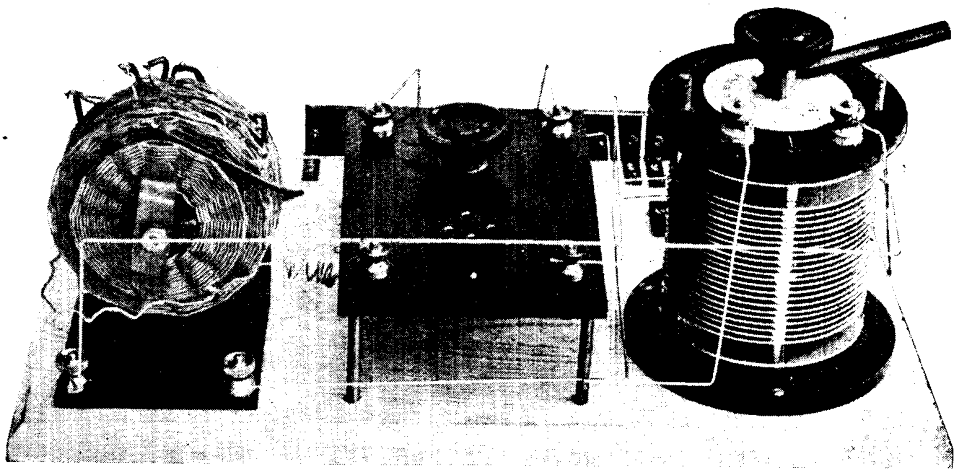


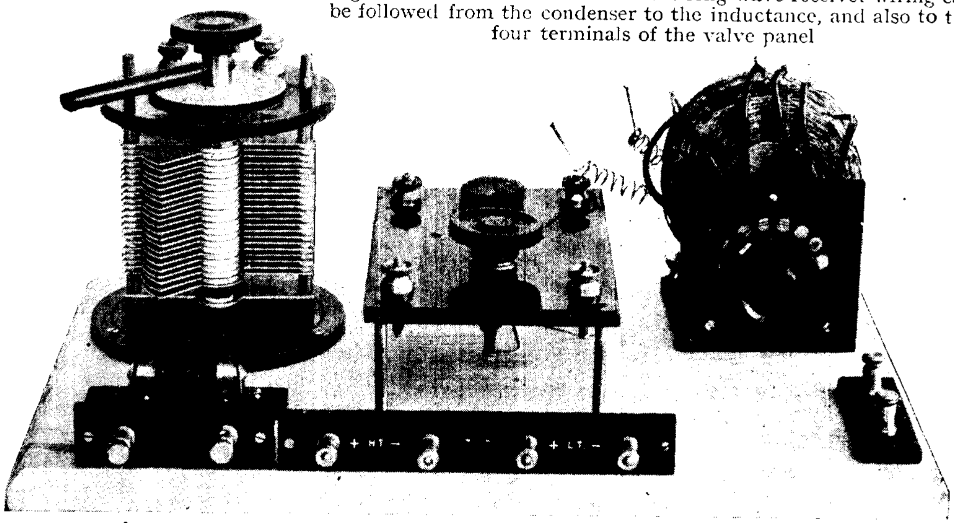
Fig. 11. The six basket coils on their ebonite support, seen from the back

HOW TO CONSTRUCT THE INDUCTANCE FOR LONG-WAVE RECEIVER



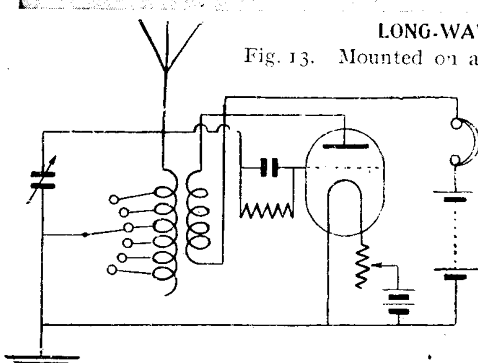
METHOD OF WIRING LONG-WAVE RECEIVER

Fig. 12. Viewed from the back the long-wave receiver wiring can be followed from the condenser to the inductance, and also to the four terminals of the valve panel



LONG-WAVE RECEIVER READY FOR WIRING

Fig. 13. Mounted on a wooden base are the components of a long-wave receiver ready for wiring

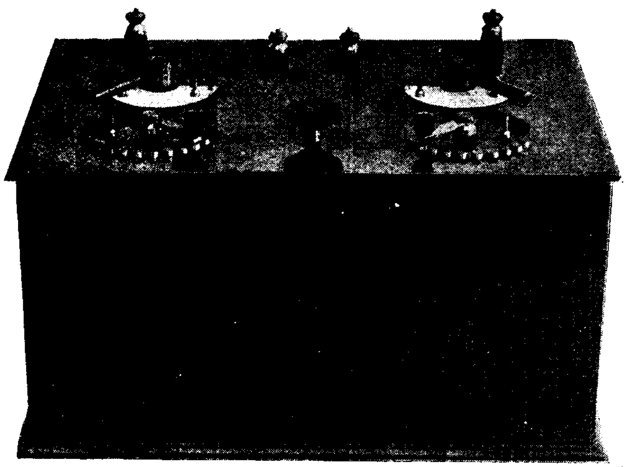


WIRING DIAGRAM FOR L. W. RECEIVER

Fig. 14. Wiring shown in Fig. 12 can be seen in this diagram. The aerial tuning inductance wiring is the principal feature, the valve batteries and 'phones following standard practice

studs. Signals on long wave-lengths are mostly sent out on the continuous wave method of transmission. This involves the use of a reaction coil as the simplest means of obtaining the heterodyne effect necessary for the reception of continuous waves.

The reaction coil is fixed, and will not require alteration when its value has been correctly adjusted. It consists of a basket coil made in a similar manner to the other coils, but is rather smaller in size. This coil is placed against the set of coils by the pressure of a light brass strip fitted over the nut at the end of the ebonite tube. The free end of the coil is connected to



LONG-WAVE TUNER

Fig. 1. Wave-lengths up to 30,000 metres can be picked up on the long-wave tuner illustrated. The tuning devices are mounted on an ebonite panel forming the top of the cabinet

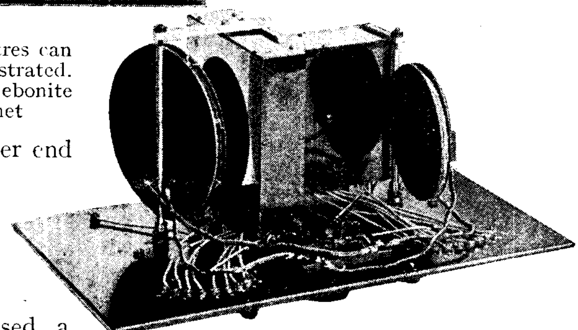
the telephone terminal and the other end to the anode of the valve.

The remainder of the wiring follows standard practice and is shown in Fig. 12. The set, ready to be wired up, is seen from the front in Fig. 13. A valve panel supported on four brass posts is used, a filament resistance and a valve holder being mounted centrally on the panel. Connexions from the legs of the latter are taken to terminals placed at the four corners of the panel. A complete view of the set after wiring is shown in Fig. 4. If no result is obtained after connecting up the set to batteries and telephones, the probability is that the reaction coil wires are connected the wrong way round. This is a matter for experiment, and if at first no result is obtained, the set should be tried the other way round. If the reaction coil is too large, a whistling shriek will be heard in the telephones. This will probably be stopped by reducing the value of the high-tension battery, or by a diminution of the brilliance of the valve filament.

If these voltages are reduced below the point of valve efficiency, the size of the reaction coil may be reduced, or the coil be removed a little farther away from the aerial tuning coils. A little experiment will soon adjust the reaction coil so that the best coupling is obtained.—*W. W. Whiffin.*

LONG-WAVE TUNER. An instrument designed for the reception of signals on long wave-lengths. Long wave-lengths are considered, for amateur reception, to be those over 2,000 to 3,000 metres. A large amount of inductance is required in order to enable a tuner to cover such wave-lengths, and it becomes unwieldy if in the form of a large cylindrical inductance.

For long wave-length reception, therefore, this type of tuner is not to be recommended. Another factor of importance when using a long-wave tuner is the provision of a suitable inductance for securing a coupling between

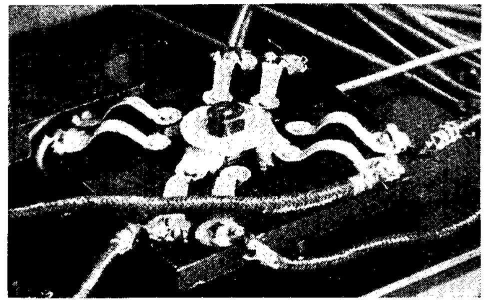


INTERIOR OF LONG-WAVE TUNER

Fig. 2. When the panel is lifted off the cabinet and reversed the whole of the apparatus appears as above

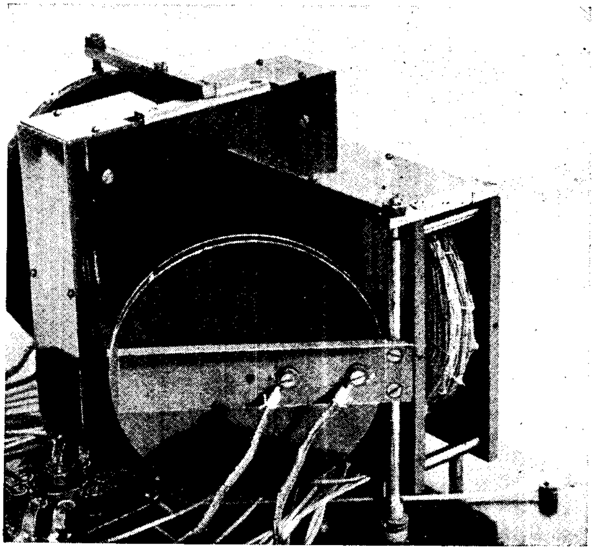
anode and grid coils, so that, owing to the reactive effect, continuous wave transmissions may be received.

The great majority of long-wave transmissions are sent out in continuous waves, such transmission being used extensively for transatlantic communication. A long-wave tuner suitable for the reception of



SWITCH FOR LONG-WAVE TUNER

Fig. 3. In this close-up view the change-over switch is seen, and by this device tuning is altered from short wave-lengths to long



LONG-WAVE TUNER BANKED COILS

Fig. 4. In this close-up view one bank of basket coils is seen on the right with the end plate removed

press messages, or other long-wave commercial signals, is shown in Fig. 1. The inside of the tuner is shown in Fig. 2, and consists of two sets of basket coils arranged at right angles to each other to secure a minimum of interaction.

In Fig. 2 the longer wave-length coil is seen to the left. Against each bank of basket coils an additional basket coil is arranged on a moving pillar operated from the top of the panel to give a variable coupling to the fixed coils.

Each bank of coils forming the aerial tuning inductance contains 10 basket coils, which may be inserted in the inductance or withdrawn from it by the studded switches shown in Fig. 1. Behind the switches, the arms controlling the reaction coupling are seen, capable of movement over graduated dials.

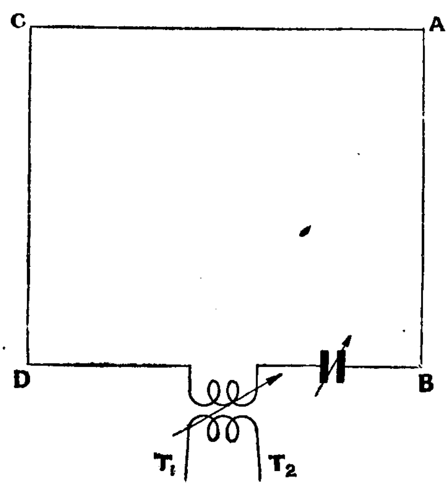
The change-over from shorter wave-lengths to the higher wave-lengths is effected by a rather ingenious switch. A close-up view of this switch is shown in Fig. 3.

Fig. 4 gives a close-up view of one bank of coils with the end plate removed. The method of obtaining long-wave tuning by means of tapped basket coils arranged to give mutual induction is one of the most efficient methods of long-wave reception, and a constructional article on this type of tuner is incorporated under the heading Long-wave Receiver (*q.v.*).

LOOP AERIAL. The loop aerial has been in use for receiving purposes for many years. It is shown in its simple form (Fig. 1), and many of its properties are also explained under the heading Frame Aerial.

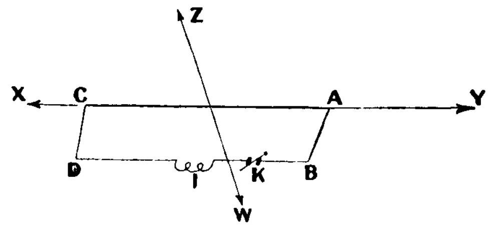
This type of aerial is very convenient when used for reception, on account of its marked directional properties. It will receive best from a station so placed that a plane passing through the sending station aerial would also touch the vertical sides of the loop A B and C D. The loop will receive equally well from the opposite direction on the same line, but it will not receive from a station situated at right angles to this direction.

Loop aerials can be used for transmitting aerials, but, as a rule, are not generally employed for this purpose. There are, however, special cases in which they can be used with advantage. The simple loop (as Fig. 1) may be employed as a transmitting aerial instead of for reception by simply connecting the transformer terminals T_1 and T_2 to a transmitter instead of to a receiver. The system will radiate waves in the directions XY or YX (Fig. 2), whilst there will be very bad radiation in the directions ZW or WZ. But if the loop is made without



SIMPLE FORM OF LOOP AERIAL

Fig. 1. This simple form of loop aerial may be used for transmitting or receiving



RADIATION OF LOOP AERIAL

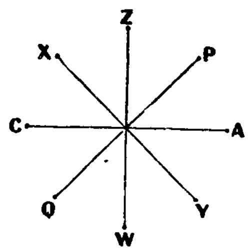
Fig. 2. Direction of radiation is represented in this diagram of a top view of a simple loop aerial

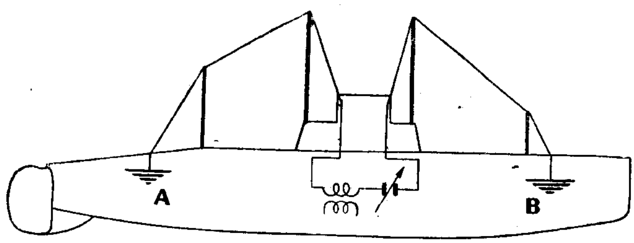
regard to the wave-length on which it is to be employed, and is only tuned to that wave-length by adding capacity K and inductance I, it may, and probably will, be a bad radiator even in its best directions.

Loop aerials may, however, be efficient radiators provided they are correctly proportioned. The simple loop aerial for maximum radiation should be so designed that its two sides C D and A B (Figs. 1 and 2) are situated half a wave-length apart. Loop aerials of this type have been employed for sending out directional signals. For this purpose many frame aerials have been arranged pointing to different points of the compass, as Fig. 3. Each loop is separate from the others, and switching arrangements are made so that each loop is automatically connected in turn to a transmitter by means of a slow-moving commutator switch.

When the aerial Z W is connected, it may further be arranged that the transmitter automatically sends out the letter N, signifying that the north aerial is in use. The signal NW might be sent from the aerial Q P and W from C A. The north aerial will, however, radiate equally well in a southerly direction, as will also the west aerial in an easterly direction. As each of the other aerials will behave in a similar manner, it will be seen that the system will only give the line or bearing without giving the sense, and other means must be adopted to give the sense, as explained under the headings Frame Aerial, Direction Finder and Sense Indicator.

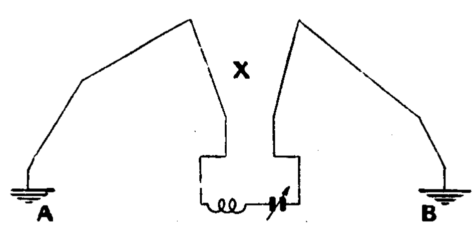
The loop aerial has been employed with success as an aerial for use on submarines when submerged. A type of double loop aerial for use on submarines is described by Morecroft in his "Principles of Radio Communication." It consists of a double loop of very highly insulated wire, with the ends of the loops A B connected to the hull of the ship, Fig. 4, which gives a general impression of the actual arrangement on the ship. Fig. 5, X, shows the same

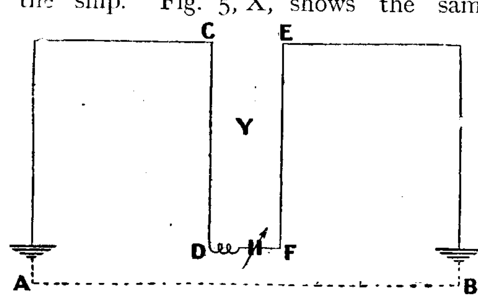




DIRECTIONAL AND SUBMARINE LOOP AERIALS

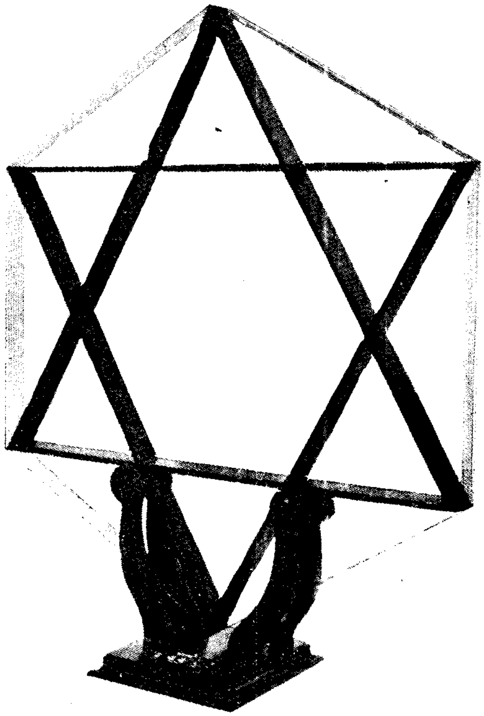
Fig. 3 (left). Directional transmissions are sent out from a loop aerial arranged in the order here indicated, the diagram showing a top view. Fig. 4 (right). Loop aerials are used on submarines, and the system is illustrated above, a double loop being shown





THEORETICAL DIAGRAMS OF A SUBMARINE LOOP AERIAL

Fig. 5, X (left). The wiring from A to B constitutes the double loop circuit of the arrangement in Fig. 4. Fig. 5, Y (right). Theoretically this is the ideal arrangement of a loop aerial suitable for submarine work



MARCONIPHONE FRAME AERIAL

Fig. 6. Hexagonal in shape, this loop aerial is supported on a framework formed by two interlacing triangles

Courtesy Marconi's Wireless Telegraph Co., Ltd.

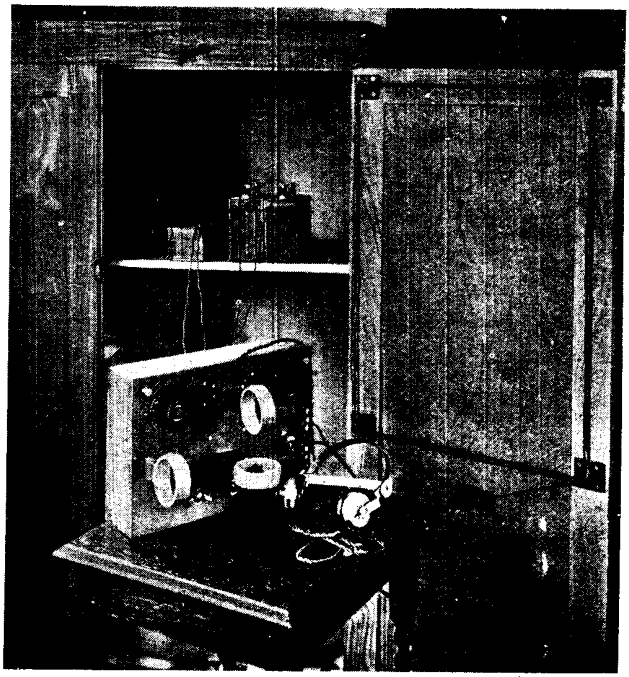
arrangement, whilst Fig. 5, Y, shows the ideal arrangement of the aerial, which has had to be distorted into the arrangement shown in Fig. 5, X, to meet the other conditions of submarine navigation.

With aerials of the double-loop type the distance from A to B should still be half a wave-length, whilst the radiation from the two wires C D and E F (Fig. 5, Y) will be very small, as they are so close together that their effects will almost cancel one another.

Morecroft states that signals have been received with loop aerials on submarines at a distance of 200 miles from the transmitting station when the top of the loop was 16 ft. below the surface of the water; this was when using a wave-length of 6,000 metres. If a shorter wave-length is used, the absorption in the water becomes greater, and under the same conditions, but using a wave of 2,500 metres, it was necessary to bring the top of the loop to within 8 ft. of the surface of the water before signals could be heard. It is, of course, a well-known fact that the penetrative power of electro-magnetic waves in water is small and almost negligible on short wave-lengths.—*R. H. White.*

Loop Aerials for General Reception. A loop aerial may be either circular, hexagonal, or rectangular in its disposition, the two ends of the wires being connected directly to what is normally the aerial and earth terminals of the receiving set. Some forms of large loop aerial are employed for direction-finding purposes, and are dealt with under the heading Direction Finder and Directional Wireless.

By far the greater number of loop aerials employed by the amateur and experimenter are disposed within a building, as, for example, around a room. This class of aerial is described in this Encyclopedia under the heading Indoor Aerial. When in the near vicinity of a broadcasting station, quite a small loop aerial is often



LOOP AERIAL ATTACHED TO A DOOR

Fig. 7. An excellent loop aerial may be made by fixing the device to the framework of a door in this way. The cupboard door can be opened or closed without affecting the wiring

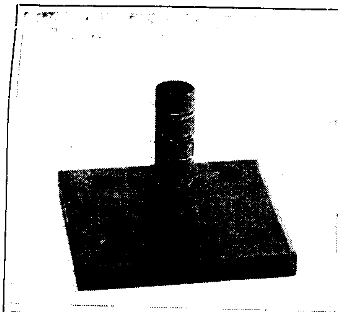


Fig. 8. Wires for the loop aerial are supported on ebonite tubing slotted as illustrated

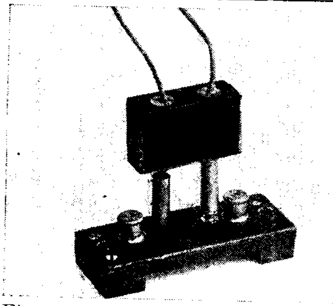


Fig. 9. Connexion of the aerial wires to the loop is made by means of a plug and socket

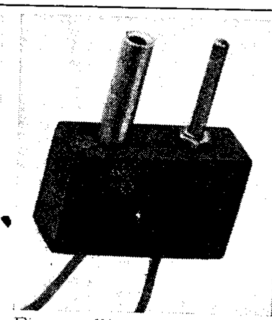


Fig. 11. Plug automatically connects aerial and earth, and cannot be reversed

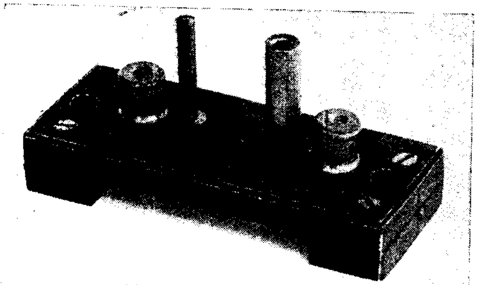


Fig. 10. Mounted on a raised base is a valve leg and socket. On either side is a connecting terminal

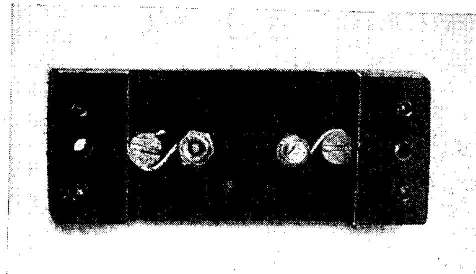


Fig. 12. Connexions are made underneath the base of the valve leg and socket to base shown in Fig. 10

CONNECTING PLUG AND WIRE SUPPORT FOR LOOP AERIAL

sufficient for reception with a large and powerful receiving set, or those with a super-regenerative or feed-back circuit.

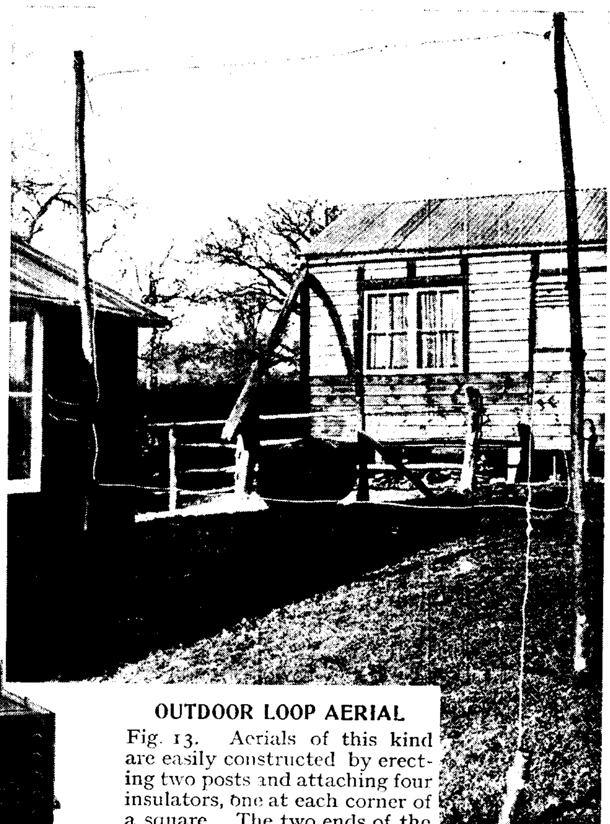
There are many forms in which a loop aerial may be arranged, and a handsome effect is obtained by the arrangement such as that followed by Marconi's Wireless Telegraph Co. for use with Marconiphones. This, as can be seen from Fig. 6, is in the form of a wooden framework shaped like two interlaced triangles, the outer points of which act as supports for the aerial wire and are suitably insulated. The frame rests upon neatly polished hardwood members as supporting arms. Upon the base are sockets for the connexions to the receiver, the ends of the aerial windings being connected, beneath the base, to the sockets.

Another arrangement is to use a series of ebonite supports, and to fix them to the door of a room or, under suitable conditions, to the door of a cupboard. This arrangement is shown complete in Fig. 7. To support the wires, four ebonite plates should be prepared 2 in. square and 1 in. thick, into the centres of which are fitted projecting pegs of ebonite rod about ½ in. in diameter. Four screw holes are drilled near the corners for fixing purposes, and four slots, $\frac{3}{16}$ in. apart, are sawn across the ebonite pegs (Fig. 8). When the four pieces have been prepared they should be fixed on the four corners of the door with small brass screws.

The next step is to prepare a convenient means of connecting the ends of the aerial wires to some form of plug socket, such as that shown in Fig. 9. This can readily be made from a small ebonite base 3 in. in length and 1 in. in width, the construction of which is self-evident from the illustration (Fig. 10). It will be observed that one valve leg and one valve socket are fixed to the base and connected by copper wires to adjacent terminals. The connexions are beneath the base in the space formed between the two additional foot pieces which are screwed to it. This is clearly shown in Fig. 12.

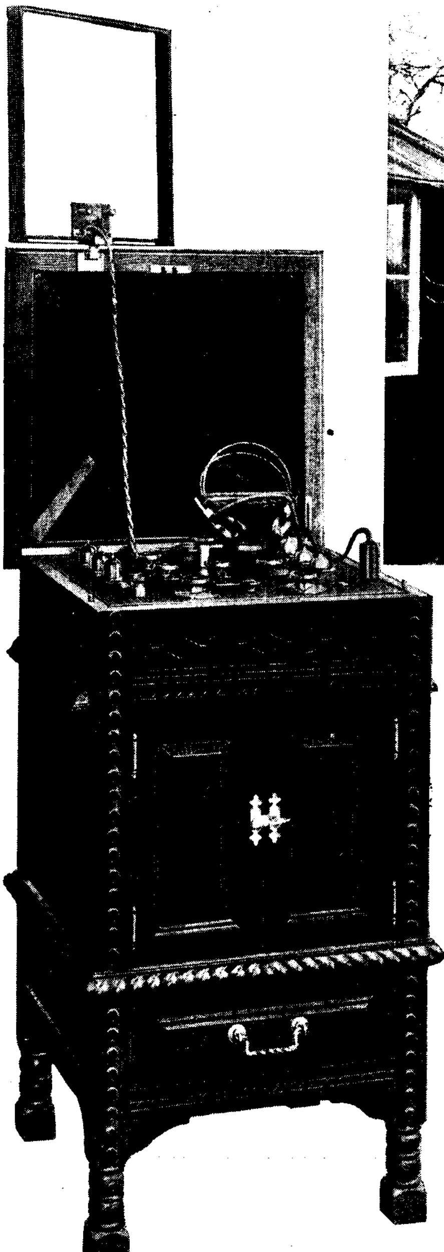
The plug illustrated in Fig. 11 comprises a rectangular block of ebonite fitted with a valve leg and valve socket, the ends of which are connected by flexible wires, the wires passing through holes sufficiently large to permit of the passage of the lock nuts, these larger holes penetrating about half-way through the block. When the wires are connected the holes are filled with wax to make the insulation complete. The socket is then screwed to the lower centre part of the door. The two ends of the aerial wire, which is simply wound around the four contacts and rests in the slots therein, are connected to the two terminals and the plug put in place, the wires from which connect respectively to the aerial and earth connexions on the receiving set.

If a cupboard door is used, the batteries and other parts can probably be stored within the cupboard and the receiving set placed upon an adjacent table, as shown in Fig. 7. Directional effects are obtained by opening or closing the door by a suitable amount. It will probably be found necessary to experiment somewhat with the number of turns and gauge of the wire. In some cases ordinary bell-wire gives good results, as does No. 22 gauge enamelled copper wire. If longer range work than ordinary broadcast reception is carried out, Litzendraht wire may be used.



OUTDOOR LOOP AERIAL

Fig. 13. Aerials of this kind are easily constructed by erecting two posts and attaching four insulators, one at each corner of a square. The two ends of the loop are taken to the instrument



CABINET SET WITH LOOP AERIAL

Fig. 14. Six valves and a loud speaker are accommodated in this Cosmos Jacobean oak cabinet. The loop aerial folds back into the top, which is open for reception

Courtesy Metropolitan Vickers Electrical Co., Ltd.

A very good outdoor loop aerial can quickly be erected by setting up a post or posts about 8 to 10 ft. high and staying them with a couple of guy-ropes. One of the posts should be located near the building containing the receiving set, the other should be so placed that the loop points towards the station it is desired to receive. The aerial consists of a single loop of ordinary seven-strand No. 22 copper wire carried on four insulators fastened to the posts with cords. The ends of the loop can conveniently be carried through ebonite tube bushings fixed into holes drilled through the posts, and from there taken in the usual way into the building. Such an arrangement is shown in the photograph in Fig. 13.

A neat and effective application of the loop aerial cabinet receiving set is illustrated in Fig. 14, which shows a Cosmos six-valve set with loud speaker, loop aerial and telephones. The loud speaker is built in the lower part of the cabinet, and when not in use is covered by the folding doors.

When the set is in operation the cover, or lid of the cabinet, is raised to the position illustrated and the loop aerial placed in position on a pivot bracket attached to the edge of the cover. An ebonite bracket and small framework act as a support for the aerial and also for the pivot pin, which enables it to be turned in any desired direction. Heavily insulated flexible wire connects the loop aerial to the tuner of the receiving set.—*E. W. Hobbs.*

See Aerial; Bellini-Tosi Aerial; Direction Finder; Directional Wireless; Frame Aerial; Hanging Set.

LOOSE COUPLERS FOR SELECTIVE TUNING

Variable Aerial Tuning Inductances and How to Make Them

Here the standard types of loose coupler are described, with their uses. Certain disadvantages which are attached to the standard type are avoided in the special loose-coupled tuner, the construction of which is fully described and illustrated with a photogravure plate. See also Close Coupling; Coil; Coupling; Crystal Receiver; Reaction, etc.

A loose coupler is an instrument consisting of two tunable inductances so arranged that the magnetic induction may be varied by alteration of the position of either coil. The loose coupler is mainly used as a means of aerial tuning, the primary inductance coil of the instrument being connected to aerial and earth and the secondary to the receiving set.

The advantage of the use of the loose coupler is in greater selectivity of signals and consequent freedom from the interference of stations of a near-by wave-length. This advantage is somewhat outweighed by increased difficulty in tuning the double circuits. This is, however, only a temporary trouble, which is lessened as a knowledge of the operation of the instrument is acquired by practice in its use.

The principle of the loose coupler may be carried out in a variety of ways, which are largely dependent on the type of inductance used. The most common type of loose coupler is shown in Fig. 1, and consists of a tubular primary coil mounted to the baseboard by means of large end pieces. Secured to one of these end pieces two rods are continued through the inside of the primary coil, and terminate at the other end in two supporting pillars.

These rods support the secondary coil, which is capable of movement right inside or outside of the primary coil. In the instrument shown—and this is common to many types of loose coupler—the rods supporting the secondary coil also make electrical connexion with it, and are fitted with terminals at one end. These terminals are clearly shown in Fig. 2, which gives another view of the apparatus described. The inductance of the primary coil may be varied by means of a sliding contact fitted to a rail on the top of the coil. The secondary has a series of tappings mounted to the end plate on the right of the coil in Fig. 1, and intermediate wave-lengths may be found by the use of a variable condenser shunted across the secondary coil.

A loose coupler embodying rather novel features is shown in Figs. 3 and 4, giving respectively a side view and an illustration of the underside of the base. The secondary coil in Fig. 3 is fitted with a vernier adjustment in the form of a cord and pulley device which is operated by the knurled knob seen to the extreme right of the illustration.

The block holding this knob, to which the driving pulley is attached, is adjustable in position with the knurled screw fitted

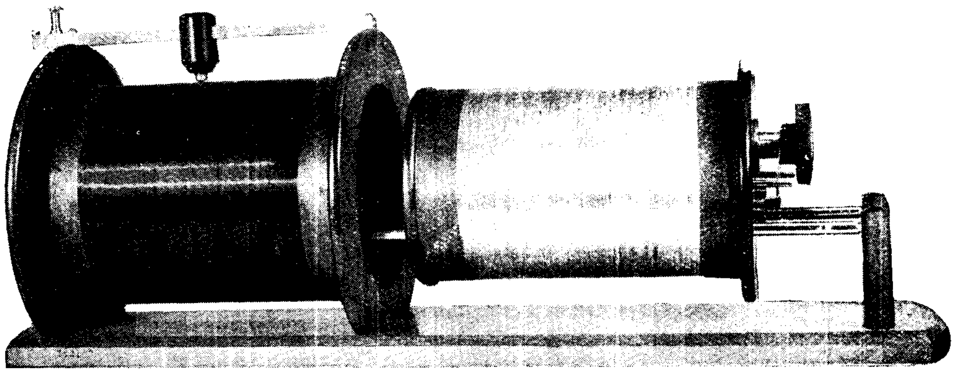


Fig. 1. Loose couplers of the most common type consist of a primary coil into which slides a secondary. Both may be varied by tappings or sliding contacts
Courtesy Economic Electric Co., Ltd.

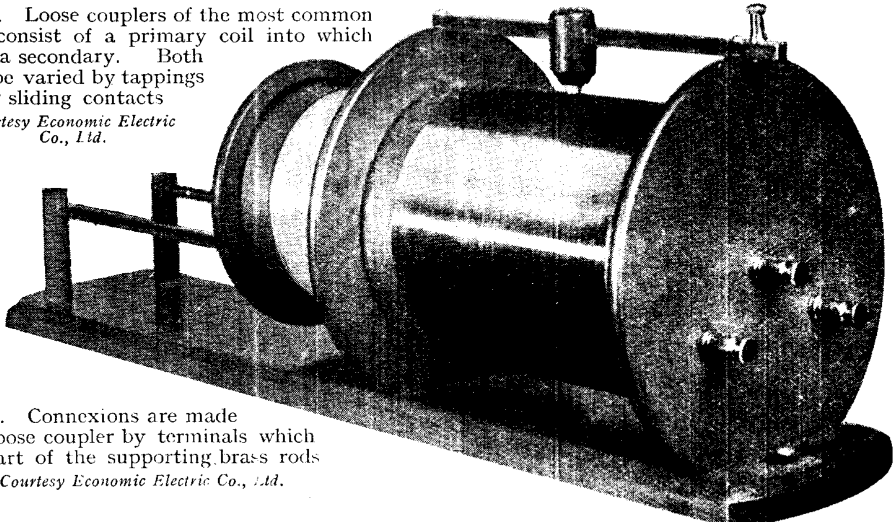


Fig. 2. Connexions are made to a loose coupler by terminals which are part of the supporting brass rods
Courtesy Economic Electric Co., Ltd.

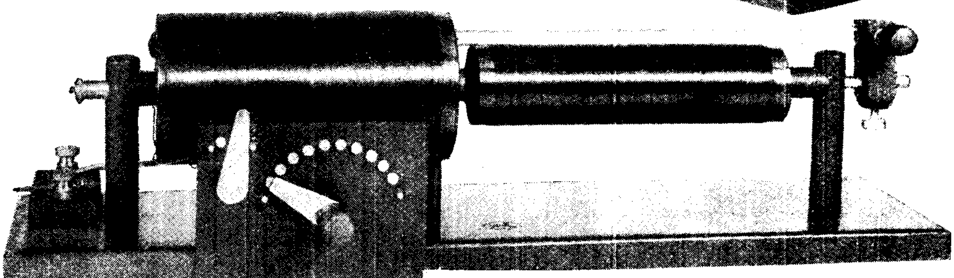


Fig. 3. This loose coupler has a vernier adjustment on the secondary coil in the form of a cord and pulley device
Courtesy L. McMichael, Ltd.

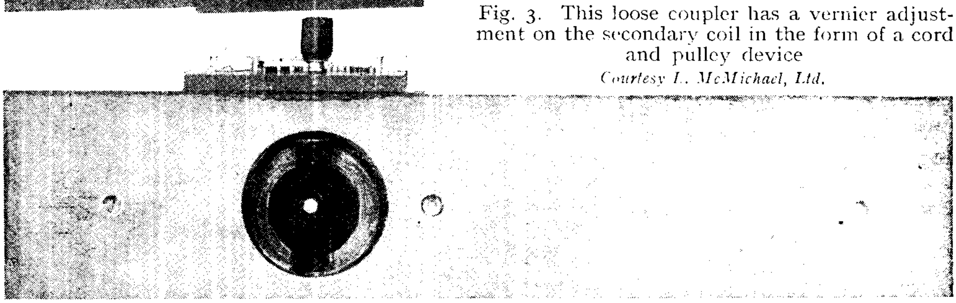


Fig. 4. In the base of the loose coupler shown in Fig. 3 is the loading coil by means of which higher wave-lengths may be tuned in

underneath it, and this enables the correct tension of the cord to be found should it become slack. In this loose coupler the tuning-in of the primary coil is effected by means of tappings to a studded switch mounted in front of the primary coil. A loading coil enabling higher wave-lengths to be reached is fitted in a recess cut under the baseboard, as seen in Fig. 4. This extra inductance takes the form of a basket coil, and is operated by the two-stud switch seen to the left of the multi-stud switch.

Loose couplers of the foregoing patterns have the disadvantage of occupying considerable space and, owing to their open construction, are difficult to keep clear of dust, which is detrimental to the successful operation of wireless apparatus. This is overcome in the pattern shown in Fig. 5, where the complete tuning arrangements are housed in a sloping cabinet, which may be designed to conform with other apparatus used in conjunction with it.

Bearing in mind the merits and disadvantages of the various types of loose coupler, the following instrument has been designed. It will be found a very useful and compact apparatus for experimental purposes and for permanent attachment to receiving equipment. Fig. 10 on the special plate shows the loose coupler in this connexion attached to a receiving set. The front of the set, as completed, is shown in Fig. 11.

The case is the first item in the construction of the instrument. Details of this are given in Fig. 6. All dimensions given are for inside measurements, enabling the constructor to choose the thickness of the wood of which it is made. In the case illustrated, white wood having a finished thickness of $\frac{3}{8}$ in. was used. The ebonite panel measures 12 in. long and 6 in. deep, and the inside of the case must be cut to suit this size. The depth of the case, also measured on the inside, is $5\frac{1}{2}$ in.

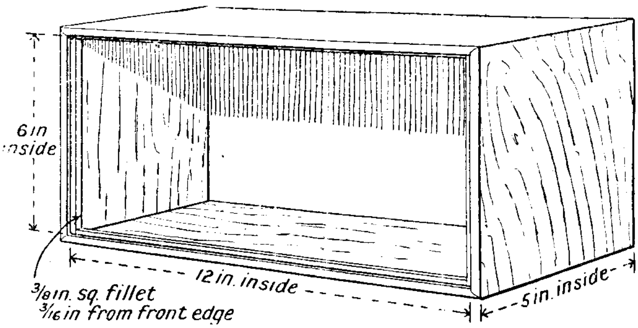
The back may be permanently attached, as all the components are mounted on the panel. Four fillets are required, to which the panel is screwed when completed, and arranged at a distance of $\frac{3}{16}$ in. from the front edges of the box. The fillets should be about $\frac{3}{8}$ in. square. The front edges of the case are slightly rounded in order to give an improved appearance.

The panel is cut from good quality matt ebonite of $\frac{3}{16}$ in. thickness. If not purchased in a matt grade, which is much to be preferred, it must be well matted. If care is taken with the drilling of the panel, according to the panel lay-out shown in Fig. 7, the ultimate assembly will be found quite easy.

The three stud switches are now made and assembled. The contact studs, which may be purchased very cheaply, are $\frac{1}{4}$ in. in diameter and $\frac{1}{4}$ in. in height. Owing to the large number of contact studs on the primary switches, they are fairly near together. Any electrical leakage between adjacent studs is minimized by the use of a small condenser spacer-washer on alternate stud stems. A close-up view of this arrangement, which is self-explanatory, is shown in Fig. 8.

POLAR LOOSE-COUPLED TUNER

Fig. 5. Constructed to keep the coils free from dust is a self-contained loose coupler. This instrument is designed to be used with other units in similar form



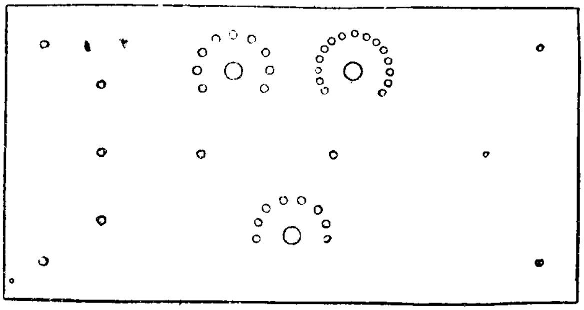
LOOSE COUPLER CASE

Fig. 6. Dimensions are given in this diagram of the case to contain the loose coupler shown complete in Fig. 11

Still further increase of distance between adjacent studs is secured by pinching the condenser washers oval in shape and arranging the pointed ends in line with the centre bush. The switch arm knob and spindle may now be fitted. The ebonite formers for the primary and secondary coils are identical in size, each having an external diameter of $3\frac{1}{4}$ in. and a length of $3\frac{1}{2}$ in. A suitable thickness for these coils is $\frac{3}{16}$ in. The secondary coil, after winding, is shown in Fig. 13. Before winding the secondary coil two holes of $\frac{3}{16}$ in. diameter must be drilled through the centre of the tube. These holes form the bearings for the rotor shaft. The rotor winding forms part of the primary circuit, and its rotation inside the secondary coil gives the required variable coupling.

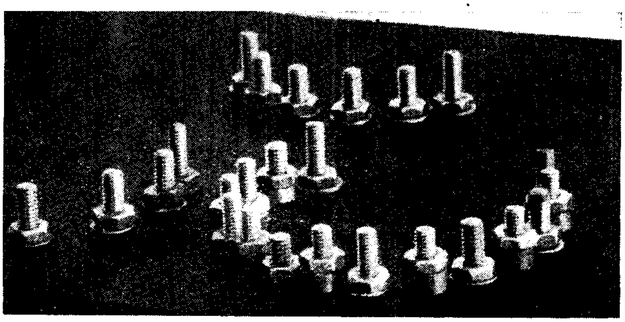
No. 24 gauge D.C.C. wire is used for the secondary coil, and winding is commenced $\frac{5}{16}$ in. from the rotor shaft hole and finished at the end of the tube. This should give 40 turns of wire if the wires are closely wound. The method recommended for fixing the beginning and end of the coil is to drill two small holes in line with the direction of winding and thread the end of the wires two or three times through these holes. Four tappings are required on the secondary coil, and are taken from the tenth, twentieth, thirtieth, and fortieth turns.

The method adopted for making these tappings is to take a loop of wire at the point where a tapping is required, and the loop is twisted round until a few tight twists are made at the end of the loop. This method enables the next turn to lie straight with the wires previously wound. Owing also to the shortness of the loop, trouble is not experienced with many stray ends of wire projecting loosely from the coil. A sharp knife rubbed over the loops will clear the insulation when it is required to solder up to the tappings of the switch.



HOW TO DRILL THE PANEL

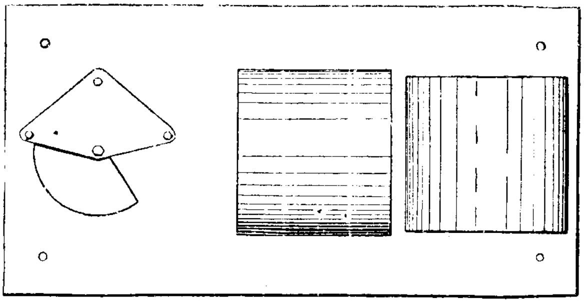
Fig. 7. Panel drilling may be carried out after carefully measuring the actual distances and spacings for the switch studs, by following this diagram



LOOSE COUPLER STUD SWITCHES

Fig. 8. How the stud switches are fixed is shown. Note the use of the condenser spacer washers to avoid close proximity of the nuts and to minimize any leakage

An alternative method for making the tappings for the coils is to solder a small piece of tin on the wire at the point where connexion is made. This is very simply done by cutting a number of small oblong strips of tin measuring about $\frac{1}{2}$ in. by $\frac{3}{16}$ in. Each piece is bent into an acute V-shape and is then ready



LAY-OUT OF LOOSE COUPLER COMPONENTS

Fig. 9. In this diagram is shown the general disposition of the principal components of the loose coupler

for fixing into position as the point of a required tapping is met. A sharp knife is used for cleaning the insulation at each tapping point, so that when the V-shaped strip is fitted over the bare wire good electrical connexion is made with the inductance. The connecting wires to the studs are also slipped into the angle of the tin, and then snipped up tightly with a pair of square-nosed pliers and soldered.

The switches are somewhat inaccessible when the coils are mounted, and the best plan is to solder short lengths of about twelve inches to each contact stud before the coil preventing access to the studs is mounted. This is shown in Fig. 13. No. 24 gauge tinned wire is suitable.

Fig. 9 shows the positions of the main components. The secondary coil is seen to the extreme right, the primary coil in the centre, and a variable condenser to the left.

It must be remembered that this illustration is of the back of the panel, and therefore the position of these components is reversed when viewed from the front. The secondary coil is mounted to the panel at the top by a 2 B.A. screwed rod screwed in a tapped hole to receive it immediately above the rotor spindle hole, and occupies a position to the extreme left of the panel, viewed from the front.

Details of the construction of this pillar are shown in Fig. 14. It consists of a short length of screwed rod rigidly fixed in the tapped hole and locked with a lock nut. A clearing hole is now drilled in the tube of the secondary coil in such a position that the rotor spindle holes in the tube and panel coincide. Another 2 B.A. nut is threaded on the stemming, after which two washers and another nut are fitted when the coil is in position. This method, however, is not available at the other end of the tube, as the wire is wound to the extreme end of the coil. At this end a small right-angle bracket is used to support the coil, one 2 B.A. screw holding it to the panel in the tapped hole previously drilled, and another screw tapped into the end of the coil after passing through a hole in the right-angle bracket. A close-up view of the first supporting pillar is shown in Fig. 14.

The primary coil is shown in Fig. 16. Two $\frac{3}{16}$ in. holes are drilled, one at either end, by which the coil is mounted. This method of mounting the coil is the same as described for the top end of the secondary coil illustrated in a close-up view in Fig. 13. Having ascertained that the coil may be mounted easily, winding is commenced. No. 24 gauge D.D.C. wire is used, tappings being taken from turns 0, 2, 4, 6, 8, 10, 20, 30, 40, 50, 60, 70, and 80. Other features of the windings are the same as shown for the secondary coil. The primary coil, after winding, is shown in Fig. 15.

Mount the primary coil in position when the winding is finished, after which both coils may be connected up to their respective switches. This stage in the construction of the loose coupler is shown in Fig. 16. Reference to the wiring diagram in Fig. 21 will show that the first stud of the first primary switch is joined to the first stud of the second or coarse adjustment switch. When both switch arms are placed on these studs the entire primary coil is withdrawn from the circuit and the tuning is carried out solely on the rotor in the primary coil. This feature is useful when working on the lowest wave-lengths.

The rotor is of the ball variety, and is $2\frac{3}{4}$ in. in external diameter. Twenty-five turns of wire are wound on each half of it, the two ends of the separate halves being soldered together in the middle, as shown in Fig. 17. A 2 B.A. clearing hole is drilled through the centre of the rotor for attachment to the rotor spindle. This spindle is secured to the rotor by lock nuts placed on either side of the rotor. One of the free ends of the rotor winding is clamped firmly under the inside nut.

Two flat washers, with a spring washer, are placed over the spindle and between the rotor and the inside of the tube. These washers prevent any forward or backward movement of the spindle. Before the rotor spindle is finally assembled a short length of flat strip brass to which is soldered a 2 B.A. nut is screwed on the rotor spindle. This strip forms the contact piece, and the free end is fastened under the nut of the tube support. The contact piece is very clearly illustrated in Fig. 14. Contact with the other end of the rotor is effected with a short length of lighting flex which, with the free end of the rotor wire, is fixed with a screw screwed into the rotor. Fig. 18 shows this feature, and from this illustration a very good idea of the rotor construction may be obtained.

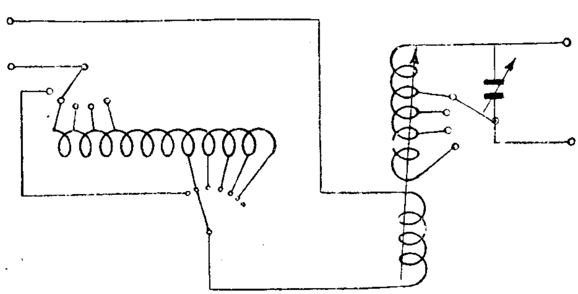
Figs. 19 and 20 on the plate show respectively the back view of the loose coupler and the top view. These illustrations give a good idea of the methods of wiring.

The six-stud switch is connected to the five tappings of the primary coil, the remainder being soldered to the eleven-stud switch. One stud at the end of this switch is left free, and permits the inclusion of a loading coil if required. The two outside stud holes are used to indicate the short and long wave-lengths of the switches. This is very effectively accomplished by black-enamelling two ordinary contact studs and neatly printing an S for short and L for long, in white enamel, on the flat face of the studs. These indicating studs, to which no connexions are made, are preserved from damage by the moving contact arm by stop pegs, which occupy the adjacent holes in the panel.

A small variable condenser of ·0003 mfd. maximum capacity is shunted across the secondary circuit, as indicated in the wiring diagram. Holes for the assembly of this component are intentionally omitted from the panel lay-out, as various types of condensers have different methods of assembly. The wiring diagram of the loose coupler is shown in Fig. 21. For the sake of clearness some of the primary tappings on the coarse wave-length switch have been omitted.

In operating the instrument the primary terminals on the left are connected to the aerial and the earth. The secondary terminals seen on the right are connected, in the case of a valve receiver, to the grid and high-tension negative. In the illustration in Fig. 10 the instrument is used with a crystal set, where the secondary terminals are connected with a crystal detector and a pair of high-resistance telephones.—*W. W. Whiffin.*

See Coil; Coupling; Crystal Receiver.



WIRING OF THE LOOSE COUPLER

Fig. 21. How the various components of the loose coupler in Fig. 11 are wired up may be seen in this diagram. It will be noticed that one coil has two sets of tappings and two switches

LOOSE COUPLING. Degree of coupling between two inductances or circuits. By coupling is meant the placing of inductances, etc., with regard to each other that electro-magnetic induction can take place between them, as in a loose coupler, or a spark coil, where the primary and secondary windings are coupled. If the coupling effect is small, it is said to be loose coupling, and if the effect is almost as great as it can be, the coupling is said to be tight.

Loose coupling may be accomplished in many different ways, the method employed depending on the types and forms of the inductances used. In the instrument known as a loose coupler, in which two cylindrical inductances are used, where one is arranged to slide in or out of the other, loose coupling is effected by drawing out the smaller one so that the amount of overlap between the two coils is small.

Where duo-lateral, basket, or slab coils are employed, the most usual method is to pivot one of the inductance coils so that it can be swung away from the fixed coil.

A different method of coupling exists between the rotor and stator of a vario-coupler. In this form of coupling the relative positions of the two inductances are not varied. Loose coupling is in this case effected by rotating the rotor so that its direction of winding is in opposition to the direction of the winding of the stator.

As a general rule loose coupling in the inductance of an aerial system makes for selectivity or freedom from interference. *See* Coupling.

LOUD SPEAKERS: PRINCIPLES, TYPES & CONSTRUCTION

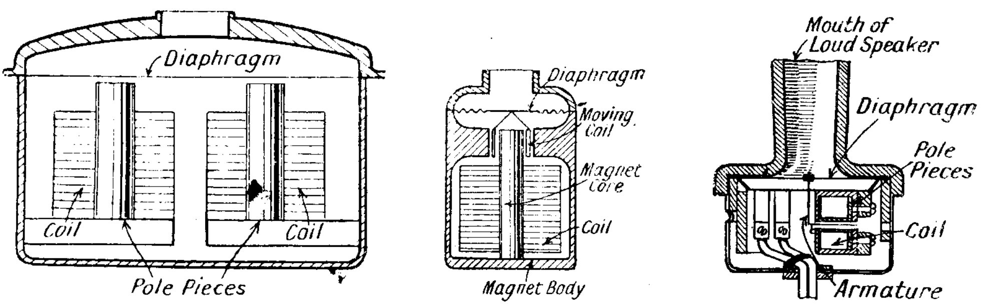
How the Loud Speaker Works and How to Make One, Fully Illustrated

As a result of the spread of broadcasting the loud speaker has become of great importance. Here the principles of its construction are discussed and hints given for securing the best quality of tone. A simple but efficient home-made instrument is also described. See also Amplifier; Choke Coil; Headphone; Intensifier; Magnavox; Microphone; Relay; Telephone

An excellent description of a loud speaker is that which classes it as an electric motor with, however, a load—in the shape of the horn or other distributing device—which is less tangible than the load of most motors. The usefulness of this definition lies in its complete recognition of the dual electrical and mechanical functions which a loud speaker in its own way very efficiently performs. The small current which enters it is used to operate an electro-magnetic system which, in its turn, communicates mechanical motion in the form of vibrations to a sound-producing element in the shape of a diaphragm. The sounds thus produced are amplified and distributed by means of a horn or other device modelled or arranged in accordance with acoustical principles.

Taking these three processes separately, there is first considered the electro-magnetic structure of a loud speaker, which consists essentially of a permanent magnet with an electro-magnet superimposed upon it. The function of the permanent magnet is to give a constant tension to the diaphragm. The electro-magnet has the usual coils wound round iron cores, and as the current which comes from the wireless receiver is varying by reason of the sound interruptions to which it has been subjected, the electro-magnet, through the coils of which this current passes, varies the pull on the diaphragm, causing it to vibrate in accordance with the sounds dealt with in the wireless receiver. The method of imparting these vibrations to the air will be considered later in dealing more particularly with the diaphragm and the horn. Restricting ourselves for the moment to the electro-magnetic structure, a simple form of this will be found illustrated in diagrammatic form in Fig. 1.

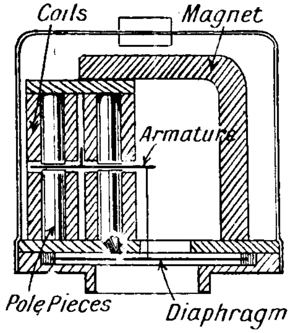
This, it will be observed, is practically the same construction as that of the familiar telephone receiver, and it follows that an ordinary telephone earpiece can be converted into a loud speaker by connecting it with a suitable horn. The operation up to the time the diaphragm is vibrated is not mechanical, as in the case of the gramophone sound box, but purely electro-magnetic, the electro-magnetic coupling being represented by the space between the poles of the magnets and the diaphragm. This gap in the magnetic field must be very small, as otherwise the pull on the diaphragm would be greatly decreased. On the other hand, if it is too small the diaphragm may occasionally strike the pole-pieces. In many patterns of loud speakers a means of adjusting the gap is provided.



THREE TYPES OF ELECTRO-MAGNETIC SYSTEMS IN LOUD SPEAKERS

Fig. 1 (left). Pole-pieces, coils and diaphragm of a simple electro-magnetic device for the base of a loud speaker are illustrated. Fig. 2 (centre). In this type a circular coil is located in a round air gap with a central iron core. The gap is traversed by a strong magnetic field. A moving coil is attached to the diaphragm, and conducts the sound-producing current. Fig. 3 (right). This is a balanced-armature type of electro-magnetic system, as applied to loud-speaker construction

A refinement of this system consists in making the diaphragm itself complete the magnetic circuit, the sensitivity being increased by the concentration of the lines of force in the diaphragm. The type includes three special kinds of loud speaker described by A. Nyman in an important lecture on the Fundamentals of Loud Speaker Construction to the Radio Club of America in September, 1923. In this, which is known as a moving coil loud speaker, a circular coil is located in a round air gap with an iron core in the centre. This air gap is traversed by a strong magnetic field excited by an inner coil which carries direct current, while the circular or moving coil carries a sound-producing alternating current, and is attached to the centre of the diaphragm (Fig. 2).



RELAY LOUD SPEAKER

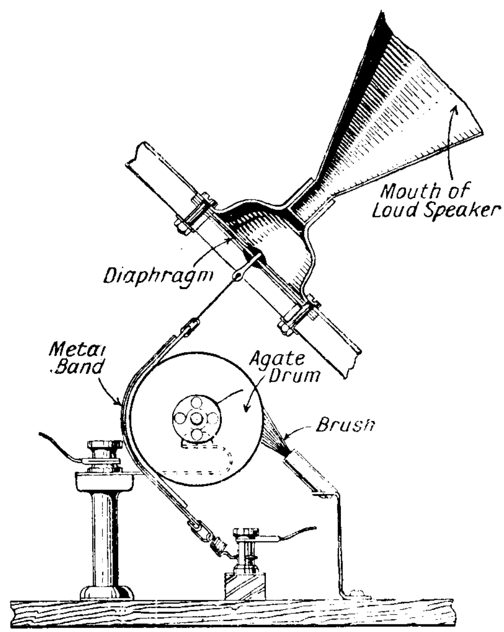
Fig. 4. Similar in construction to that of a polarized telegraphic relay is a relay type of loud speaker

Fig. 3 shows a balanced armature type of electro-magnetic system as applied to loud-speaker construction. In this a small iron armature is located in the centre of a coil and suspended by two thin piano wires. The coil is surrounded by two U-shaped pole-pieces forming two air gaps. A permanent magnet produces magnetic flux in these air gaps. The armature is caused to rock by the simultaneous energizing of the diametrically opposite pole-pieces by the current in the coil, and the rocking is communicated to the centre of the diaphragm through a thin connecting rod.

Fig. 4 shows what is known as the relay type of loud speaker, from the similarity of its construction to that of a polarized telegraph relay. A thin iron armature is located between four pole-pieces, each carrying a coil. These pole-pieces are magnetized by an L-shaped magnet, and the ends are connected in such a manner that diametrically opposite pole-pieces exert simultaneous attraction. The armature operates through a rod on the diaphragm.

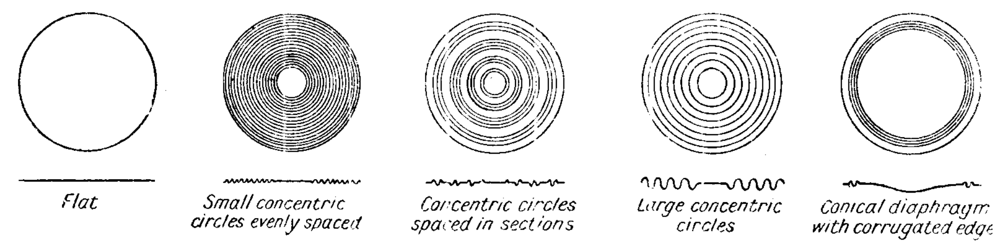
In addition to the above-mentioned types of electro-magnetic structure an electrostatic method has been applied to the making of loud speakers. The construction usually takes the form of an agate cylindrical drum over which a band of copper or similar metal is wrapped. The cylinder is revolved by a small motor or clockwork at a uniform rate. To one end of the band is directly coupled—mechanically—a diaphragm, the band being secured at the free end by a fairly stiff spring. Contact is made to lead the current by means of a brush or similar method to the cylinder, and, as the current varies, the attraction of the band to the cylinder varies with it, and the drag on the diaphragm due to the rotation is accentuated and reduced. The method gives good results, but the need of a separate motor to drive the cylinder, and the noise created by it, are somewhat serious drawbacks. The method of construction is shown in diagram form in Fig. 5 and suggests clearly the method of working.

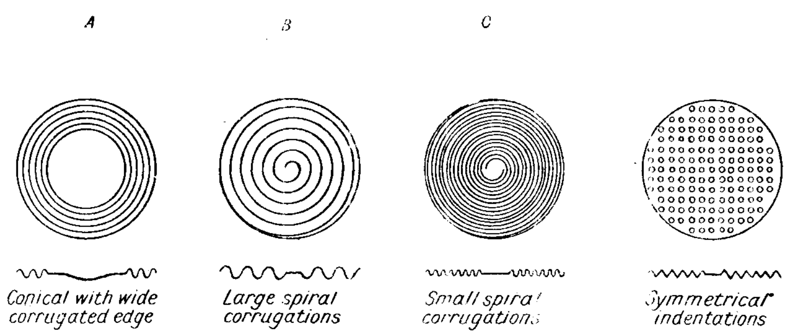
We now come to the sound-producing element or diaphragm, which in the simplest form of loud speaker, as in the ordinary telephone receiver, is merely a thin, flat disk of iron, or of metal with an iron centre, which vibrates in resonance with the frequencies of the electro-magnetic



ELECTROSTATIC LOUD SPEAKER

Fig. 5. In this type a metal band is driven over an agate drum, the attraction of the band to the cylinder varying with the current passing through the band





SELECTION OF DIAPHRAGMS USED FOR LOUD SPEAKERS

Fig. 6. These diagrams show the diaphragms which have been used on different types of loud speakers. Below each circular diaphragm is a section showing how the corrugations run on the surface

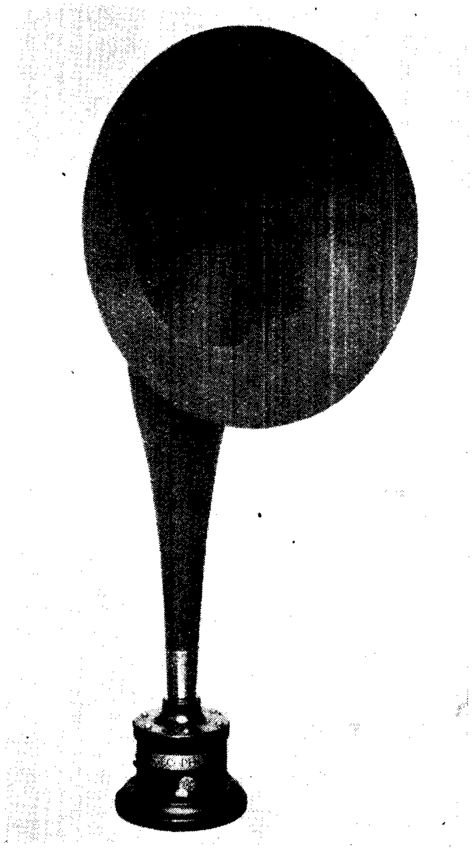
structure. In the more advanced types other metals and substances, notably aluminium and micarta, have been successfully employed. In the case of metal diaphragms considerable improvement has been attained by the introduction of corrugations, some types of which are here illustrated (Fig. 6). According to A. Nyman, types B and C have been found to give the most satisfactory results. Type C, in particular, which is based on mathematical considerations worked out by Dr. Philip Thomas, gives a curve in a test chart in which the "resonance points"—the presence of which is detrimental to good production because they either respond at a frequency different from that applied, or give an excessive volume of sound when their own fundamental frequency is applied—are distinctly less marked than in other cases. This diaphragm has corrugations spaced at radii bearing a ratio to each other corresponding to prime numbers. In modern types of loud speaker cone-shaped diaphragms are frequently used.

The sound-amplifying and distributing element in loud speakers usually takes the form of a horn of one or other of a great variety of shapes. At first a simple inverted cone was regarded as a satisfactory means of imparting the vibrations of the diaphragm to the air in such a way as to broadcast the sound waves over a considerable area. But the obvious deficiencies of this form of distribution where any sort of localized effect is desired have led to the "curling" of the horn till its trumpet mouth is at right angles, or nearly so, with the ground. A horn of the latter description naturally sends the sound waves in one direction only, but considerable divergence is obtained by reason of the wide mouth.

The length of the horn, and the material of which it is made, greatly affect its efficiency. Theoretically a horn longer than one quarter of the wave-length of the lowest pitch available gives the best reproduction. However, in practice the length of the horn seldom exceeds 3 ft., approximately one-fourth of the wave-length of 90 cycles, the fundamental of the horn. If the horn is shorter than 1 ft. (270 cycles fundamental), bass and baritone voices are likely to be distorted, since their fundamental, which is below 270 cycles, would be reduced (Nyman). In practice a horn 2 ft. long has been found capable of critically good reproduction.

The most recent tendency as regards the material of which the horn is constructed appears to be in the direction of a return to metal, usually highly enamelled. But in the very efficient types of loud speaker the horn continues to be made of a moulded composition in which it may be conjectured that some sort of papier mâché is involved.

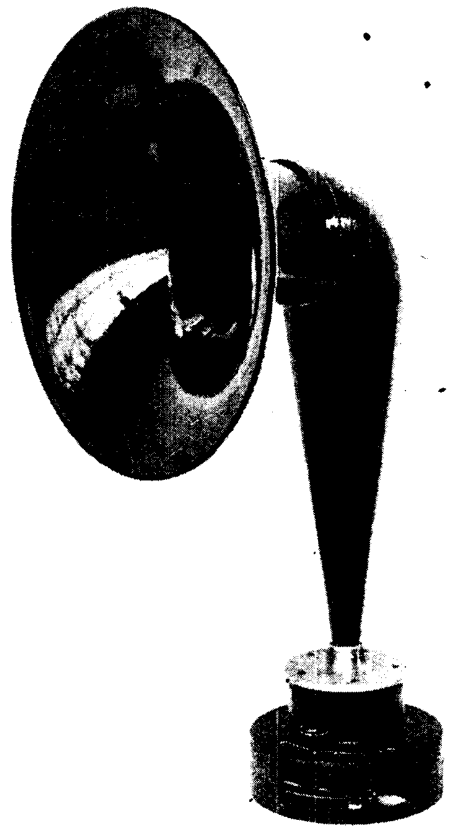
Apart from horns, various sound-distributing devices have been introduced for the sake either of increased portability or in order that the loud speaker may not produce a jarring note mid aesthetic surroundings. The most conspicuous of these variations is the Burndept Loud Speaker de Luxe, which takes the form of a large vase of classical design. Loud speakers have also been made in the form of a shell, and hornless loud speakers are sometimes enclosed in cabinets, the walls and doors of which provide the necessary amplifying and distributing properties. The principle, however, remains the same, that of striking the air with the vibrations which have been produced in a diaphragm by electrical means interacting with the alternating current derived from a wireless receiver.—*O. Wheeler.*



GECOPHONE LOUD SPEAKER

Fig. 7. Blaring effect due to vibration is reduced in the Gecophone loud speaker by an ebonite horn. This loud speaker is actuated on the electro-magnetic system

Courtesy General Electric Co., Ltd.



FULLER LOUD SPEAKER

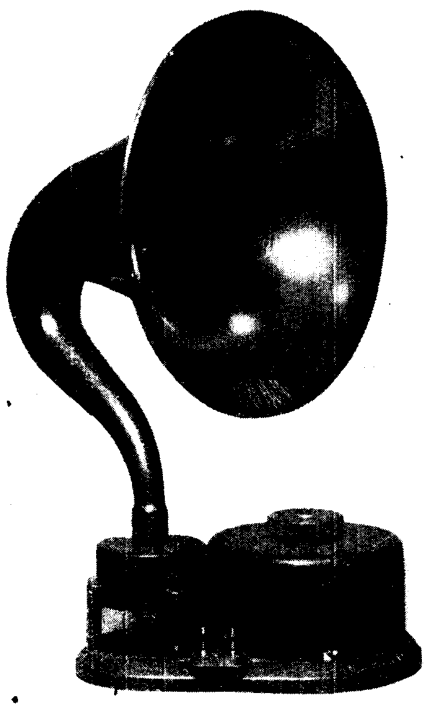
Fig. 8. In the Fuller loud speaker, which has two controls in the base, one regulates the purity of the sound and the other the strength of the sound

Courtesy Fuller's United Electric Co., Ltd.

Types of Loud Speakers. The Gecophone loud speaker illustrated in Fig. 7 is well known, and in the pattern illustrated comprises a circular base with a casting containing the diaphragm and electro-magnetic system. Mounted upon the top of the case is a moulded ebonite horn neatly finished with a matt surface. The purpose of using ebonite is to avoid blaring due to the vibration set up in the horn.

A somewhat different arrangement is adopted in the Fuller loud speaker illustrated in Fig. 8, as contained in the base of the instrument are two controls. These are provided to regulate the purity of the sounds produced by the instrument and also to regulate the quality and strength of the sounds. In addition they have the effect in working of acting as a tone filter and to some extent cutting out unwanted interference and internal noises.

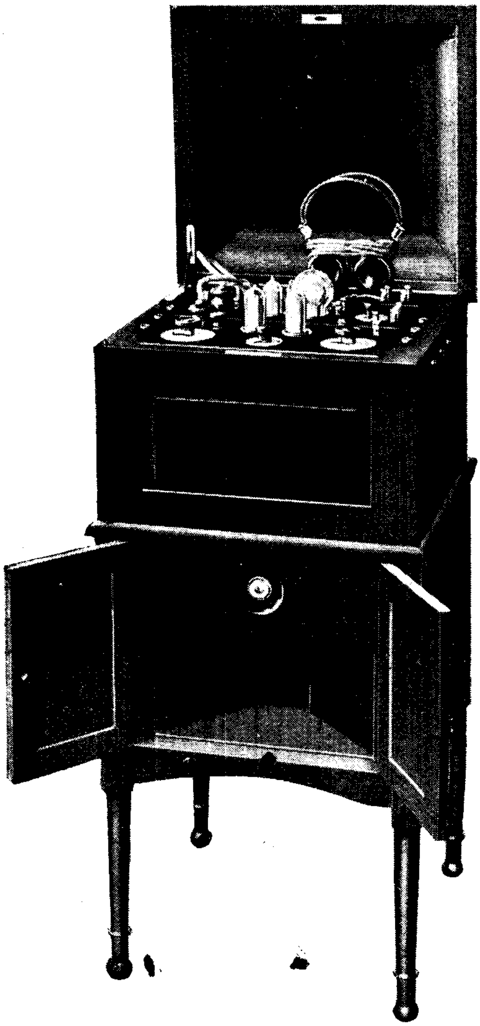
The Crystavox loud speaker illustrated in Fig. 9 is a new departure in the design of this class of instrument, and is intended for use with a crystal set where reasonably loud signals are normally heard in the telephones. An internal view of the mechanism is given in Fig. 10, from which it will be seen that essentially the apparatus comprises a microphone relay, which is energized by an accumulator. Stated briefly, the action of the microphone relay is to magnify the incoming signals from the crystal set and hand them on with increased strength to the electro-magnetic system of the loud speaker, and consequently the diaphragm of the latter is able to function with greater strength.



CRYSTAVOX LOUD SPEAKER

Fig. 9. This loud speaker, the Crystavox, is for use with a crystal set only, and no valve is required. It consists essentially of a microphone relay

Courtesy S. G. Brown, Ltd.



ENCLOSED SET WITH LOUD SPEAKER

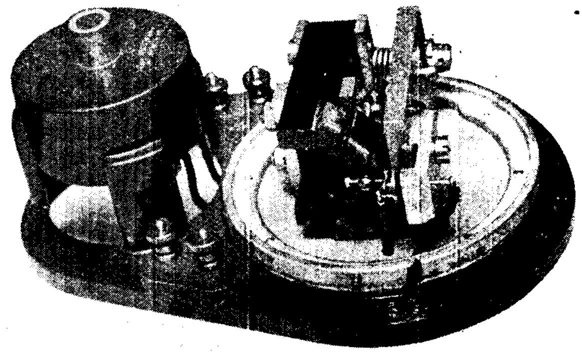
Fig. 11. In this cabinet is an entirely closed or self-contained loud-speaker set, similar to the enclosed sound amplifier of a gramophone cabinet. Four valves are used

Courtesy Metropolitan Vickers Electrical Co., Ltd.

An example of the entirely enclosed or self-contained loud speaker set, by the Metropolitan Vickers Co., is illustrated in Fig. 11. This shows a Cosmos four-valve receiving set of the cabinet type, with a pair of telephones for tuning purposes, and with a self-contained, built-in loud speaker. The flare or opening of the trumpet is normally covered, when not in use, by the folding doors, which are open when the set is in operation.

The receiving set and the amplifier are contained within the upper part of the cabinet, and comprise the usual detector and amplifying valves, with the addition of one power valve, giving ample volume of sound for loud-speaker work.

Four different types of loud speaker by the Western Electric Co., Ltd., are shown in Fig. 12. The first one on the left-hand side is a very large instrument designed for delivering great volumes of sound when occasion demands, either in large halls or in the open air. Its principle of action is designed upon the balanced armature system. The whole of the reproducer is contained within a very heavy base casting, which prevents any possibility of its being easily knocked over. The horn is made of a moulding in a special non-sonorous material, which is non-metallic, and does not resonate. This is finished in a dull matt surface.

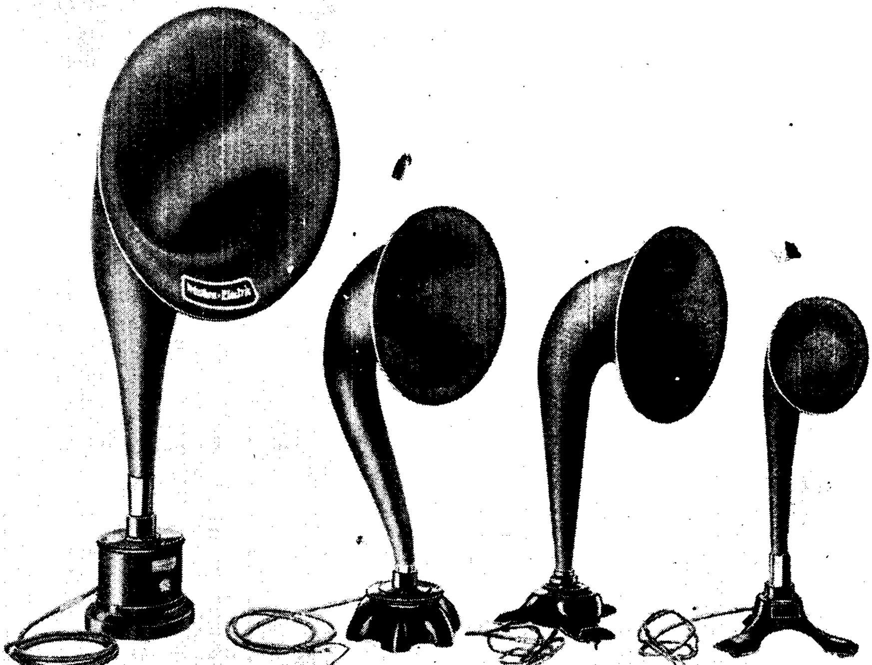


INTERIOR OF CRYSTAVOX LOUD SPEAKER

Fig. 10. An accumulator is employed to energize the Crystavox loud speaker, of which the above is an interior view, showing the microphone relay

Courtesy S. G. Brown, Ltd.

The second instrument is smaller, but



FOUR DIFFERENT EXAMPLES OF A LOUD SPEAKER

Fig. 12. Four different types of loud speaker made by the Western Electric Co. are illustrated The left is for large halls or open-air work, and those on its right are for smaller rooms and private houses

Courtesy Western Electric Co., Ltd.

works on the same principle, and has a non-metallic diaphragm. This instrument is designed for use in the home where a good volume is desired.

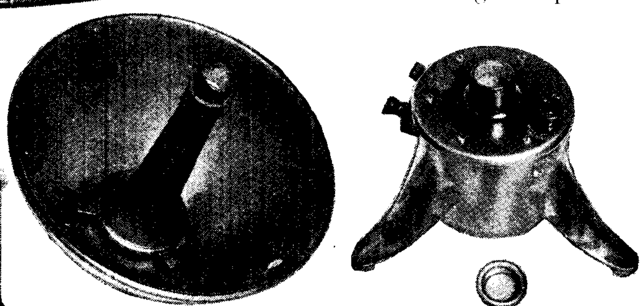
The third from the left is constructed on the ordinary telephone principle. It is fitted with a device for altering the tone by effecting an adjustment of the distance between the pole faces and the diaphragm. This device is actuated by rotating a milled ring which surrounds the base of the horn. The latter is of the same material as the loud speakers previously described, and is finished in a similar manner.

The fourth instrument is a very small one designed for small rooms, and to be produced at a low cost. No adjustment of any kind is fitted. The legs upon which it stands are well splayed in order to form a firm stand.

The loud speaker illustrated in Figs. 13 and 14 represents a type where the sound waves are reflected downwards and distributed in all directions. The movement is the standard Sterling magnetic type, fitted with a knob to control the space between the magnet faces and the diaphragm. Terminals having insulated milled nuts are mounted on an ebonite block secured to the base casting. The feet are rubber-studded. The small metal stamping shown in Fig. 14 is a dust cap to put over the hole in the sound-box when the dome is removed. Fig. 14 shows the internal arrangements of the sound reflector. A belled-out tube is mounted on top of the telephone receiver. This tube has three lugs projecting from it. The dome, which is parabolic in shape, is inverted over the tube, being supported by the lugs, and having a space of about ½ in. between its underside and the top of the tube.

The sound waves proceeding up the tube are caught by the parabolic reflector and repelled outwards and downwards. This instrument is designed particularly for use on dining or drawing room tables, and is tastefully finished in shades of gold and black. This finish makes it a very attractive addition to any set designed purely for entertainment purposes, and harmonizes with most interior decorations.—*R. B. Hurlon.*

Fig. 13



STERLING DOME LOUD SPEAKER

Fig. 13 (left). In this type of loud speaker the sound waves are reflected downward and distributed in all directions. Fig. 14 (above). The interior of the sound reflector is shown and is parabolic in shape

Courtesy Sterling Telephone and Electric Co., Ltd

How to Improve the Tone of Loud Speakers. Successful operation depends on a variety of circumstances, chiefly, perhaps, a good instrument of modern design, a well-balanced receiver circuit, and proper tuning thereof. Generally the best results follow the use of a stage of H.F. amplification, a crystal detector, and a stage of L.F. amplification, the set being without reaction. This gives very pure reproduction and good tonal qualities, but is often of insufficient strength and lacking in volume to fill a large room adequately.

The first requirement is, therefore, sufficient signal strength to actuate the diaphragm of the loud speaker properly.

This, if effected by many stages of amplification, results very often in serious distortion, causing a blaring and tinny sound from the loud speaker and a lack of true tonal quality. Sometimes the low tones are deficient or absent, and in others the reverse is the case.

As a rule H.F. amplification seems to increase the sharpness of tone and accentuate the high notes, while L.F. amplification tends to increase volume, and generally brings in the lower tones at relatively greater strength. So much depends on the tuning, nature of circuit, and details of the loud speaker that generalizations are often misleading.

Distortion in loud speakers may be assigned to two main causes: first, those which may exist in the loud speaker itself; secondly, those to be found in the receiving set. Each of these main causes may again be divided up into different sections. Probably the receiving set itself is the offender, and the incorrect use of reaction is most likely to be the cause of distortion.

Experiments in the reduction of reaction coupling should therefore be made, and if not entirely successful in eliminating distortion, the functioning of the valve or valves should be suspected. The output of the valve is limited according to the type used, and if it is called upon to do more work than it can normally manage, distortion will ensue. This is particularly true in the case of the last valve where multi-stage low-frequency amplification is employed. As amplification is increased with further stages, it will be necessary to increase the grid voltage in a negative direction if distortion in the loud speaker is to be avoided. This may be effected by the use of grid-biasing batteries (*q.v.*).

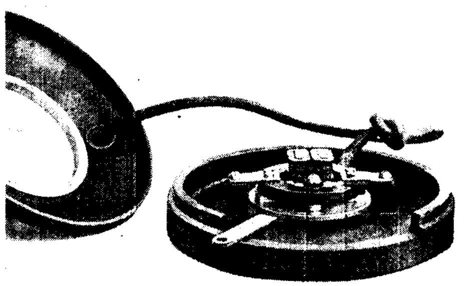
Separate taps to the high-tension batteries are an advantage, and the voltage should be progressively increased to the last valve. The use of a higher anode voltage is of advantage in another direction, tending towards better reproduction from the loud speaker, as when higher filament current is used the flat portion of the valve curve is longer.

There are many other causes of bad reproduction in loud speakers attributable to the receiving sets, and these should be studied in connexion with the article on Faults, and especially that part dealing with faulty high-tension batteries.

A practical way of dealing with the matter is to connect the loud speaker in the usual way to the telephone terminals. The set is then tuned to the nearest broadcasting station, so that the loud speaker plays softly, but with the maximum of purity. The set is then more closely tuned, judging the effect of each adjustment in turn and reducing any feature that causes blaring or distortion and emphasizing others.

Many of the better quality loud speakers are provided with an adjusting mechanism which has the effect of altering the closeness of the diaphragm to the loud-speaker magnets. In some patterns the diaphragm is moved, and in other the whole of the magnets and their supports are capable of adjustment towards or from the diaphragm.

The latter is the case in the Ethovox Junior, the interior of the loud-speaker body of which is seen in Fig. 15. It



ETHOVOX LOUD SPEAKER DIAPHRAGM CONTROL

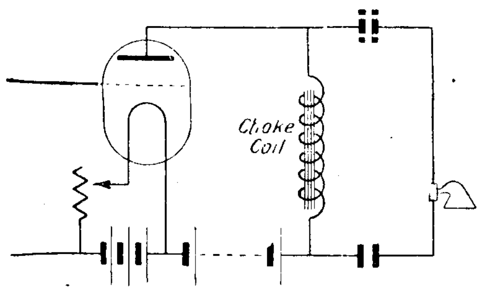
Fig. 15. Details of the interior of the loud speaker show how the magnets are adjusted in relation to the diaphragm

will be seen to consist of two main castings, the upper one forming a support for the trumpet and incorporating the diaphragm on its underside. The lower plate, or casting, supports the magnets of the loud speaker, which is fitted centrally to a screwed rod having a quick thread. An arm projects through the joint between top and lower plates, and is attached to the magnet unit. The latter is screwed to the lower plate by a suitably drilled and tapped hole to match the quick thread on the magnet unit. The effect of moving the control arm is to rotate the screwed rod up or down in the hole in the lower plate, thus altering the position of the magnets with regard to the fixed diaphragm.

The adjustment of this control in loud speakers is of importance, and should be slowly and carefully regulated to suit the volume of sound with which the loud speaker is to operate. If the blaring is found only on the loudest sounds, it is probable that, owing to the increased movement of the diaphragm under these conditions, it makes metallic contact with the ends of the magnets. It may be remedied by adjusting the control device of the loud speaker to give a larger clearance. Where the loud speaker is not capable of adjustment the volume of sound should be reduced.

In many loud speakers the direction of connexion of the leads is important, and a reversal of connexion may have beneficial results.

The tonal qualities of the loud speaker may often be improved by the addition of an iron-core choke, which is shunted across the loud speaker and a fixed condenser arranged in series with it. The choke should have a high impedance, yet offer a low electrical resistance to the steady flow of anode current. The effect of an additional condenser in the opposite lead of the loud speaker should also be tried. The arrangement of choke and condenser is illustrated in Fig. 16, where the optional condenser is shown in dotted lines. The best value of the con-



IRON-CORE CHOKE IN ANODE CIRCUIT

Fig. 16. By including an iron-core choke and a large condenser in the circuit the anode current is prevented from reaching the loud-speaker windings, while the modulated currents pass through the condenser to the loud speaker, thus improving the tone

densers should be found by experiment, but about ·5 mfd. can be tried as a start.

It is often a disadvantage to insert the loud speaker direct in the anode circuit of the valve, as, for one reason, its insulation is subjected to the strain of the high-tension battery, and even a slight leakage of current may give rise to howling and parasitic noises. A telephone transformer may be used to overcome this difficulty, and is arranged with its coil of higher resistance in the circuit of the set itself. The lower-resistance coil of the transformer is connected direct to the loud speaker. Where this method is adopted care should be taken to ensure that the resistance of the loud speaker is suited to that of the output of the transformer. This must also be done where the loud speaker is connected direct to the set, where a resistance of 2,000 ohms or more is usual.

The secondary windings of the inter-valve transformers may be shunted with a resistance of, say, ·5 megohm, giving an important effect on the resulting purity of tone. The transformers must be of the best make for loud-speaker work, and of different manufacture if two stages are employed.

It is sometimes found desirable to incorporate a resistance in series with the loud speaker, and it should preferably be of the variable variety, so that the best results may be quickly found.

The addition of a fixed condenser across the terminals of a loud speaker of the low-resistance type frequently results in more mellow reproduction, and the value of the condenser should be found by experiment, usually ranging from ·001 to ·005 mfd.

A novel tone filter giving three different tones, which may be selected to suit the requirements of a particular musical transmission, is described in the article on the Cockaday Circuit, and may easily be adapted for use with a loud speaker.

Cognate subjects which should be studied as bearing on the subject of loud speakers include Choke Coil, Filter Circuits, Telephone Condenser and Tone Filter.

How to Make a Simple Loud Speaker. The loud speaker shown in Fig. 17 gives excellent results under all normal conditions, and can be made up very easily from cardboard and wood covered in imitation leather paper. The telephone is either a single earpiece or one side of a double-head set, the magnets, pole-pieces, and bobbins being remounted in a wooden box with an adjustment screw and a larger diaphragm.

It will be desirable to proceed with the detail and construction of the base and housing for the telephone, which may be seen in Fig. 18, to consist of a circular base and square box supported upon a small pillar. The base is $4\frac{1}{2}$ in. in

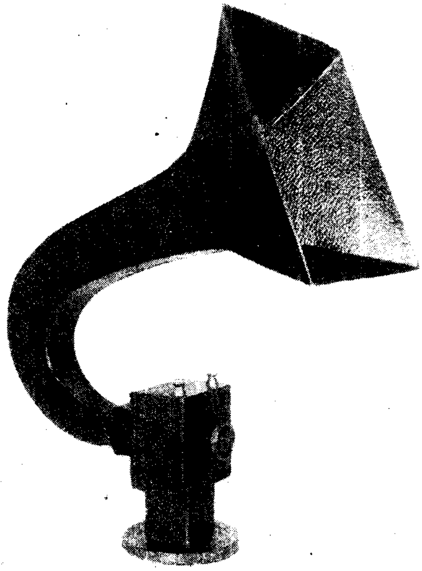


Fig. 17. Amateurs can easily construct a loud speaker after this design

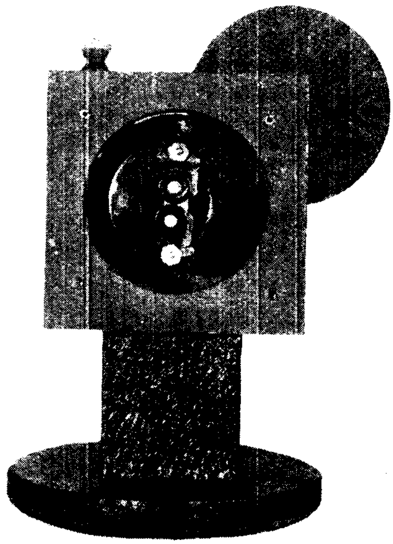


Fig. 18. How the telephone and diaphragm are fixed in the base. This is the base construction

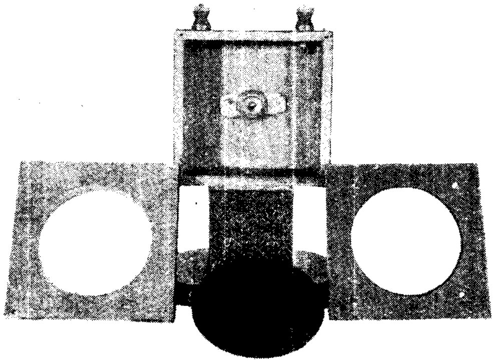


Fig. 19. In this photograph are shown the diaphragm and seating before the telephone is inserted

Fig. 20. Covered with imitation leather, the horn is here shown complete

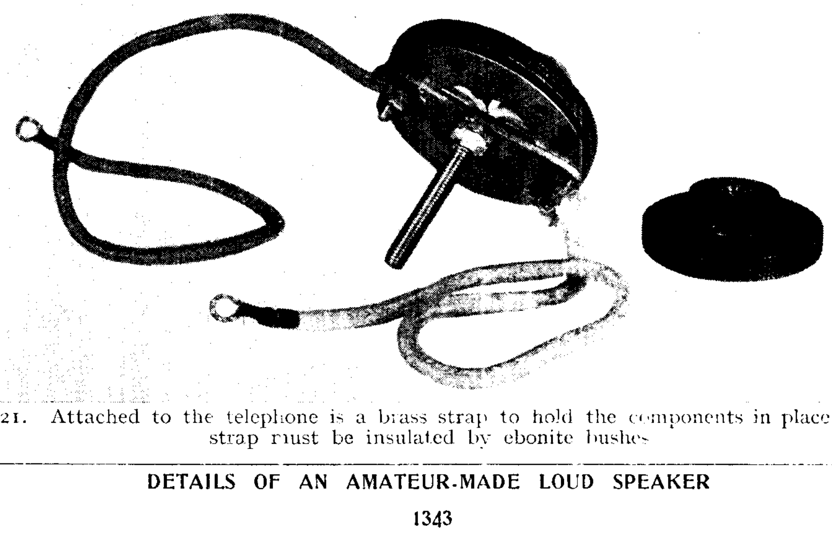


Fig. 21. Attached to the telephone is a brass strap to hold the components in place. This strap must be insulated by ebonite bushes

DETAILS OF AN AMATEUR-MADE LOUD SPEAKER

diameter by ½ in. thick. A solid block of wood 2 in. each way is prepared and fastened to the centre of the base, upon which is mounted a thin wooden box of ¼ in. thickness, the outside dimensions of which are 3½ in. square and 1½ in. deep.

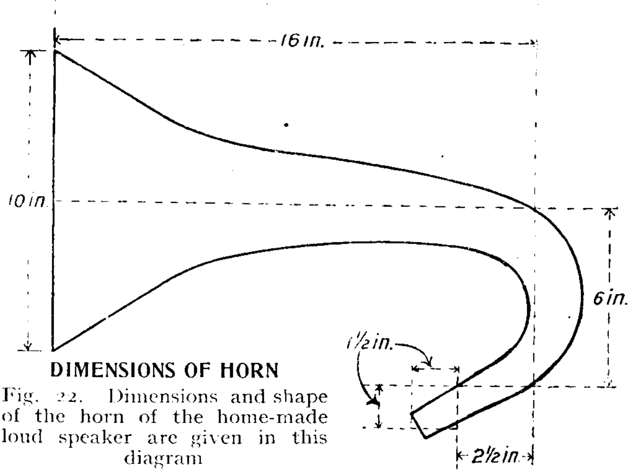
The adjustment side of this box is also covered with ¼ in. wood; whilst for the other side a piece of ½ in. wood is prepared with a 2¾ in. diameter hole cut in the centre with a fret saw (Fig. 19). This forms the seating for the diaphragm. Another piece of wood the same outside dimensions as the latter, but ¼ in. thick, may be cut out for the small end support of the horn. This should have a hole in the centre ½ in. square.

The telephone should be removed from its original case. The one used in this loud speaker is a Sidpe, and is held in its original case by two screws, which form the terminals for the telephone leads. These screws must be removed very carefully, as the components of the telephone will otherwise fall apart.

A brass strap should be prepared to hold the components in place. The vulcanite bushes which previously insulated the terminals from the case must be used to insulate this strap. A piece of $\frac{1}{16}$ in. brass will be quite suitable. Holes are drilled in either end to agree with the holes in the case of the telephone, and in addition a hole should be drilled in the centre to accommodate a piece of 2 B.A. screwed rod, say 1¼ in. long.

This rod should be firmly soldered to the centre, which is clearly shown in Fig. 21. A bush is required, tapped to 2 B.A., to which is soldered a foot-piece of ⅛ in. brass, with a clearing hole for 2 B.A. This may be seen in Fig. 19, showing the interior of the box, and serves to allow the telephone to be adjusted in position in respect to the diaphragm by means of an ebonite knob on the exterior.

A packing piece of cardboard 3½ in. square, with a central hole of 2¾ in. diameter, will be required for clamping the diaphragm to its seating. The diaphragm is a piece of sheet iron or ferrotype plate, and is 3 in. in diameter. Several diaphragms may be prepared, as it will probably be found that one of them will give better results than the others.



DIMENSIONS OF HORN

Fig. 22. Dimensions and shape of the horn of the home-made loud speaker are given in this diagram

For the construction of the horn, three or four sheets of card or packing board known as "six-sheet" will be required, measuring 27 in. by 34 in. each. The two side pieces should be cut out of similar shape to Fig. 22, the card being ruled with a central line which is 16 in. long, the horizontal line being 6 in. A freehand outline completes the shape, with the aid of a pair of dividers to check the symmetry. These two similar pieces should now be temporarily fastened together at a gently tapering angle by means of rough pieces of wood cut to a suitable length and tacked between the two at varying distances, leaving the mouth 10 in. wide and the base 1 in. wide.

Paper patterns for the top and bottom pieces should be cut out as a guide for the cardboard, using stiff brown paper. The top and bottom pieces of cardboard having been cut out, they may be fastened in position with good Scotch glue and strips of brown paper, beginning by joining the two sides to the bottom piece. When this is dry, proceed to fasten the top piece in a similar manner, removing the temporary stays as they are approached, this process being carried out to the end of the horn. The whole is then allowed to thoroughly dry, when it may be rubbed down with glass-paper. It is essential that the production of the horn be not hurried.

A little wooden box is next prepared, 2 in. square by 1½ in. long. This is glued into position on the square piece of wood already prepared with a square hole, and the horn should be fastened into position with glue and sawdust packing. The horn and base may now be assembled.

The telephone may now be provided with a pair of flexible leads, and a couple of terminals may be fitted in the top partition of the box. The 2 B.A. screwed rod may be screwed through the central bush, which has previously been fitted to the centre of the telephone box. When sufficiently through so that there is ample clearance, at least $\frac{1}{8}$ in. from the diaphragm plane, the exterior should be provided with a washer, spring washer, pointer and ebonite knob, cutting the 2 B.A. rod as necessary, but leaving sufficient thread to allow the magnets and pole-pieces to screw up to the diaphragm.

When this is completed satisfactorily the telephone leads should be fastened to the terminals. The diaphragm should now be put into position and the complete loud speaker assembled. The thick piece of wood with the circular opening being fastened in position upon the telephone box with glue and screws, the diaphragm should be laid in position, the card packing on the top, and the horn, with square piece, screwed on top of all.

Join the telephone terminals of the set with a short flexible lead to each of the terminals of the loud speaker, and gently revolve the knob until the best reproduction is obtained. The loud speaker constructed in accordance with the particulars given has none of the harsh reproduction which is sometimes the case with a metal horn. After a satisfactory trial the whole may be covered with imitation leather cloth (Fig. 20) or paper, and the base, in addition, provided with a circular piece of velvet to prevent slipping or damage to furniture.—*F. Huson.*

LOW FREQUENCY. It has become the practice in everyday language to designate the band of frequencies used in present-day wireless practice as high frequency and low frequency. This division, although convenient, must not be taken to mean that there is any fixed frequency above which a frequency is high or below which a frequency is low, and the terms high and low are used only in a comparative sense, therefore, and are not absolute.

In wireless telegraphic practice use is made of frequencies lying between the limits of about 300,000,000 and 10,000 periods per second, and these frequencies are classed as high- or radio-frequency oscillations.

In the wireless transmission of speech and music, however, use is made of a band of frequencies known as audio-frequencies. This band covers a range of about 50–20,000 periods per second. The upper limit has been given by Galton as the maximum frequency to which the human ear can respond, while frequencies below 50 are hardly distinguishable as musical notes.

The low-frequency band has come to be known among wireless workers as audio-frequency, to differentiate it from the radio- or high-frequency band. The radio- or high-frequency oscillations received in the aerial are rectified to L.F.

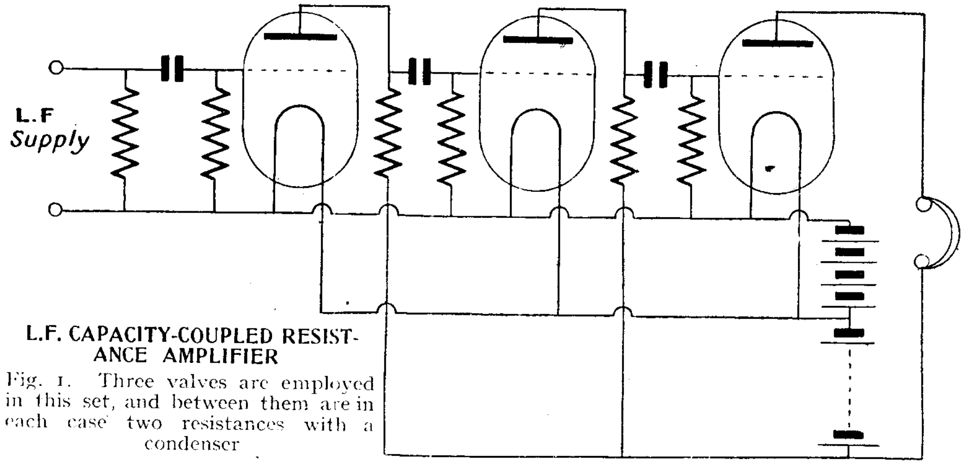
The electrical engineer, as distinct from the radio engineer, would, on the other hand, consider any frequency above about 1,000 periods per second as high, as alternating current generators are seldom designed for frequencies greater than 500 periods per second. This does not include, of course, the special types of high-frequency alternators used for wireless purposes. *See* next entry. *See* also Amplification; Amplifier; High-frequency Amplifier.

LOW-FREQUENCY AMPLIFIERS & HOW THEY WORK

Principles and Methods of Using the Best Types of L.F. Amplifiers

Here are explained the principles and standard methods of low-frequency amplification, including amplification by resistance-capacity and transformer coupling. Several good types of amplifiers are also illustrated and described. See also associated headings, such as Amplifier; Audio-frequency; Frame Aerial; High-frequency Amplification, etc.

The waves used for wireless telegraphy and telephony are of two principal kinds, damped and continuous, but of whichever kind the wave may be, it is generally of such a wave-length or frequency as to be inaudible, unless some means is employed, at either the transmitting or receiving end, of producing a low frequency. With damped waves produced from a spark transmitter, the sparks themselves are of low frequency, for as a rule the spark frequency will lie between some fifty



L.F. CAPACITY-COUPLED RESISTANCE AMPLIFIER

Fig. 1. Three valves are employed in this set, and between them are in each case two resistances with a condenser

cycles and two thousand. Frequencies of this order produce waves which are audible in a wireless receiver, and are considered as low frequencies when in comparison with the frequency of the actual high-frequency oscillations of the wave train, which will be of a frequency of from hundreds of thousands of cycles to millions of cycles per second, and therefore quite inaudible to the ear. There is, of course, no actual point at which a high frequency may be said to change to a low frequency, and the terms must be considered as being used in a purely comparative sense.

By the use of valves, either the high- or the low-frequency oscillations may be magnified or amplified; in some cases arrangements are made to carry out both operations in the same valve.

The more general arrangement, however, is to employ a high-frequency amplifier first, then to rectify the amplified current, and finally to increase the volume of the signal by means of low-frequency amplification.

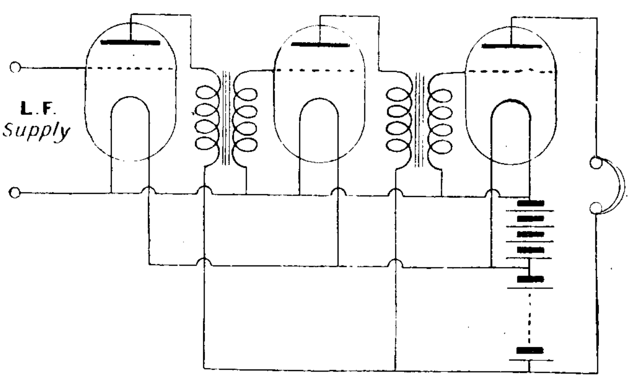
Low-frequency amplification is necessary when a large current is required from the receiver in order to work many pairs of telephones or one or more loud-speaking telephones.

Low-frequency amplifiers are, in general, of two types—resistance amplifiers and transformer-coupled amplifiers. So-called resistance amplifiers give the purest quality of amplification, and are to be recommended when many stages of low-frequency amplification are wanted, and when it is intended to employ the amplifier for the magnification of speech or music (*see* Fig. 1, which shows a three-stage resistance amplifier with the last anode directly connected to the telephones).

In practice a telephone transformer may be inserted in place of the high-resistance telephones, thus enabling low-resistance telephones, which have certain definite advantages, to be employed.

Fig. 2 is of a similar amplifier, but with transformer coupling between the valves.

Two or three stages of low-frequency amplification may be employed, and each of them will have a step-up effect over the preceding valve. Customarily, the ratio of amplification over a single transformer is in the neighbourhood of 4 or 5 to 1. The second stage might have an increase of 3 to 1 over the first, and the third another 2 or 3 to 1 increase. Arranged in this way each



LOW-FREQUENCY TRANSFORMER-COUPLED AMPLIFIER

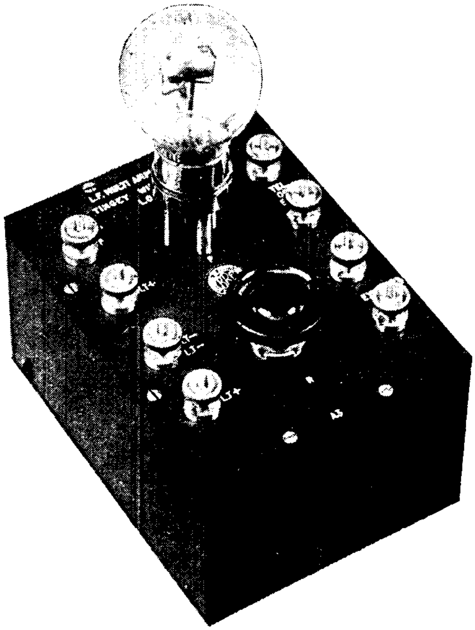
Fig. 2. This set differs from that shown in Fig 1, in that, in place of resistance-capacity, iron-cored transformers are used

stage of amplification amplifies the signals it receives from the previous valve, and in two or three stages enormously magnifies the volume of sound.

It is seldom practicable to use more than three stages of low-frequency amplification, otherwise trouble will probably arise from internal noises in the set due to a variety of causes, generally associated with imperfect connexions and inefficient insulation.

A low-frequency amplifier may form an integral part of a receiving set, and may or may not be used with high-frequency amplification. In many cases, however, a low-frequency amplifier is made up in the form of a complete unit, and may be employed as such to amplify signals from practically any form of detector, although with some circuits embodying the super-regenerative principle it is not always practicable to do so without modification of the circuit itself. In the ordinary way, however, a low-frequency amplifier can be added to an existing set.

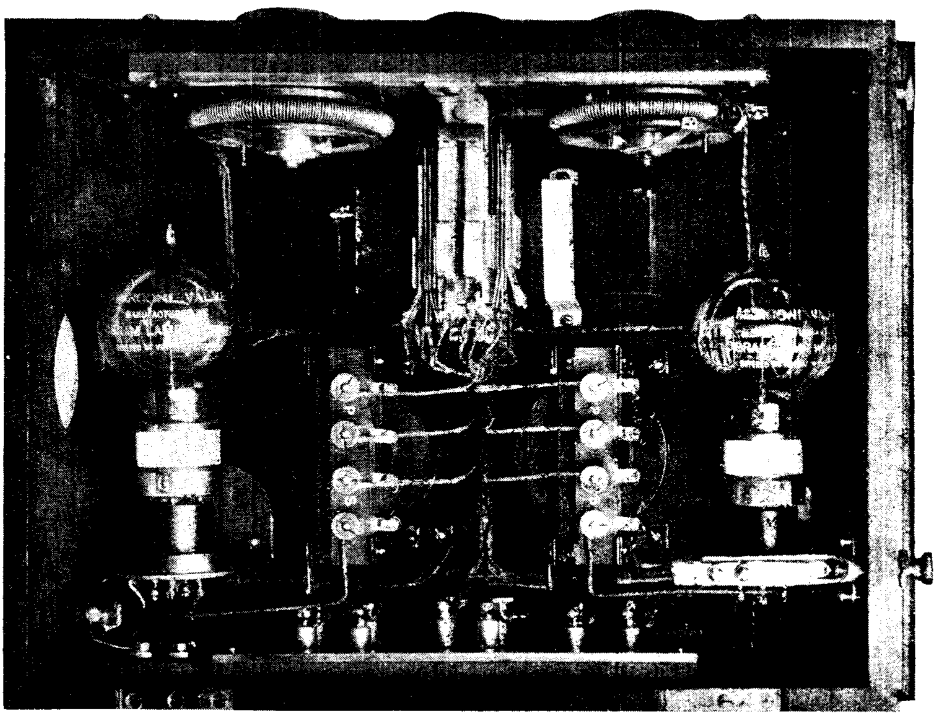
An example of the commercial pattern of single-valve low-frequency amplifier is



TINGEY L.F. AMPLIFIER

Fig. 3. Tingey's one-valve self-contained low-frequency amplifier unit is illustrated

Courtesy Tingey Wireless, Ltd.



INTERIOR OF GECOPHONE TWO-VALVE AMPLIFIER

Fig. 4. Photographed from above the interior of the open Gecophone appears as shown here. The valves, transformers, rheostats, and jacks can be clearly seen

Courtesy General Electric Co., Ltd.

given in Fig. 3, which comprises a polished wood case with an ebonite panel mounted on the top, and carrying terminals for connexions to the telephones, high- and low-tension batteries, and for the input from the detector.

Another type of low-frequency amplifier, known as the Oracle, shown in Fig. 5, is arranged to permit of any number of stages of low-frequency amplification being used in tandem, the arrangement of terminals permitting this. In the Oracle set a single valve is used and inserted into the short valve sockets shown in the illustration. It is controlled by a filament rheostat in the usual way. Mounted beneath the panel is a specially wound transformer. All connexions are brought out to terminals on the top of the panel to provide ease of connexion and manipulation.

A two-valve low-frequency amplifier is illustrated in Fig. 6. This embodies a switching device permitting one or two stages of amplification to be used, as

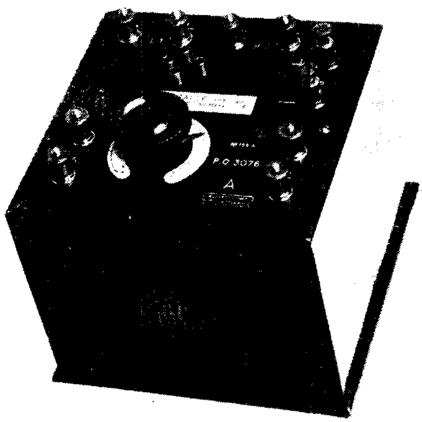


Fig. 5. Any number of stages of L.F. may be used in tandem by employing the Oracle amplifier. A feature of this set is the specially wound L.F. transformer

Courtesy Bassett-Lowke, Ltd.

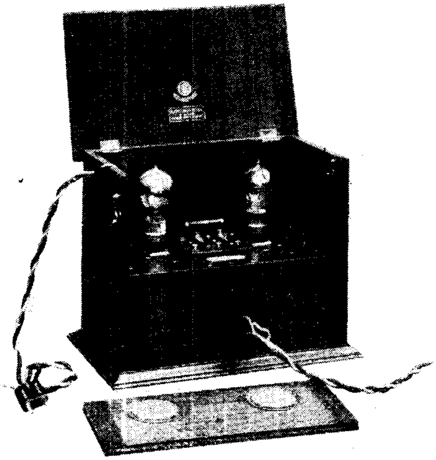


Fig. 6. By means of a switching device, either one or two stages of low frequency may be employed in this Marconiphone set

Courtesy Marconi's Wireless Telegraph Co., Ltd.

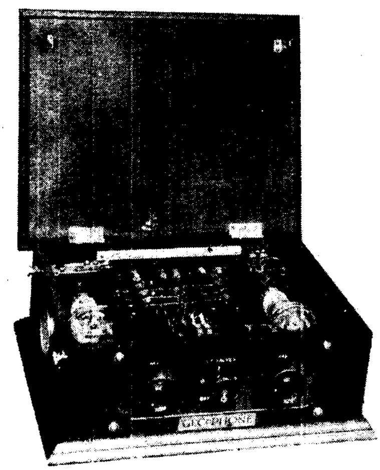


Fig. 7. All connexions of the Gecophone two-valve L.F. amplifier are made by plugs and jacks

Courtesy General Electric Co., Ltd.

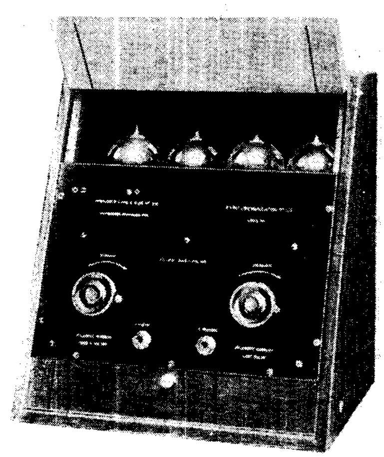


Fig. 8. One rheostat controls three valves in this Polar L.F amplifier, another the fourth valve, which may be a power valve

Courtesy Radio Communication Co., Ltd.

COMMERCIAL TYPES OF LOW-FREQUENCY AMPLIFIERS desired. Connexions to telephones, loud speaker, and the receiving set, are effected by means of flexible wires and plug-in connectors. The instrument is arranged with a hinged lid and detachable front panel, enabling it to be closed whenever necessary.

The Gecophone two-valve low-frequency amplifier is shown in Fig. 7 and the plan view of the interior in Fig. 4. In this case the whole of the components are neatly arranged within a cabinet, which can normally be used with the lid closed, and all connexions are effected with standard plugs and jacks, and removing a plug automatically makes and breaks the circuit.

An example of a four-valve low-frequency amplifier is shown in Fig. 8, as supplied by the Radio Communication Co., Ltd. In this case one filament rheostat controls the first three valves, and a second filament rheostat controls the fourth valve, which can be, if desired, a power valve.

Plug-in connexions enable the telephones or loud speaker to be plugged in either on one, two or more valves, as desired. The whole is enclosed in a neat sloping-fronted case with a small hinged panel on the front, which provides for inspection of the valves or their removal, and, when closed, protects them from injury.

The construction of a low-frequency amplifier is dealt with under the headings Amplifier and Audio-frequency Amplifier (*q.v.*). *See also* Intensifier; Inter-valve Coupling.

LOW-FREQUENCY CURRENT. This is the name usually given to an alternating current which has a frequency of only a few hundreds per second. It is a comparative term, there being no hard-and-fast dividing line between high- and low-frequency currents.

LOW-FREQUENCY IRON-CORE INDUCTANCE. A variable inductance having an open-ended iron wire core. Such an inductance is used with Marconi spark transmitters. Its function is to put the circuit in resonance with the alternating current frequency. In the 1½ kw. transmitter there are two such inductances, each consisting of a bobbin wound with double cotton-covered wire over an open-ended wire core.

LOW-FREQUENCY TRANSFORMER. Low-frequency transformers are used in alternating current circuits, where the frequency of the current is between the limits of 25 and 20,000 periods per second. In power circuits supplied with alternating current the frequency usually lies

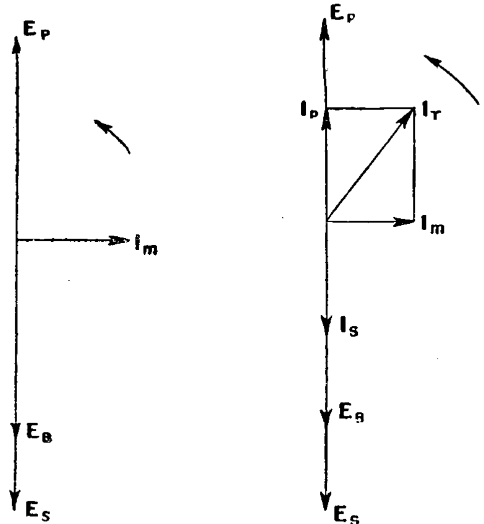
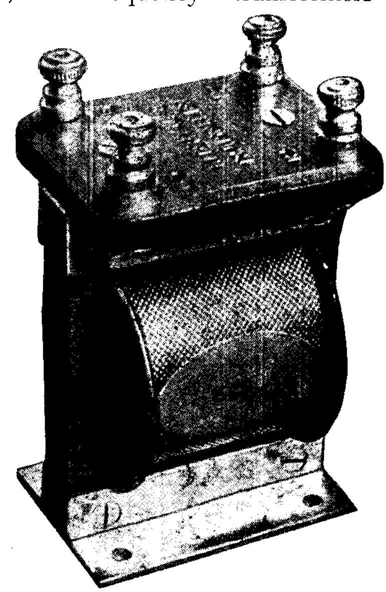


Fig. 1 Fig. 2.

VECTOR DIAGRAMS OF L.F. TRANSFORMER

Fig. 1. Lag of the magnetizing current is shown in this vector diagram. Fig. 2. In this case the action of a loaded transformer is represented

between the limits of 25 and 500 periods per second. In radio engineering, however, low-frequency transformers are



STANDARD L.F. TRANSFORMER

Fig. 3. This is a standard type of inter-valve low-frequency transformer suitable for attaching to a panel or baseboard

included in circuits supplied with alternating currents of frequencies between the limits of 25 and 20,000 periods.

In a wireless transmitter designed for the transmission of speech and music, that is, for audio-frequencies, low-frequency transformers are used for both the above-mentioned sets of frequencies. Thus low-frequency transformers are used: (1) to transform the low-tension alternating current supply (of the usual power-supply frequency) to high tension; (2) to transform the alternating current supply down to a voltage for applying to the filaments of the valves; (3) as microphone transformers, for including in the grid circuit of a modulating valve, and (4) as intervalve transformers in audio-frequency magnifiers.

The same fundamental principles of design are used in each case; due attention being paid, of course, to the electrical and mechanical constants to make it suitable for the particular purpose for which the transformer is required. The design of transformers suitable for the purposes under (1) and (2) follows the general principles laid down in the standard textbooks on Transformer Design. (*See also* Transformer.)

Let the number of turns of the primary winding equal the number of turns of the secondary winding = N.

Then if E_v = the induced voltage (R.M.S. value).
A = area of cross-section of the coil.
n = the frequency of the A.C. supply.
B = maximum flux density.
E_v will $= 4{\cdot}4\ NAnB \times 10^{-8}$

If the ratio of the primary to the secondary turns $= \frac{N_p}{N_s}$, then the induced voltage $E_v = 4{\cdot}4 \frac{N_p}{N_s} AnB \times 10^{-8}$ volts,

or the $\frac{\text{Primary voltage}}{\text{Secondary voltage}} = \frac{N_p}{N_s}$

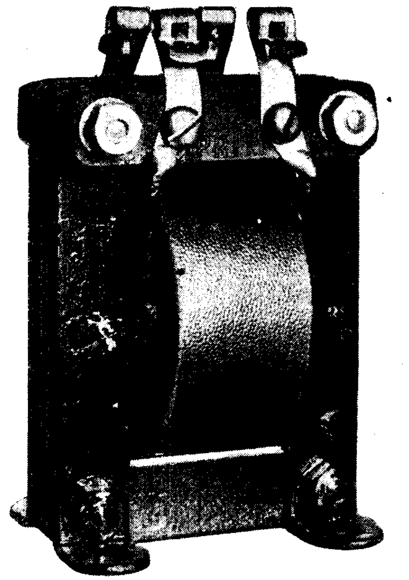
The current obtained from the transformer is in inverse ratio to the voltage of the primary and secondary.

If $W_p = W_s$
then $W_p = I_pE_p \cos\theta$, where $\cos\theta$ is the power factor
and $W_s = I_sE_s \cos\theta$
therefore $\frac{I_p}{I_s} = \frac{E_s}{E_p}$

If the secondary is open-circuited, then the primary acts as a simple choke coil, a back electro-motive force being induced which is equal and opposite to the applied electro-motive force. The current flowing, known as the "magnetizing current," will be 90° behind the applied electro-motive force, as shown by the vector diagram Fig. 1, where E_P is the voltage applied to the primary, E_B the back electro-motive force of the primary, and I_m the magnetizing current. The phase of the secondary voltage, if the transformer is unloaded, will be the same as the back electro-motive force voltage of the primary, *i.e.* E_S, that is, 180° out of phase with the applied voltage.

When the secondary is connected to a non-inductive load current flows in the secondary winding, and this necessitates a proportionate increase in the primary current. The magnetic flux in the coil, however, must remain constant for any condition of loading of the secondary. Hence there are two components of the primary current, one component which magnetizes the coil, and the second component, which produces a flux tending to neutralize the effect of the secondary.

The diagram Fig. 2 shows by vectors the action of a loaded transformer, assuming the secondary is connected to a



BURNDEPT L.F. TRANSFORMER

Fig. 4. Spring clip terminals, which allow of rapid and sound electrical connexions, are a special feature of this transformer

Courtesy Burndept, Ltd.

non-inductive load and that there are no transformer losses. From this diagram it will be seen that the magnetizing current I_m is at right angles to the primary voltage E_P, and the secondary voltage E_S, and that the load current I_S is in phase with the secondary voltage E_S. The two components I_m and I_S therefore combine to produce an increase in the flux.

Therefore a current I_P will flow in the primary, in phase with E_P and 180° out of phase with E_S. The load current I_P and the magnetizing current I_m combine to produce an increase in the magnetic flux, and the phase position of the resultant current is shown by I_r.

Low-frequency transformers used for inter-valve coupling vary considerably in their electrical constants, the transformation ratio for different types of transformers varying from 1 : 3 to 1 : 20. Theoretically the square of the ratio of primary to secondary turns should be equal to the ratio of the resistances of the circuits to which the primary and secondary are connected. It should be remembered that the resistances of the primary and secondary are no criterion of their transformation ratio, as generally the primary and secondary are wound with different sizes of wire,

The cores should be built of soft iron. preferably stalloy laminations, and may be either of the open or closed type. The closed type is generally used on account of magnetic efficiency; it can therefore be made small and light.

It should also be noted that the dimensions and electrical constants must be so chosen that at no time does the core become magnetically saturated; that is, the transformer must be so designed that only the straight part of the magnetization curve is utilized, thus preventing distortion of the wave form of the current.—*R. H. White.*

A typical transformer is illustrated in Fig. 3, and comprises a rectangular, laminated iron core with a central horizontal member about which is built up the insulated bobbin wound with the primary and secondary windings, the ends of both windings being brought out to terminals located on the top of the appliance and mounted on a moulded ebonite plate. Angle brass feet are employed as a means for securing the plates to the base or panel of the apparatus.

A somewhat different pattern of transformer is illustrated in Fig. 4, but performs essentially the same function. A notable feature is the arrangement of the terminals, which end in a form of spring clip, thus enabling the connecting wires to be inserted into position and held securely by the resiliency of the metal. This obviates the need of soldering and ensures perfect electrical connexions. *See* Audio-frequency Transformer.

LOW TENSION. This expression is loosely used for any electrical circuit where the potential difference between the two ends is comparatively small. A low-tension battery or accumulator, for example, is one of two to six volts, and such a battery is used to supply the necessary current to heat the filament of a valve. The low-tension circuit is that circuit supplied by the low-tension battery, and is in this case synonymous with the filament circuit. The low-tension battery is often known as the A battery (*q.v.*). *See* Filament; High-tension Battery.

LUBRICATION. The act or process of reducing friction between two moving surfaces by the introduction of a film of material, the lubricant, between them. Most lubricants are preparations of oils and fats, and are then known under the general term of lubricating oil. They may also be minerals, such as graphite, and used in the dry state.

In some classes of apparatus the desired diminution of friction and the preservation of the working surfaces may be obtained by the use of a liner or bush of some special composition, generally known as an anti-friction material. In some cases, graphite and other anti-friction material is compounded with the metal of which the bearing is made, and therefore forms a type of self-lubricating arrangement.

Lubricants for wood- and for some slow-moving apparatus are used in the form of natural earths or artificial preparations. In this class may be included French chalk, fuller's earth, blacklead, and the like. Prime movers, such as a steam engine or internal combustion engine, are nearly always lubricated by high-grade animal or mineral oil possessing the qualities of a high flash-point and the ability to retain the maximum lubricating qualities at high temperatures.

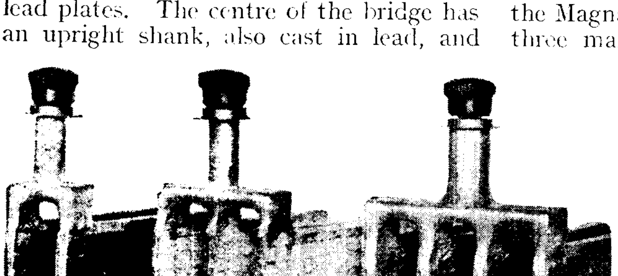
Many different brands are on the market, and those supplied by reputable firms are specifically marked for the particular purpose for which they are suitable and should be used accordingly. Electrical have their bearings lubricated generally on the ring-oiler system, and use a light grade of lubricating oil, a supply of which is contained in a sump or cavity forming part of the bearing and its supports.

Small machines, such as workshop tools, lathes, and the moving parts of light machines, are best lubricated by means of light machine oil. Enclosed ball bearings are sometimes lubricated with light grease, while in other cases they run in oil. Small gear boxes are generally made oil-tight so that the gears can run in a bath of suitable gear oil.

To ensure efficient lubrication it is essential that there be a space between the moving part of a shaft and the fixed part, or bearing, to allow the lubricant to enter and remain there. This space may be of the order of only one half-thousandth of an inch or less, but in ideal conditions the shaft and the bearing should always be separated by a film of lubricant. This film is maintained by a supply of lubricant, which may be conducted to it through a channel connecting the bearing surface with a suitable container such as a small sump.

In some cases the oil may be pumped under pressure through channels formed in the shaft itself or in the bearing. It is important that there be a means of egress for any particles of dirt or foreign matter which might enter with the oil, although by straining the oil and adopting an entirely enclosed system to conduct the oil from its source of supply to the bearings, such foreign matter should be a minimum.

LUG. Name used to describe a lead or other metallic connecting member which unites the negative or positive plates, respectively, of an accumulator. A group of such lugs is illustrated, and comprises a bridge piece of cast lead, burned on to the lead plates. The centre of the bridge has an upright shank, also cast in lead, and carries on the top a suitable brass terminal with ebonite or other insulating nut. The lug fits through a rubber or other insulating material formed in the top plate of an enclosed type of accumulator. Should the lugs of an accumulator be broken for any reason, they can usually be repaired by the lead-burning process. *See* Accumulator; Storage Battery.



LUGS FOR VARIOUS TYPES OF ACCUMULATOR

Two, three, four, or five plates may be joined by lugs of the kind illustrated. Accumulator lugs are made of lead or some other metal

Courtesy J. W. Barnard & Co., Ltd.

M

MAGNAVOX. Name given to a series of loud speakers, power amplifiers, and other sound-reproducing accessories manufactured in England by the Sterling Telephone and Electric Co., Ltd. An illustration of the standard model of the Magnavox loud speaker is given in Fig. 1. The electrical design of this instrument is quite different from other forms of loud speaker. It is worked on the electro-dynamic principle, as distinct from the electro-magnetic. The essential feature of the electro-dynamic system is the mutual attraction and repulsion which exists between two electrically energized coils, and it is this system which is embodied in the Magnavox.

Fig. 1 shows the external appearance of the standard instrument. The base consists of a stout piece of mahogany, lined on its underside with heavy baize. Two terminals are mounted on a piece of ebonite near the front edge of the base, and behind this is a step-down transformer of special design, enclosed within a sheet iron box for shielding purposes. The input side of this transformer is connected to the terminals shown.

Situated immediately behind this transformer is a cylindrical metal case containing the Magnavox reproducer. This consists of three main features. The first is a large solenoid, known as the field coil, within the field of which is freely suspended a second coil attached at its upper extremity to the centre of the diaphragm. The field coil is energized by any 6 volt battery (the filament battery will serve for this), and consumes approximately ½ ampere. All the radio impulses from the receiver are transferred to the suspended coil via the step-down transformer.

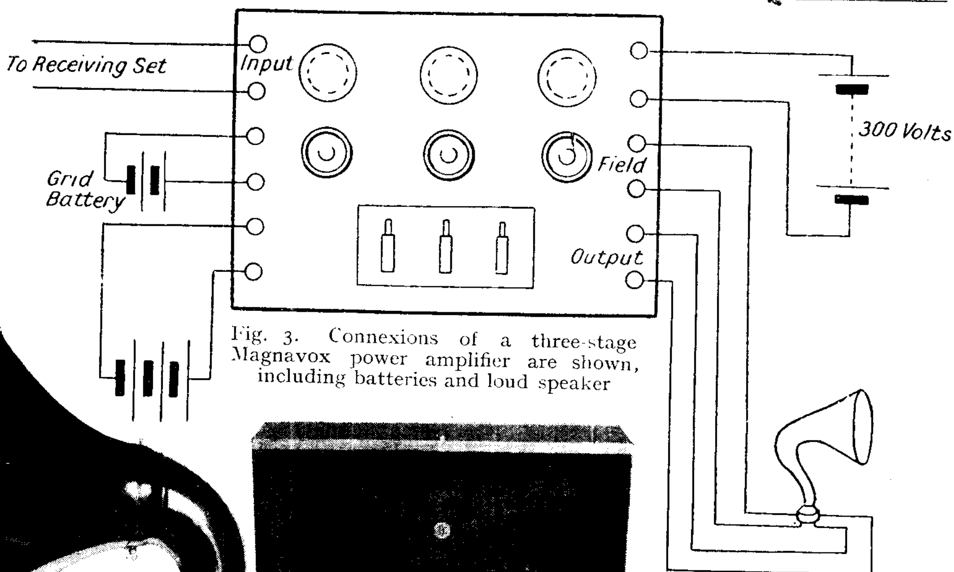
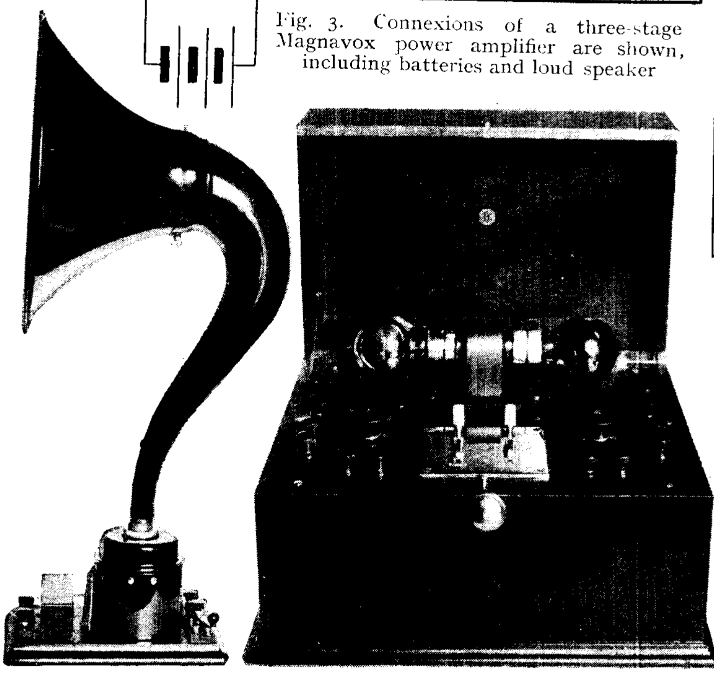


Fig. 3. Connexions of a three-stage Magnavox power amplifier are shown, including batteries and loud speaker



MAGNAVOX LOUD SPEAKER AND POWER AMPLIFIER

Fig. 1 (left). The standard model of Magnavox loud speaker illustrated is worked on the electro-dynamic principle. Fig. 2 (right). With the aid of this power amplifier a large concert hall may easily be filled with sound. Either one or two valves may be used

Courtesy Sterling Telephone and Electric Co., Ltd.

Thus a coil itself carrying modulated current is suspended within a strong magnetic field of constant strength.

The result of this is that the radio-energized coil tends to move up or down in accordance with the strength and direction of the received impulses. As it is attached to the centre of the diaphragm, it follows that the latter moves with it, and converts the movement of the coil into sound waves. The advantages claimed for this method of construction are: (1) that the volume obtainable is unlimited, it depending solely on the power available from the set; (2) that it is very responsive to weak signals, and (3) that distortion within the loud speaker itself is reduced to a minimum.

An illustration of the Magnavox power amplifier appears in Fig. 2. This instrument is of the two-stage power type. Each valve is fitted with a separate switch and filament resistance, thus giving independent control in order that any desired volume up to the maximum may be obtained. The transformers used in this instrument are of very heavy constructon, and voltages up to 750 may be used with safety, although for normal working a voltage of from 100 to 300 is recommended. Special terminals are fitted on this amplifier, allowing the filament current for the valves to be used for energizing the field of the Magnavox.

A diagram of connexions to be used in working the power amplifier and Magnavox in combination is given in Fig. 3. The method of connecting the field of the loud speaker to the amplifier will be noted from this diagram. Fig. 4 is an interesting circuit diagram showing the connexions necessary and the apparatus

MAGNAVOX LOCAL AMPLIFIER

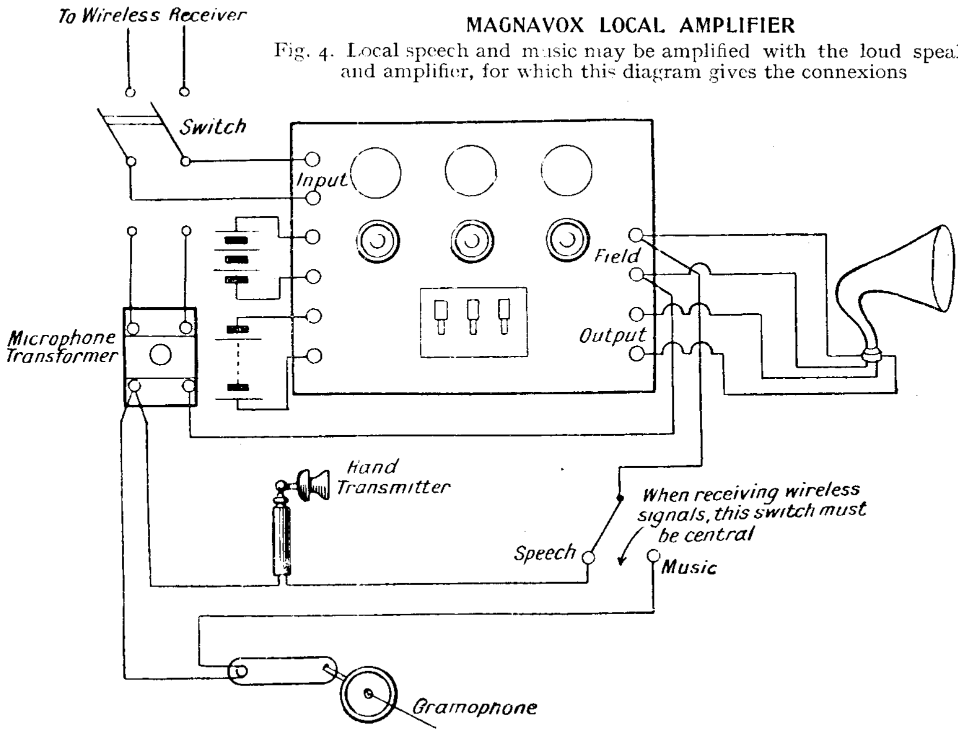
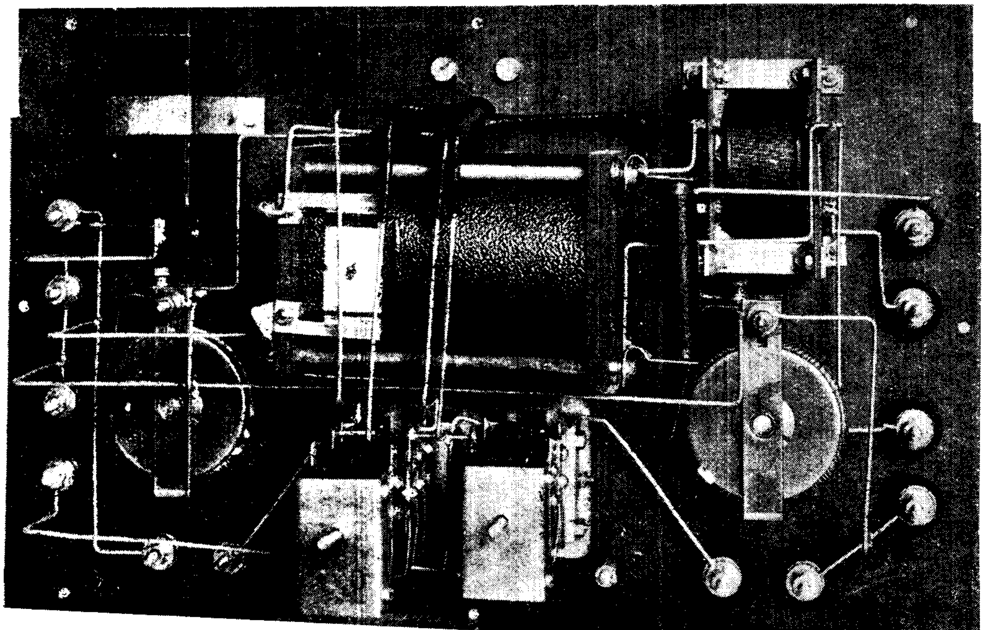


Fig. 4. Local speech and music may be amplified with the loud speaker and amplifier, for which this diagram gives the connexions



BACK OF PANEL OF MAGNAVOX TWO-VALVE POWER AMPLIFIER

Fig. 5. In the centre is the power transformer, and in the top right-hand corner is the inter-valve transformer. The two filament resistances and their wiring are also shown

Courtesy Sterling Telephone and Electric Co., Ltd.

used for reproducing radio messages or amplifying local speech or gramophone music. The positions of the microphone and gramophone attachment in the circuit should be noted.

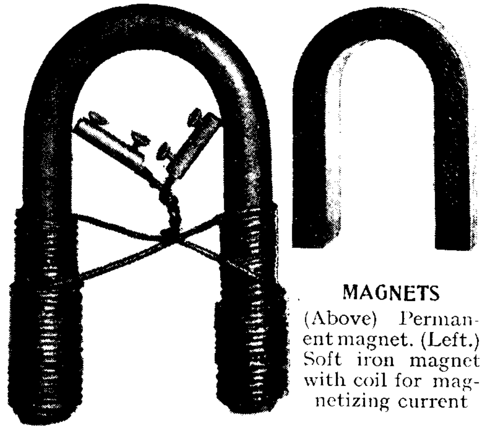
The latter instrument is a special tone arm which is fixed to the gramophone as an addition to normal fixtures. Its fitting in no way interferes with the normal use of the gramophone. This attachment consists of the usual diaphragm, with its stylus bar and needle, but which has in addition at the back of the diaphragm the usual carbon granule microphone construction. A further feature of this fitting is that an automatic switch is incorporated, which closes its circuit when the reproducer is put on the record. In other positions it is entirely disconnected. These applications of the Magnavox are useful where music and announcements have to be given before large numbers of people, either in a large hall or open spaces.

Fig. 5 is a view of the interior of the power amplifier. This instrument is unusual in that the panel is metal, enamelled black, and with a matt surface. The input intervalve transformer is shown in the top right-hand corner, and the power transformer, a much larger instrument, in the centre. To the left of this, and a little higher up, is a metal-cased fixed condenser of large capacity across the H.T. A high resistance of the non-inductive type is fitted across one side of the transformer.

The switches are shown side by side at the bottom of the panel. These are of a type in which the moving contacts are arranged on a strip of ebonite, which moves upwards and brings the set of contacts upon it in line with another set fixed on either side. The levers which actuate the switches are clearly shown in Fig. 2.

Igranic filament rheostats are used, one being fitted in the L.T. circuit of each valve. All the terminals are surrounded by insulating bushes and the wiring is for the most part bare and well spaced in order that no interaction may occur. *See* Amplifier; Loud Speaker.

MAGNESIUM. One of the metallic elements. Its chemical symbol is Mg, and atomic weight 24·32. It is found widely distributed in its compounds, and pure is a silvery white ductile metal. It is diamagnetic, and burns with a brilliant white light, being used largely for flashlight photography for this reason.



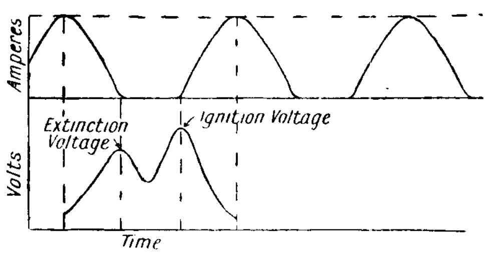
MAGNETS
(Above) Permanent magnet. (Left.) Soft iron magnet with coil for magnetizing current

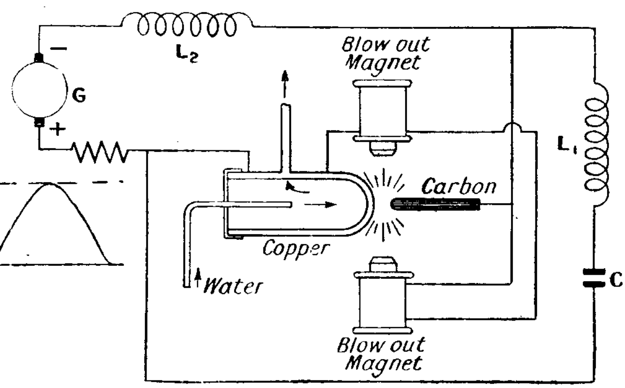
MAGNET. Any substance which has the power of attracting iron, steel, nickel, and certain other substances. Magnets may be natural, as the lodestone, or artificial, and either permanently or temporarily magnetic. Permanent magnets consist of hard steel which has been magnetized by contact with another permanent magnet or by being placed within a coil through which a strong electric current has been passed. Temporary magnets are made of soft iron and lose their magnetism when the energizing force is removed.

Magnets are usually in the form of a straight bar or horseshoe-shaped. The illustration shows two horseshoe-shaped magnets. The magnet on the left is of soft iron, and indicates how such a piece of soft iron may be magnetized by coils wound round it as shown, and connected to a source of electric current. A permanent horseshoe magnet should have an iron keeper across its poles when not in use, and bar magnets should be placed together in pairs, the S. pole of one to the N. pole of the other and keepers across the ends. Soft iron or mild steel magnets magnetized by means of an electric current are known as electro-magnets. *See* Dynamo; Electro-magnet; Field Magnets; Magnetism.

MAGNETIC BLOWOUT. The function of the magnetic blowout in wireless work is to de-ionize the gap between the electrodes in the arc oscillator. It was discovered by Duddell in 1900 that if across the terminals of a direct current arc there were connected in series an inductance and a capacity of suitable values, an oscillatory current is set up. In the Poulsen arc the working conditions are such that the discharge current from the condenser is large enough to extinguish the arc when at or near its maximum value, but is not large enough to start it again in a direction opposite to that in which the direct current supply is flowing. The oscillations in this case are undamped, and under proper conditions may have a large energy component.

In Fig. 2 is a diagram of a typical oscillation generator by means of a direct current arc; the terminals or electrodes consist of a large copper water-cooled electrode on the left, and a carbon electrode on the right, and these may be supplied with direct current at any voltage between 200 and 1,200, according to the size of the arc. When this arc is used to generate undamped oscillations the current which flows at any instant between the electrodes is the resultant of the steady current supplied by the generator G and the current in the condenser circuit C. The arc itself is usually originated by striking or bringing together the two cold electrodes, and then immediately separating them; directly contact is broken the spark which occurs volatilizes the carbon electrode and it becomes incandescent, current being carried between the electrodes by the ions. The ions are molecules of air or gas which by the fact of their presence in the spark gap have acquired an electric charge. Particles of the electrode also may break off and assist in carrying current across the gap.





MAGNETIC BLOWOUT CURVE AND CIRCUIT

Fig. 1 (left). Current and voltage wave relations of an oscillating arc are shown. Fig. 2 (right). This is a circuit diagram of a direct current arc oscillator with magnetic blowout

When the arc is first started the full current is not immediately established, but there is a slight delay while ions are being formed in the gap in sufficient numbers to carry the full current. If the gap has been extinguished only a short time previously, there will still be present a number of ions which have not yet lost their charges, and therefore a shorter time will be required to build up the current. If the applied voltage at the arc electrodes is reduced, current will cease, and the ions will lose their electric charge. In order to make the arc sensitive to changes in applied voltage provision must be made for rapidly de-ionizing the arc gap.

If for any reason the current through the arc falls to zero the voltage will rise only to the value required to start the arc again, which is called the "ignition" voltage. If the voltage is raised sufficiently while the arc exists, the current will decrease until the arc is extinguished; this is called the "extinction" voltage. This relation between current and voltage waves of an oscillating arc is shown in Fig. 1.

If the operation of an arc oscillator or transmitter of this type is considered the following stages may be traced out. Let it be supposed that the arc terminals are supplied with a steady direct current at an appropriate voltage, which, as stated before, may lie between 200 and 1,200 volts according to its size; also that the shunt circuit containing the condenser and inductance C and L_1, Fig. 2, is for the moment disconnected. Owing to the generator supply line itself containing a large inductance, L_2, the current supplied by the generator will tend to remain constant owing to the inductance effect, but the instantaneous voltage across the arc terminals or electrodes may vary. It is essential that the inductances should have a low resistance and a low distributed capacity. If now the shunt circuit is connected, the condenser C will begin charging, its lower plate being positive if the generator polarity is as marked in the diagram; in other words, it will divert current from the arc, since the current supplied by the generator cannot increase suddenly owing to the inductance L.

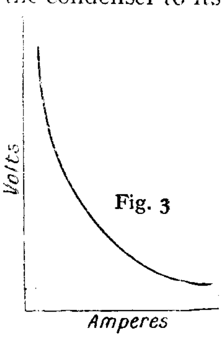
During the time the current through the arc itself is falling, the potential difference across its electrodes increases because of the falling characteristic shown in the graph, Fig. 3, and this, of course, assists in charging up the condenser C. The charging of the condenser continues until its counter electro-motive force is equal to that of the applied electro-motive force from the direct current source, and as the charging nears the state of balanced and opposed electro-motive forces, the charging current gradually falls off, allowing current in the arc circuit to increase to its former value, with a corresponding drop in voltage.

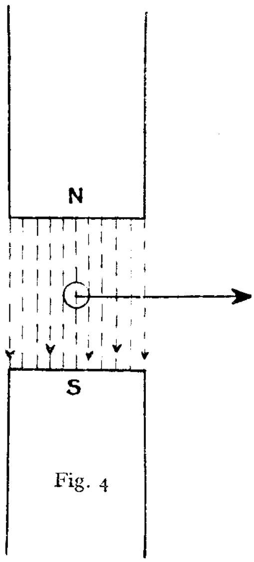
But this lowering in voltage across the terminals of the arc again allows the condenser to discharge itself, while the effect of inductance in the circuit tends to keep the current flowing. The result is that the condenser becomes oppositely charged, its top plate in Fig. 2 now being the positive. On this opposite charge nearing its end the charging current through the arc becomes gradually less and less, the total arc current falling and giving rise to an increase in the arc potential again, which ultimately recharges the condenser to its original state of polarity. Continuous oscillations are thus set up throughout the circuit.

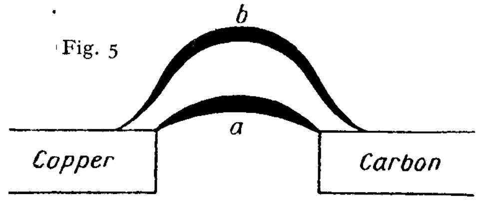
Various means for rapidly de-ionizing the arc gap are adopted, such as the use of an anode made of copper, containing a channel for water circulation; an arc chamber filled with hydrogen or hydro-carbon gas; and the employment of a strong magnetic field, or "blowout." This field is provided by two powerful electro-magnets, which are placed in such a position that the direction of this field is at right angles to the flow of ions across the arc electrodes. The charged ionized space between the electrodes may be likened to a flow of current in a straight conductor, which, as is well known, is acted upon when placed in a strong magnetic field in such a way as to divert it from its normal path to one where it is less influenced; hence the "blowout" effect. This may be represented by the magnetic field from N and S in Fig. 4, the tendency being to push the flexible conductor out of the stronger region into a weaker one, as shown by the direction of the arrow.

By the action of this intense magnetic field the arc flame, which is to all intents and purposes a flexible conductor, is blown to one side of the arc gap to such an extent as to rupture the arc. The path of the flame at ignition is shown at *a*, Fig. 5, and at extinction by *b* in the same figure.

The blowout magnets used in practice are very large and powerful; the strength of field required to operate properly depends to a certain extent upon the wave-length and the magnitude of the radio-frequency current, but flux densities of 10,000 to even 15,000 lines per square centimetre are by no means uncommon, with a 100 kilowatt arc designed to operate over a fairly wide range of wave-







THEORY OF THE MAGNETIC BLOWOUT

Fig. 3 (left). In the characteristic curve here shown is represented the relation between voltage and current of an electric arc. Fig. 4 (centre). Blowout action of a magnetic field on a current-carrying conductor is shown. Fig. 5. This diagram shows the blowout effect on ignition and extinction currents in an electric arc lengths. The shorter wave-lengths require the more powerful magnetic fields.—*A. H. Avery.*

MAGNETIC CIRCUIT. The law of the magnetic circuit closely resembles that of the electric circuit due to Ohm. If instead of the factors volts, amperes, and resistance, are written magneto-motive force, flux, and reluctance, the resemblance becomes evident.

The law of the magnetic circuit may be written

$$N = \frac{M}{Z};\ \text{also}\ Z = \frac{M}{N},\ \text{and}\ M = Z \times N$$

where N represents the flux of magnetic lines, M the magneto-motive force, and Z the reluctance of the circuit.

In the magnetic circuit the power which gives rise to the lines of magnetic flux originates, as a rule, from the exciting effect of an electric current passing through a coil of insulated wire termed a solenoid. If a single circular ring of wire is considered, having a radius of r centimetres, and a current of A amperes is passed round it, the strength of the field H (in air) at the centre of the ring would be

$$H = \frac{2\pi A}{10r} = 0{\cdot}068 \times \frac{\text{amperes}}{\text{radius}}$$

If there are a number of turns T in the coil, the field strength will become

$$H = \frac{2\pi AT}{10r}$$

In the case of a long, straight coil of wire (a solenoid) whose radius, r, is small as compared with its length, l, the field strength H will approximate

$$H = \frac{4\pi AT}{10l},$$

$\frac{T}{l}$ being the number of turns per centimetre in length. If now the coil is bent into a circular closed ring of radius R, the value for H at the centre will be

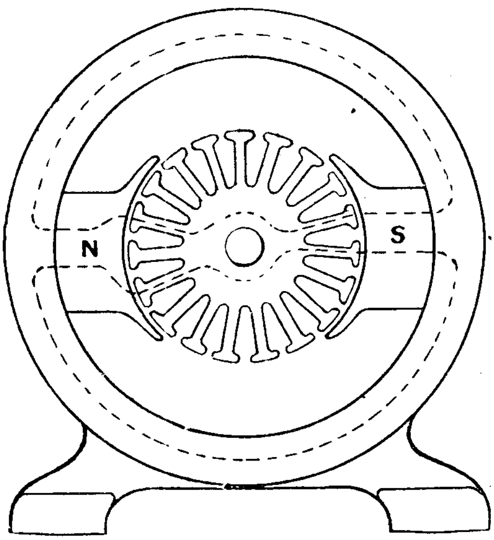
$$H = \frac{4\pi}{10} \times \frac{AT}{2\pi R}$$

since l is now equal to $2\pi R$. As the total work done on a unit magnetic pole is a measure of the magneto-motive force acting round a closed line of length l, and $l = 2\pi R$, the magneto-motive force, M.M.F.

$$= Hl = \frac{4\pi}{10} \times \frac{AT}{2\pi R} \times 2\pi R = \frac{4\pi AT}{10}$$

$$= 1{\cdot}257 \text{ ampere-turns.}$$

The other factor in determining flux lines, namely, the reluctance of the circuit, although similar in effect to the ohmic resistance of an electric circuit, is hardly so simple to arrive at, as it is influenced by many factors. Generally speaking, it may be said that magnetic reluctance varies directly as the length of the magnetic path and inversely as its sectional area, and so far it is in line with its electric prototype.



MAGNETIC CIRCUIT

N and S are the two pole-pieces of a dynamo or motor, and the dotted lines represent the magnetic circuit

But another factor has to be taken into consideration, namely, the permeability of the magnetic circuit, and unfortunately no simple figure can be assigned to this according to the specific attributes of the material through which the lines pass, such as air, water, iron, etc., but it may be a very variable quantity, according to the density with which the lines are packed in any unit area.

It is a matter of common knowledge that magnetic lines pass much more readily through iron and steel, and one or two other metals, such as nickel and cobalt, than they do through air and other magnetically inert substances or gases. The same degree of magneto-motive force applied to a solenoid will give rise to a certain number of lines of force in air. If the centre of the solenoid is filled with nickel or cobalt a slight increase in the number of magnetic lines may be traced.

If filled with hard steel the increase is far more noticeable; with soft iron the flux is enormously increased. This multiplying effect upon the magneto-motive force, or rather upon the field in air resulting from a definite M.M.F., is a measure of the permeability, but the value is not a constant one, and depends upon the flux density in the material itself. Soft iron may increase the flux lines due to a fixed M.M.F. some hundreds of times if the flux density or number of lines per square inch is kept within certain limits. But on increasing the M.M.F. there is found to be nothing like a corresponding increase beyond this point; that is, the permeability falls off as the flux density increases.

Reluctance, the equivalent of electric resistance, may therefore be summed up in the expression

$$Z = \frac{l}{A\mu}$$

μ being the symbol adopted for permeability.

The reluctance of a magnetic circuit, whether it be the core of a transformer, or the field magnet of a dynamo or motor, is usually rather a composite affair, being made up of a number of separate reluctances all in series, and each of which has to be computed separately. For instance, in the field magnet of a dynamo, Fig. 1, the origin of the magnetic flux lines is in the exciting coils, that is, the "ampere-turn" effect of the coils which are wound on the poles N. S. In order to obtain an accurate estimation of the total reluctance of the circuit, a fresh calculation would have to be made for every part of the circuit where either the material or the sectional area changed in nature or dimensions. The complete closed magnetic circuit is indicated by the dotted lines, and, taking an extreme case, it is clear that, starting at the N. pole, the reluctances would be divided up into the following sections:

(1) N. pole: wrought-iron stampings.
(2) Yoke: cast iron.
(3) S. pole: wrought-iron stampings.
(4) Air gap: air.
(5) Armature tooth: wrought-iron stampings.
(6) Armature body: wrought-iron stampings.
(7) Armature tooth: wrought-iron stampings.
(8) Air gap: air.

Of these (1) and (3) could be dealt with together, being similar; also (4) and (8) and (5) and (7). The summation of the total reluctance would therefore be

$$\text{Total } Z = \frac{l'}{A'\mu'} + \frac{l''}{A''\mu''} + \frac{l'''}{A'''\mu'''}$$

and the total flux lines N would be

$$N = \frac{\frac{4\pi AT}{10}}{\Sigma\left(\frac{l}{A\mu}\right)}$$

The ampere-turns necessary to drive this flux through the circuit can now be expressed as

$$AT = \frac{N\Sigma\left(\frac{l}{A\mu}\right)}{1{\cdot}257} = 0{\cdot}8N\Sigma\left(\frac{l}{A\mu}\right)$$

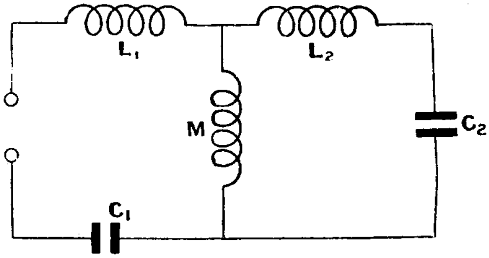
A magnetic circuit can be either closed or open; that is to say, it can be composed wholly of iron throughout, or it may include air or non-magnetizable matter in its course. When the circuit is wholly of iron, such as a closed ring, the lines are confined almost entirely to the boundary of the iron core. When there is an air gap in the circuit, such as in a choking coil or the core of an ordinary spark coil, there is a large amount of leakage, and the lines tend to take the shortest cut back to the opposite pole; that is, to make the air circuit as small as possible.

A good idea of their behaviour is obtained by regarding them as stretched elastic threads which, by their natural elasticity, will take the shortest possible path between any two points at which they are held, but with the difference that there is also mutual repulsion between any two lines proceeding in the same direction, which causes them to bulge away from one another and take a resultant position which is compounded of the two forces of attraction and mutual repulsion, resolved in proportion to their respective magnitudes.—*A. H. Avery.*

See Flux; Magnetism.

MAGNETIC COUPLING. When two electric circuits have some part in common, or are linked together by an electrostatic or magnetic field, they are said to be coupled. Energy may be transferred from the one to the other without any direct connexion.

There are three types of coupling commonly employed—namely, resistance coupling, inductive or magnetic coupling, and capacity coupling. Diagrams illustrating the features of three principal types appear in Figs. 1, 2, and 3; and so far as magnetic coupling is concerned, a distinction must be drawn between two distinct types. If the inductance is common to both circuits, as in Fig. 1,



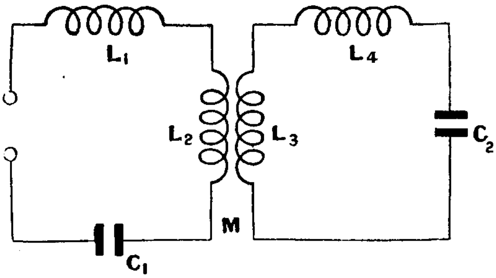
DIRECT COUPLING

Fig. 1. Two circuits, L_1, C_1, M, and L_2, C_2, M, are directly coupled. The inductance is common to both circuits

it is termed direct coupling, whereas if there is mutual inductance through two electrically separate circuits it would be called inductive coupling.

Mutual inductive coupling is used very extensively in constructing radio apparatus. It often happens that the two coils which constitute the mutual inductance possess sufficient capacity to act as the two plates of a condenser whose capacitative reactance may be appreciable at radio-frequencies. In such cases the combined effect of the coupled coils is a combination of inductive coupling and capacitative coupling.

The transference of energy from the primary to the secondary (that is, from the excitation side to the aerial in the case of a transmitting equipment) is carried out by means of a transformer, known as a jigger (*q.v.*). Transformer coupling may be regarded as a kind of electrical sieve, since the tuned aerial circuit responds only to energy drawn from the excitation circuit which has the same period of oscillation, and draws very little energy from the excitation side when the wave-length is appreciably different. The energy so passed to the



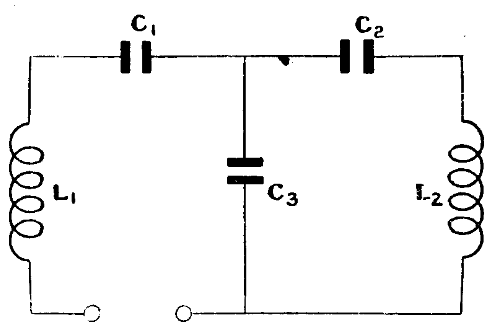
INDUCTIVE COUPLING

Fig. 2. Inductive or magnetic coupling is represented. The two electrically separated circuits have mutual inductance

aerial circuit is thus radiated at a nearly constant wave-length.

Circuits are said to be closely coupled when any change in the current in one is able to cause considerable effects in the other. When either circuit is little affected by the other, it is regarded as loose coupling. In general practice the coupling between two circuits coupled inductively is brought about by changing the distance between the two coils of which it is constituted; increasing the distance between them makes the coupling weak or loose, as also does any change in their relative axes. Altering the angle at which the axes of the two coils are inclined will cause fewer lines of force to interlink with one another.

Since the amount of energy which passes from one circuit to the other by



CAPACITY COUPLING

Fig. 3. Common to both circuits is the capacity C_3. In each of the coupled circuits is also another condenser, and inductance may be loose or close-coupled according to the position of the coils

way of the coupling depends upon the degree of mutual inductance, which, again, depends upon the number of turns common to both circuits, as well as their distance apart, it is possible to express this as a coupling coefficient, which may be defined as the ratio of the common reactance of the two circuits to the square root of their individual reactances. If X_m is the reactance common to both circuits, X_1 is the reactance of circuit No. 1, and X_2 the reactance of circuit No. 2, and K is the coupling coefficient, then

$$K = \frac{X_m}{\sqrt{X_1 X_2}}$$

In Fig. 1 the total reactance of circuit No. 1 is $\omega(L_1 + M)$, and that of circuit No. 2 is $\omega(L_2 + M)$, while that of the common reactance is ωM. Therefore it may be written

$$K = \frac{\omega M}{\sqrt{\omega(L_1+M)\ \omega(L_2+M)}} = \frac{M}{\sqrt{(L_1+M)\ (L_2+M)}}$$

In the inductive coupling shown in Fig. 2 the total inductance of circuit No. 1 is indicated by $L_1 + L_2$. Part of this is in inductive relation to circuit No. 2, and part otherwise. Similarly the inductance of circuit No. 2 consists of two parts, L_3 and L_4, one part magnetically coupled to circuit No. 1 and the other part not so coupled. The common reactance is ωM. In this instance the following holds good

$$K = \frac{\omega M}{\sqrt{\omega(L_1+L_2)\ \omega(L_3+L_4)}} = \frac{M}{\sqrt{(L_1+L_2)\ (L_3+L_4)}}$$

The inductively coupled circuit in Fig. 2 can be considered as a direct-coupled circuit after proper transformations have been made. A transformation of the inductance and the capacity of circuit No. 2 will leave the oscillatory constant (LC) of the same value as it was originally if the inductance of circuit No. 2 is decreased in the ratio of L_2/L_3, and its capacity increased in the ratio of L_3/L_2. The value M of the equivalent circuit is obtained by multiplying the actual value of M by the ratio $\sqrt{L_2/L_3}$.

An extreme case of close coupling would be represented by an ordinary induction coil having the primary and secondary both wound on a common core, and their position fixed in relation to one another. Practically all the energy would then be transferred from one circuit to the other, and the coupling would be 100 per cent. But where the inductive transfer of energy is small, as in the variometer coil inductance when the movable element is turned through an angle of 90° in relation to its fixed winding, the coupling would be to all intents and purposes zero.

For a capacitative coupling, such as illustrated in Fig. 3, the coupling coefficient would be represented by

$$K = \sqrt{\frac{C_1C_2}{(C_1 + C_3)\ (C_2 + C_3)}}$$

As the coupling becomes loose, K would approach zero, while for the closest possible coupling K would be unity, or 100 per cent.—*A. H. Avery.*

See Close Coupling; Coupling; Magnetism.

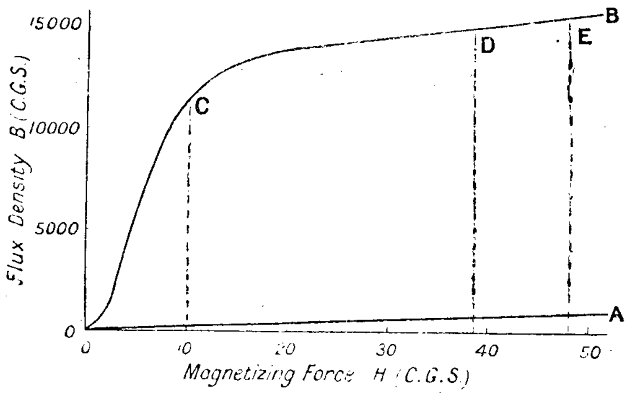
MAGNETIC DENSITY. The intensity of a magnetic field may be expressed in terms of its flux density, or the number of lines of magnetic force that would pass through a space having unit area. Whether this unit of area is expressed in C.G.S. or in English notation is immaterial, as it does not alter the density of the field. That is to say, if a flux density of 100 lines per square centimetre were taken, for example, as a basic strength of field, there would be 645 lines of force in an area corresponding to one square inch, since there are 6·45 square centimetres per square inch.

The magnetic density, or, as it is more usually spoken of, the flux density, in a bar of iron or steel is of great importance, more especially in the construction of generators, motors, or other electro-magnetic apparatus. The most economical results can only be obtained by making the best use of the material; it would be wasteful to magnetize the iron far below its possible performance, and it would be equally wasteful to endeavour to push it to very high values of flux density.

Every grade of magnetic material has its own peculiar properties, by which the applied magneto-motive force H is enormously increased by the permeability or "multiplying power" of the iron being dealt with. In air, a certain expenditure of magnetizing force would produce but very weak results as compared with the same magnetizing power expended on soft iron, the measure of the increased effects being determined by the value of the permeability, μ of the particular sample of iron, and also by the stage of its magnetization.

At very low values of flux density, say 1,000 to 10,000 lines per square inch, the slightest increase in the applied magnetizing force increases the number of magnetic lines several hundredfold; as the flux density value rises in lines per square inch, however, the iron behaves as though it became less responsive, and more magnetizing power has to be expended in increasing the flux density than at the initial stages; the permeability falls off.

In fact the proportion between cause and effect may be said to be continually changing, until towards the end of the magnetization curve, beyond what is known as the saturation point, the permeability becomes negligible in its effects, and, instead of increasing the flux density



B. H. CURVE SHOWING MAGNETIC DENSITY

Fig. 1. These curves, A and B, show how the flux density, B, for soft iron varies with the applied magnetizing force, A

greatly beyond the excitation effect to be expected from the magnetizing coil alone, the effects are hardly greater than those due to the latter by itself.

The effect of flux density upon the permeability curve of a sample of soft iron can be well followed by referring to Figs. 1 and 2. Fig. 1 shows the actual magnetizing force (curve A) applied in steady increments to the sample of iron in question. Curve B represents the resulting flux density produced in lines per square centimetre in the iron. At first there is no apparent correspondence at all between the two curves A and B, as, after a slight lag in the starting point of curve B, it rises sheer away from A, showing an enormous number of lines arising from a very little expenditure of magnetizing power.

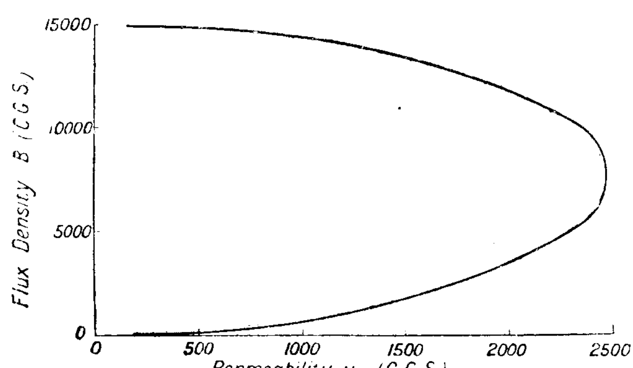
But after reaching the point C on curve B, known as the "knee" of curve, the resulting increase in flux density becomes much less in proportion to the increase in applied magnetizing force, and towards the later stages of the curve, D and E, the increase in flux density is little, if any, more than the increase in magnetizing force H, as is evident by the fact that these two portions of the two curves have become practically parallel, and rise with the same gradient.

Considered as a multiplying effect, the peculiar shape of Fig. 2, representing a permeability curve of the same sample of iron, is well accounted for. The maximum value of the permeability curve occurs at a point where the flux density reaches 8,000 lines per square centimetre. After that, it diminishes at an increasing rate, and falls to a negligible value after the flux density has passed about 15,000 lines per square centimetre, say 100,000 lines per square inch.

Such curves are of considerable value, since they tell us how much copper can be economically expended in the magnetizing coil of any magnet, and how the greatest results can be attained with the least material. The flux density, in cases where the magnetizing coil is only filled with air or magnetically inert material, is always equal to that due to the magnetizing force alone, that is to H. When iron or magnetic matter is present the flux density will be increased in proportion to the value of the permeability existing for that particular stage of magnetization.

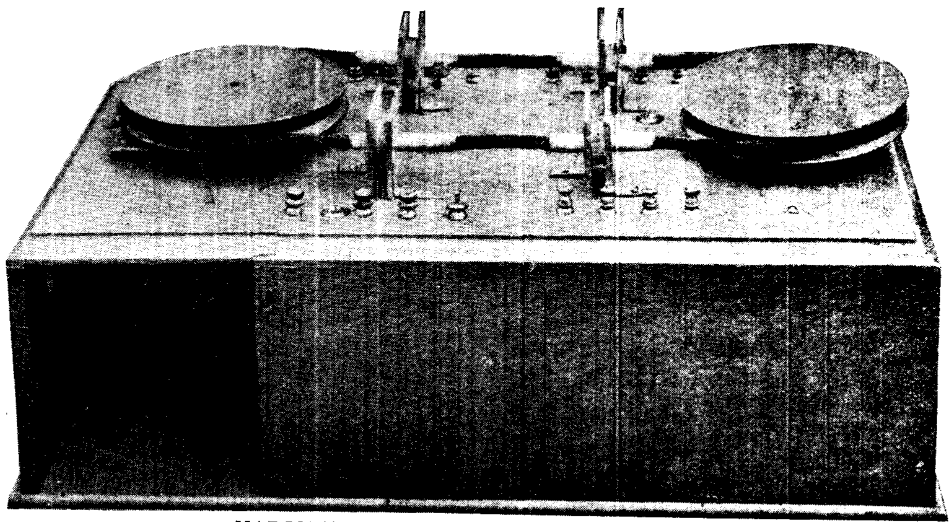
Working flux densities in ordinary commercial cast iron seldom exceed 40,000 to 50,000 lines per square inch. In best wrought iron, however, this value can be pushed to 100,000, or even 120,000 lines per square inch, consequently, wrought iron should be used in the magnetic circuit rather than cast iron, so lessening the copper required for the exciting coils.—*A. H. Avery.*

See B. H. Curve ; Flux ; Magnetism.



PERMEABILITY CURVE FOR WROUGHT IRON

Fig. 2. This is a permeability curve of the same piece of metal for which the magnetic density curve is shown in Fig. 1



MARCONI'S ORIGINAL MAGNETIC DETECTOR

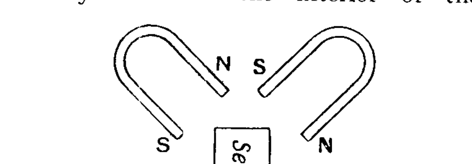
Fig. 1. An endless band of insulated strands of soft iron wire pass round two pulley wheels. The band passes through a narrow glass tube. Wire wound round the tube forms the primary of the receiver or detector

Courtesy Marconi's Wireless Telegraph Co., Ltd.

MAGNETIC DETECTOR. A form of detector, the action of which is dependent upon the hysteresis of iron. In the Marconi type, which is usually encountered, and shown in Fig. 1, an endless band composed of a number of insulated strands of soft iron wire is passed round two pulley wheels and maintained in constant motion at a steady rate by means of a clockwork motor actuating the wheels. For a short distance this band passes through a narrow glass tube, round which are wound a number of turns of insulated wire. This winding constitutes the primary of the receiver, one end being connected to earth and the other to the aerial. A secondary coil is mounted directly over the primary, and joined in series with telephones.

Close to these coils are set a pair of U-shaped permanent magnets, placed with opposite poles adjacent, under whose sphere of inductive influence the iron band passes continuously. Assume the band to be travelling as indicated by the arrow heads, Fig. 2, and examine the changes experienced by any given part of it. As the latter approaches the magnets, it first comes under the influence of a north pole, and thus, becoming magnetized, assumes the properties consequent upon its new condition, *i.e.* it possesses a magnetic field composed of lines of force. Due to the constant motion of the band, the part under consideration passes away from the north pole and approaches the south pole. Owing to the property of hysteresis, its magnetic state is not altered immediately. Before this change can occur, complete demagnetization is necessary, but once this is accomplished, the iron may be re-magnetized in an opposite direction.

The requisite coercive force to annul the residual magnetism is supplied by the incoming waves, which set up oscillations in the primary circuit, part of which is wound directly over the band. The magnetic field thus suddenly decays and builds up again, and in so doing causes the lines of force to cut the secondary winding, inducing an electro-motive force giving rise to a current which passes through the telephones and deflects the diaphragm. As a constant supply of iron is being steadily fed into the interior of the



ACTION OF MAGNETIC DETECTOR

Fig. 2. Arrows indicate the direction of the moving band. The diagram shows the principle of the magnetic detector

primary, it can be seen that changes of magnetism will occur whenever oscillating currents are flowing, and the telephones will respond accordingly.

It should be noted that, since the secondary is not an oscillatory circuit, tuning arrangements are confined to the primary.

Stability and reliability of action are the special features of this instrument, but it is not so sensitive as the crystal detector.

MAGNETIC EQUATOR. In terrestrial magnetism an imaginary line passing through places on the surface of the globe where the angle of inclination of the dip needle is zero. It follows approximately the direction of the geographical equator, but is not parallel thereto, and cuts the latter in several places. The term is synonymous with aclinic line.

MAGNETIC FIELD. The space over which a magnet exerts its influence. The medium in the neighbourhood of a magnet is in a state of stress, and it is this space, extending in all directions round the magnet, which is called the magnetic field. A similar field is set up when a current is flowing in a conductor. *See* Electricity; Flux; Lines of Force; Magnetism.

MAGNETIC FLUX. Total amount of magnetic induction through a circuit measured by the number of lines of induction which are linked with the circuit. *See* Flux; Lines of Force.

MAGNETIC FORCE. Force at any point in a magnetic field which a unit of quantity of magnetism would experience if placed at that point. *See* Flux; Lines of Force; Magnetism.

MAGNETIC INDUCTION. The act of creating a magnet from a piece of magnetic material. If a steel magnet be taken, and a piece of soft iron placed close to it, or in actual contact, the iron will be found to possess magnetic properties. Magnetism has been induced in the piece of iron, and this magnetism will be largely if not wholly lost when the steel magnet is removed. If hard steel is substituted for the soft iron some magnetism—residual magnetism, as it is called—remains. *See* Magnetism.

MAGNETIC INDUCTIVE CAPACITY. If any magnet is assumed to exert M units of magnetic force at each pole, and the length between its poles is denoted by L, the product $M \times L$ is termed the magnetic moment of the magnet.

If the magnetic moment of a magnet be divided by its volume, another definition is arrived at, namely, the intensity of magnetization. Although based on the surface unit measurement of pole strength, this term is intended to convey an idea as to the internal magnetic state.

Since volume is the product of sectional area into length, it follows that if any magnet of uniform section had its surface magnetization situated on its ends only (which is not the case in actuality), the intensity of magnetization could be found by dividing the strength of the pole by the area of its end surface.

Calling I the intensity of surface magnetization, M the number of units of magnetic force at the pole, L its length in centimetres, and S its section in square centimetres,

$$I = \frac{\text{Magnetic moment}}{\text{Volume}} = \frac{M \times L}{S \times L} = \frac{M}{S}$$

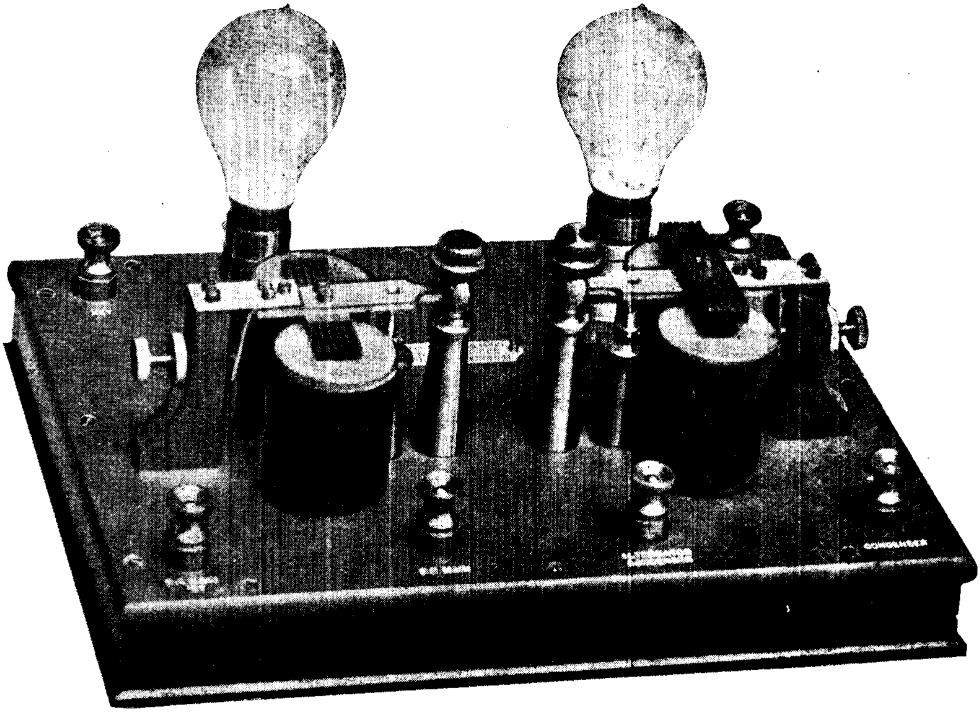
If the value for I is assumed to be due to the iron having been under the influence of a magnetic field of intensity H, the ratio between the resulting intensity of magnetization I and the magnetizing force H producing it can be expressed by a numerical coefficient of magnetization termed the susceptibility or magnetic inductive capacity, denoted by symbol K.

In this case, $I = KH$, and $K = I/H$. For every line of magnetic force emanating from the magnet there will be K units of magnetism on the end surface of the magnet.

In magnetic substances such as steel, iron, nickel, and cobalt the susceptibility K has a positive value; but there are also substances, such as mercury, zinc, bismuth, copper, etc., which are found to possess feeble negative coefficients. These are termed diamagnetic bodies, and all others exhibiting positive susceptibility coefficients are termed paramagnetic.

There are 4π lines of force proceeding from every unit magnetic pole; hence if each line of force from the magnetizing field in which the iron is placed produces K units of magnetism, due to the particular susceptibility of that sample of iron, there will be 4π lines added by the iron to every one line in the existing field, and the permeability of the iron, μ, will be equal to $1 + 4\pi K$.

The value of B may go on increasing so long as H is increased, as is evident from a study of the curves of magnetization given in the section on Magnetic Density. But since the susceptibility K



AUTOMATIC RELAY USED IN TRANSMITTING APPARATUS

Fig. 1. Where alternating primary currents are used an automatic relay protects the contacts of the Morse key. This photograph shows the Marconi double magnetic key relay. By its use there is no fear of the operator receiving shock from the current

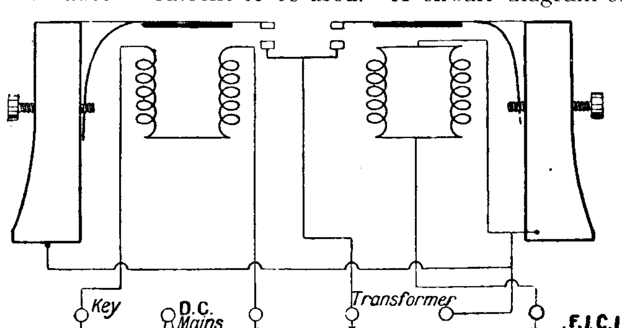
Courtesy Marconi's Wireless Telegraph Co., Ltd.

decreases as saturation sets in, the surface magnetization I will have a true limit.

It is a curious fact that in weak magnetic fields the susceptibility of nickel considerably exceeds that of iron under the same conditions. *See* Flux, Lines of Force; Magnetism.

MAGNETIC KEY. A form of automatic relay which is used in transmitting apparatus where alternating primary current is used, in order to protect the contacts of the Morse key. It will be appreciated that should the key be released at a point coincident with the maximum value in the current fluctuation, considerable sparking would occur and damage to the contacts accrue. This is prevented by an automatic relay, worked from the key, which short circuits the key contacts and provides another path for the current. Thus the contacts are practically at zero potential.

Fig. 1 is an illustration of a double magnetic key relay, which provides another step in the prevention of damaged contacts, and, further, gives protection to the operator from shock by allowing direct current to be used. A circuit diagram of



CONNEXIONS OF MAGNETIC KEY

Fig. 2. In this circuit diagram of the magnetic key illustrated in Fig. 1 the connexions may be seen and the method of operation understood

this arrangement is given in Fig. 2, and the two illustrations should be read together in order to understand fully the method of operation.

Reference to Fig. 1 will show that the device consists essentially of two two-pole electro-magnets, each having an armature directly over it. The first magnets are actuated by D.C. which is at a low voltage, and in the circuit of which the tapping key is connected. When the key is depressed the magnets are energized, and the armature flies towards them. This movement causes two contacts to come together, and a second circuit is closed.

The second relay is operated on the completion of this circuit, and the operation of this relay causes two further contacts to close, which are connected in the primary side of the transformer of the transmitting set. Thus the depression of the Morse key by the operator causes the transformer primary circuit to be made or broken strictly according to the Morse signals. The two lamps shown at the back of the instrument are pilot lamps in the D.C. and A.C. circuits respectively, and are used to indicate whether current is present or not in those circuits. The connexions of these are not shown in the circuit diagram.

MAGNETIC MOMENT. The couple or torque acting on a magnet placed in a field of uniform intensity in such a position that its axis is at right angles to the lines of force. In the case of a uniformly magnetized bar magnet the magnetic moment, usually denoted by the symbol M, is given by the product of the strength of either of the poles, reckoned in terms of unit pole strength, into the distance between them in centimetres.

MAGNETIC NEEDLE. Thin strip of magnetized steel used in various instruments to denote polarity. Also the compass needle. *See* Magnetism.

MAGNETIC POLES. Name generally given to the two positions on the earth's surface to which the isogonic lines (*q.v.*) appear to trend, or where terrestrial magnetism appears to be at a maximum. *See* Magnetism.

MAGNETIC RELUCTANCE. The opposition offered to the passage of lines of force in a magnetic circuit. It is the reciprocal of permeance or permeability, and is analogous to resistance in current electricity; but whereas, in the latter case, conductivity is independent of current value, in the present instance permeability is not constant, but decreases as the flux density increases. Reluctance may be calculated from the length, cross-sectional area, and permeability of the circuit.

$$\text{Reluctance} = l/\mu A$$

where μ = permeability, l = length in centimetres, and A = cross-sectional area in square centimetres. *See* Magnetic Circuit; Magnetism.

MAGNETISM: MODERN THEORIES AND THEIR APPLICATIONS

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

This article is necessarily complementary to that which appears under the heading Electricity, by the same author. It gives a clear and simple, yet profound, explanation of the most modern theories of magnetism, with a series of valuable photographic demonstrations of the ways in which magnetic forces act. See Electricity; Ether; Inductance; Induction

It is hardly necessary to describe the characteristic property of a magnet: everyone is familiar with the fact that a bar or horseshoe of steel may be endowed with the power of attracting other pieces of steel or iron. Magnetic properties, although possessed to some extent by a very large number of substances (possibly by all), are only evident to any important extent with iron, nickel, and cobalt, and for practical purposes only with iron and the various steels made from this element.

It has been usual for many years past for writers to treat magnetism and electro-magnetism as two totally distinct phenomena—magnetism, on the one hand, being understood to refer to the permanent or semi-permanent property, and electro-magnetism, on the other hand, to the magnetic property which is called into evidence by the establishment of an electric current, and which is exhibited only during the continuance of the current (*see* Electricity).

It is in some ways convenient to separate the subjects of magnetism and electro-magnetism in this way, but it is apt to give rise to the impression that they are distinct and unrelated phenomena.

It is therefore important to point out that, according to the modern theory of permanent magnetism, this is probably a special case of electro-magnetism, and the electric current causing it may be that due to the rotations of electrons (*q.v.*) within the atoms of the substance. Each atom may be regarded as containing infinitesimal electrical circuits which will give rise to electro-magnetic "fields" (Fig. 1). Thus it is probable that all magnetism is electro-magnetism, and is due to the mysterious relationship which exists between electricity and ether (*q.v.*). This relationship has been dwelt upon under the heading Electricity.

It was thought at one time that magnetism was a fluid which resided in a magnetic body and was capable of being transferred to another body: the fact that one body might be magnetized by contact with another, already magnetic, lent support to this belief. Without discussing the history of magnetic theories, however, we may say at once that magnetism is not in any sense a fluid.

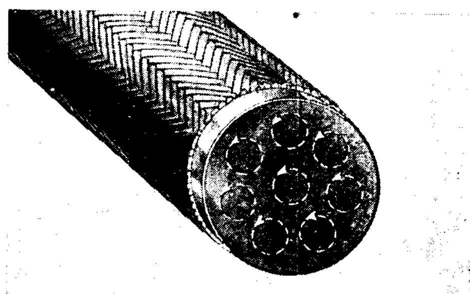
Although there is such a close relationship between electricity and magnetism (as we have just stated, it is now believed that the latter cannot be produced except by the former), yet the two are quite different in their nature. Electricity consists of a swarm of positive and negative electrical particles. Each of these particles is probably made out of that primordial medium which we call, for want of any better name, the "ether of space." Electricity may thus be regarded, for manipulative purposes, as a fluid consisting of an aggregation of electrical particles, just as water is a fluid consisting of water-drops.

Magnetism, on the other hand, is not to be regarded as having a permanent and indestructible existence, as is electricity. It is, in fact, conceived as a state of strain in the ether-medium: its existence is temporary and dependent.

[*Note.*—This statement, which is introduced for clearness, although quite sufficient for the present purpose, must not be taken as rigidly accurate. The territory between matter (or electricity) and energy is only now being explored, and it is possible that electricity and energy are, to some extent at any rate, manifestations one of another, and that matter may not be so indestructible or "uncreatable" as has hitherto been believed.]

Wherever electricity exists, there is ether-strain. If the electricity is stationary, the strain is known as electric strain or displacement: if the electricity is in motion, there is magnetic strain or displacement. We must regard the existence of the magnetic field as representing the storage of energy, for work has to be expended in starting an electric current, and this work goes to the setting up of the magnetic ether-strain. When the current ceases, the ether-strain vanishes and the work which was done in establishing it is recoverable.

A "magnet," then, is a body which is permanently surrounded by a certain kind of ether-strain: wherever it goes it takes its ether-strain "field" with it. An electrified body (such as a charged



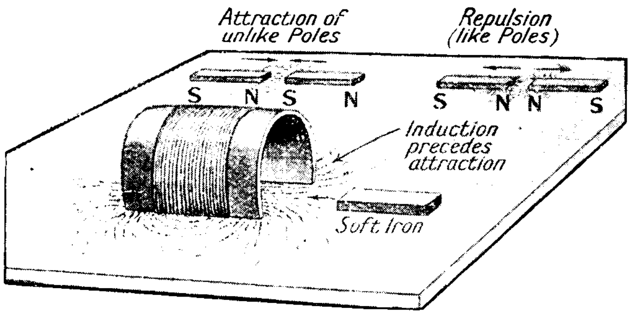
PERMANENT MAGNETISM

Fig. 1. Illustrated in this diagram is the modern theory of permanent magnetism as due to electrons rotating in orbits

insulated ball) is analogous to a magnet, except that the ether-strain which surrounds it is of a different kind. The latter is known as an electric "field," the former as a magnetic "field."

The most characteristic feature of a magnet is the force which it exerts upon another magnet: we have no very direct evidence of the magnetic ether-strain surrounding it, but the force is evident from the simplest experiments. The question, then, naturally follows: Why should the existence of these regions of ether-strain, or magnetic fields, give rise to forces upon the bodies? That question, although a very simple and obvious one to ask, it is quite impossible to answer. As stated in the article on "Electricity," we are entirely ignorant of the ultimate physical nature of force, whether magnetic, electric, gravitational, or any other variety (Fig. 2).

It is probable that all forces are ultimately of a similar nature, and that they



MAGNETIC POLAR ATTRACTION AND REPULSION

Fig. 2. Unlike magnetic poles attract. Like magnetic poles repel. Before soft iron is attracted it is converted by induction into a temporary magnet

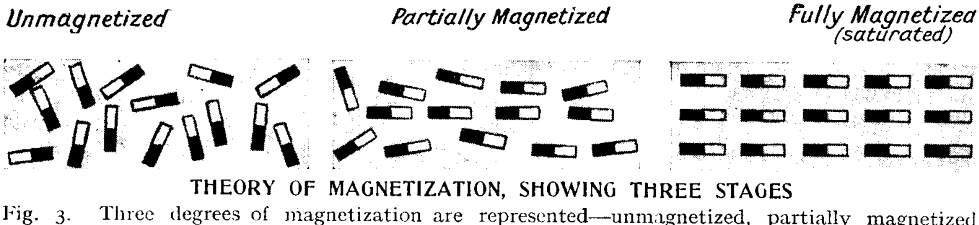
arise from ether-strain as well as being associated with its production.

It has been mentioned that a magnetic substance is one whose molecules or atoms possess the properties of elementary magnets. But a magnetic substance may be in an unmagnetized condition, owing to the fact that these elementary magnets are not arranged in any special way, and are therefore mutually complementary, so that the body as a whole exhibits no magnetism, or practically none (Fig. 3).

The process of "magnetizing" the body (by rubbing it with another magnet or placing it in a magnetic field) consists in forcing all the elementary magnets out of their local self-satisfied groups or circles into an axial arrangement, all with their south poles pointing towards one end of the body and their north poles towards the other end. If the substance is such that the elementary magnets fall into a state of disorder the moment the controlling magnetic field is removed (with the result that the magnetism of the body, as a whole, disappears), the substance forms only a temporary magnet: soft iron is such a substance, and is particularly useful for that reason. If the orderly arrangement persists after the removal of the controlling field, the magnetization is said to be permanent: this is only a relative term, however, as a "permanent" magnet gradually loses its magnetism, that is, the elementary magnets fall into disorder, only more slowly. Permanent magnets also have important practical uses in cases where a magnetic field is required without the necessity of maintaining the same by means of an electric current.

Substances in which a given magnetic field produces a relatively high degree of magnetization are said to be of high "permeability" (*q.v.*). The property of resisting magnetization (or de-magnetization), on the other hand, is known as coercive force, or more properly as retentivity. The retentivity of hard-tempered steel, for example, is very high, whilst that of soft iron is small. The retentivity, however, is not characteristic simply of the substance, but depends also upon the form of the body. Elongated forms of magnet and those shaped as closed, or nearly closed, magnetic circuits retain their magnetism better than those shaped as short rods or cubes. It has also been found that long, thin steel magnets are more powerful in proportion to their weight than thicker ones, and for this reason compound permanent magnets are sometimes built up of laminations, each of the laminations being separately magnetized before assembly.

The existence of a region of magnetic force or a magnetic "field" around a permanent magnet may be very simply shown by placing the magnet upon (or beneath) a sheet of cardboard on which iron filings are sprinkled, the board being then tapped to allow the filings to fall



THEORY OF MAGNETIZATION, SHOWING THREE STAGES

Fig. 3. Three degrees of magnetization are represented—unmagnetized, partially magnetized, and fully magnetized to the point of saturation. Elementary magnets in the first stage are in haphazard formation, but when the magnetic substance is fully magnetized the elementary magnets are arranged so as to assist one another

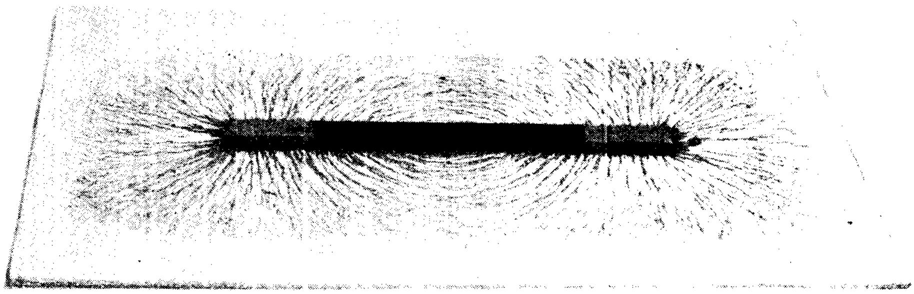


Fig. 4. This photograph shows how iron filings have arranged themselves so as to map out the magnetic field due to the bar magnet

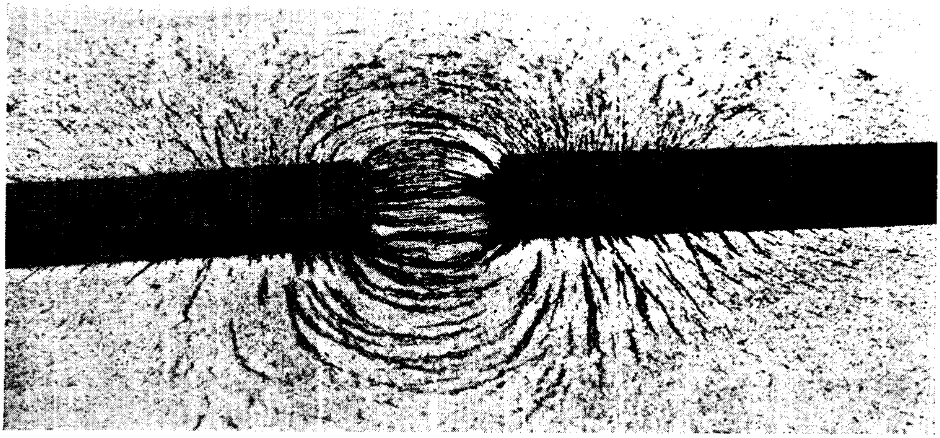


Fig. 5. Unlike magnetic poles are here seen placed near each other, and around them have been sprinkled iron filings, which have arranged themselves without assistance according to the lines of force. The result is shown in this photograph, the field of attraction being clearly apparent

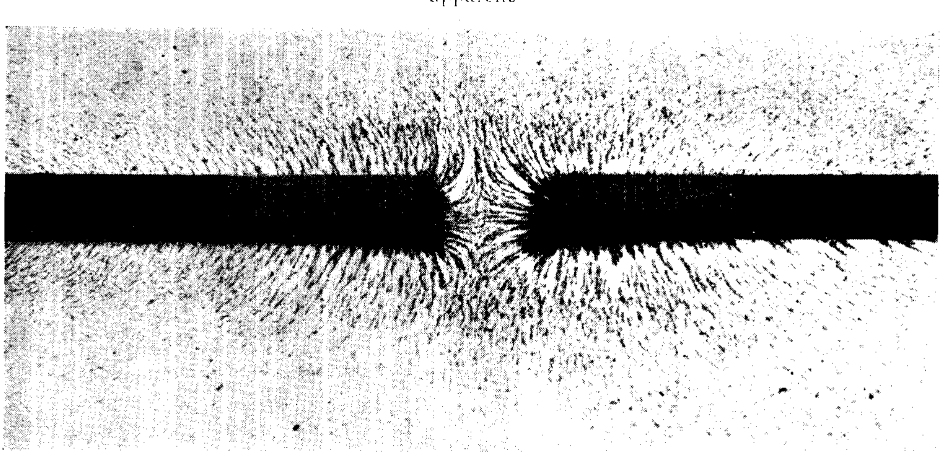
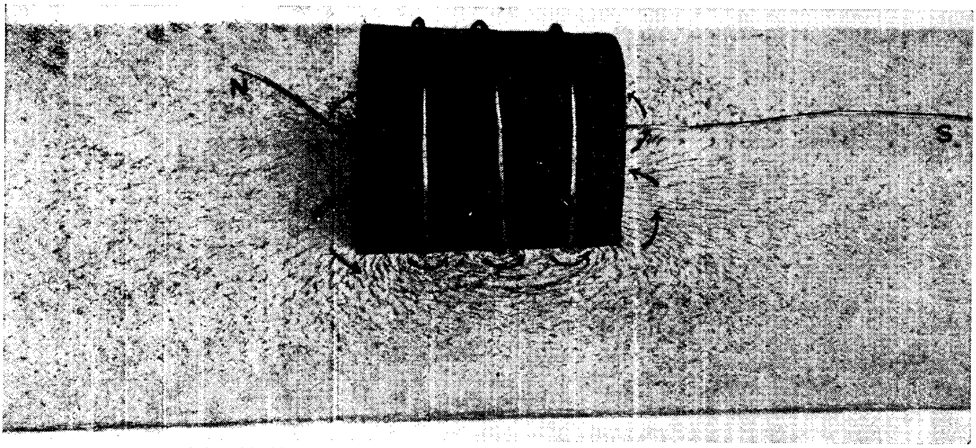


Fig. 6. In this case the like poles of two magnets are brought into close proximity, and the photograph shows the field of repulsion. The iron filings have arranged themselves under the influence of the magnets only

DEMONSTRATION OF MAGNETIC ATTRACTION AND REPULSION BY PHOTOGRAPHS

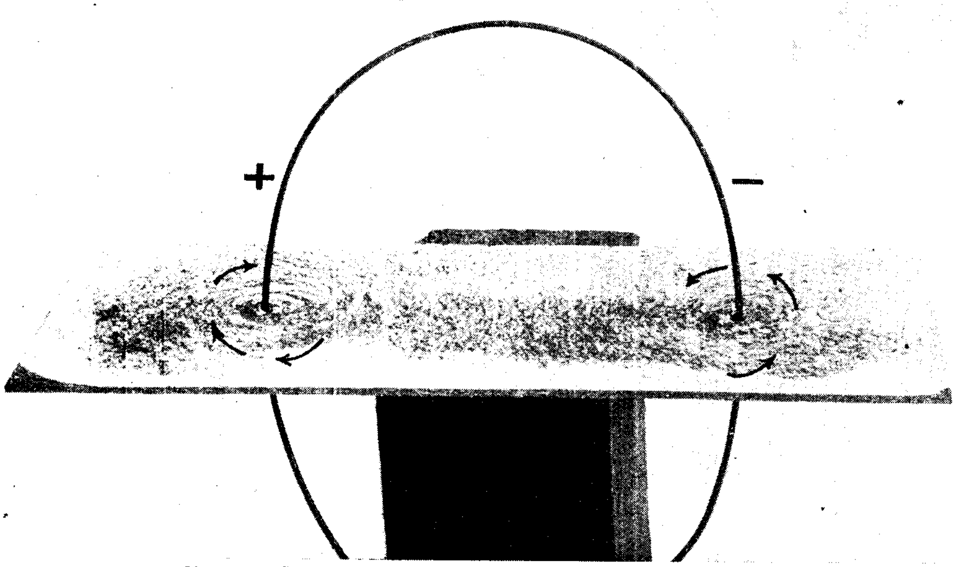


WHAT TAKES PLACE IN A CURRENT-CARRYING COIL

Fig. 7. N. and S. are the two polar extremes of the magnetic field, due to the coil of wire, which is carrying an electric current. What has happened to the iron filings which have been influenced by the magnetism of the coil can be seen, and gives a good idea of the magnetic field

into position under the influence of the magnetic force. It will be found that each filing will lie in a position tangential to a curve proceeding from one end of the magnet to the other end. A horseshoe magnet is simply a bar magnet bent up so that the ends come close together, and the magnetic field between its poles may be similarly mapped out (Figs. 4, 5, 6).

It is important to observe, however, that the lines of magnetic force are not merely external to the magnet, but form an unbroken circuit through the magnet itself. The direction of a magnetic line of force at any point is defined as "the direction in which a small magnetic north pole, if placed at the point, would tend to move under the influence of the magnetic force." There can be no such thing as an isolated north (or south) magnetic pole, any more than there can be such a thing as a rod with only one



MAGNETIC FIELD DUE TO CONDUCTOR-CARRYING COIL

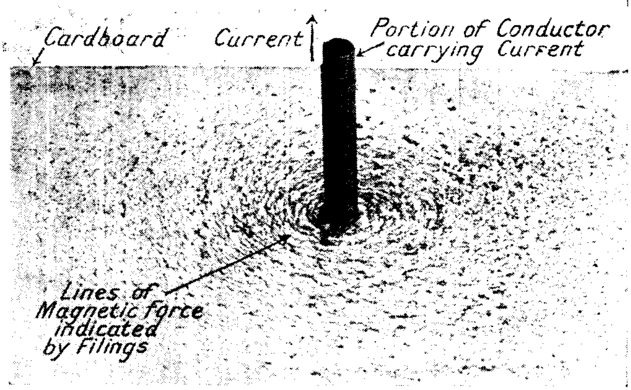
Fig. 8. Positive and negative poles are indicated in this conductor, which is carrying a current. On the board through which the conductor passes is a sprinkling of iron filings. The behaviour of the filings shows the distribution of magnetic force

end, but it is easy to see how the definition describes what is meant by the direction of magnetic force at a point.

Again, the strength of a magnetic field at any point (the "intensity," as it is sometimes called) is defined in a similar way to the direction of the field at a point. The strength of a magnetic field at any point is measured by the force with which it acts upon a unit magnetic pole placed at that point. Hence unit intensity of field is that of a field which acts upon unit pole with unit force.

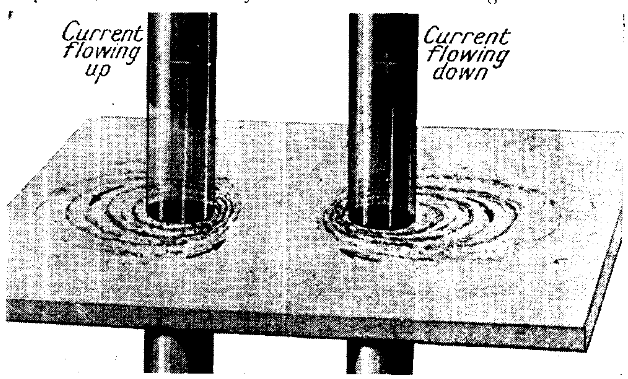
A most valuable conception of the magnetic field is due to Faraday, who introduced the notion of magnetic lines of force, the direction at each point representing the direction of the magnetic force at that point, and the density of the lines representing the strength of the field at that point, so that the lines of force are represented as more crowded together in a region of high magnetic intensity and more widely separated in a region of low magnetic intensity. Limitations of space prevent us from discussing this conception of the magnetic field any further, but it is one of extreme simplicity and usefulness, and is the basis of all modern mathematical treatment of the magnetic field (Fig. 7, 8, 9).

It is well known (*see* Electricity) that a coil of wire carrying a current behaves in a precisely similar manner to a permanent magnet. When the current is started, a magnetic field is created, and when the current ceases the magnetic field vanishes. The strength of the magnetic flux (the number of lines of force threading through the coil) is greater the greater the current which is flowing in the wire of the coil.



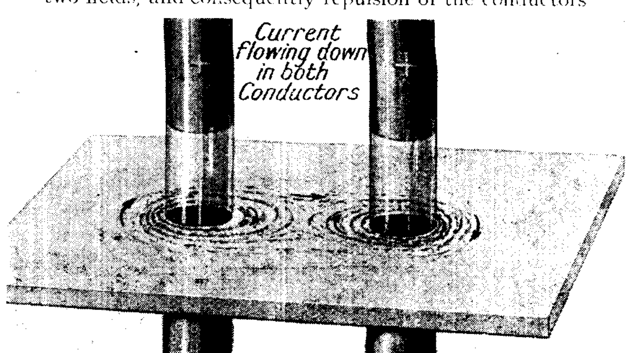
MAGNETIC FIELD AROUND STRAIGHT CONDUCTOR

Fig. 9. This is a photograph of a wire conductor in which a current is flowing in the upward direction. A magnetic field is created around the wire, the lines of force being circular. Iron filings, sprinkled upon the cardboard through which the wire is passed, indicate clearly the circular lines of magnetic force



MAGNETIC FIELDS REPELLING

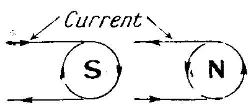
Fig. 10. Here are two conductors carrying currents in opposite directions. The region between the conductors is crowded with lines of magnetic force, since the lines due to the two conductors assist one another. There is thus repulsion of the two fields, and consequently repulsion of the conductors



MAGNETIC FIELDS ATTRACTING

Fig. 11. In this figure the currents are in the same direction in the two conductors. In the region between them the magnetic fields due to the two conductors are opposed, and so tend to counteract each other, the result being attraction between the conductors

Now just as the starting of a current produces a magnetic field, so the production of a magnetic field within a coil of wire will produce a current in the wire. There is this important difference, however, that whereas the magnetic field due to a current persists so long as the current lasts, the induced current produced in a coil by the establishment of a magnetic flux through the coil only lasts so long as the strength of the magnetic field (the amount of the magnetic flux) is changing: directly the flux becomes steady, the induced current vanishes (Figs. 10, 11, 12).



DIRECTION OF CURRENT AND POLARITY

Fig. 12. Relation between direction of current and polarity of the equivalent magnet is shown in this diagram

The amount of the flux through a coil of wire placed in a magnetic field depends not only upon the area of the coil which is exposed to the lines of magnetic force, but also upon the distribution of the lines of force in the field. In the simpler illustrations accompanying this article the field is shown as symmetrical, because the permeability (*q.v.*) of the surrounding medium (air) is uniform. But if a portion of a substance of higher permeability (*e.g.* iron) be introduced into the field, the lines of force will tend to crowd into the iron and forsake the air region, with the result that the flux per unit area through

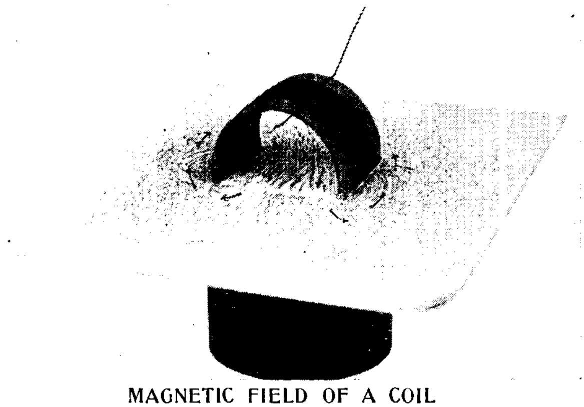
EFFECT OF COILING A WIRE

Fig. 14. Greater magnetic field is produced by a coil of wire than by a single straight portion, as the above photograph reveals

the iron will be greater than it was in the same region before the iron was introduced. If, then, the coil of wire be placed in such a position in the field that it surrounds the piece of iron, it will encompass a greater flux than otherwise. Or, to put it more plainly, if instead of using an air-core coil, we use an iron-core coil, we shall have a greater concentration of the lines of force through the coil and, consequently, a greater induction (Figs. 13-17).

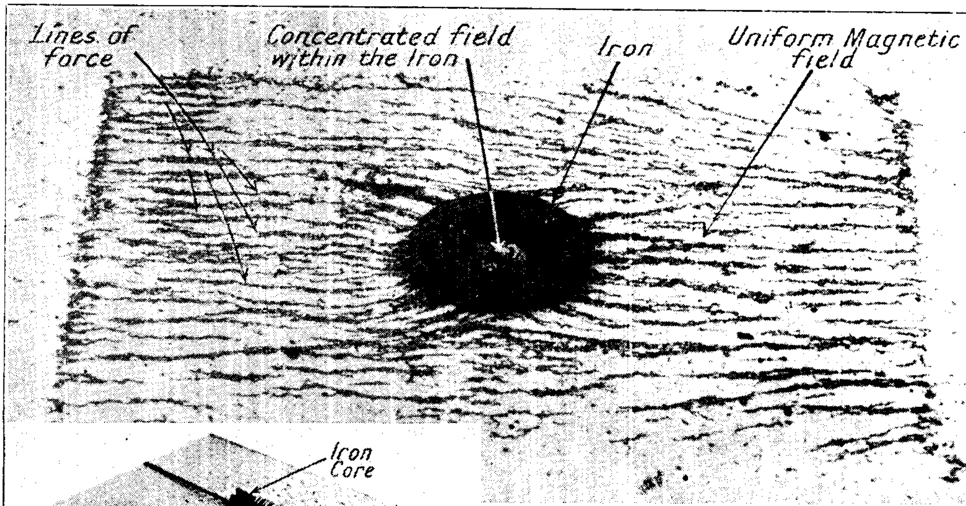
When current is passing through one coil and it is desired to secure as large a proportion of the flux as possible through a second coil, a simple plan is to wind the second coil on top of the first coil: it will be evident that practically the whole of the flux due to the primary coil is then encompassed by the secondary coil.

This is the principle usually adopted in the spark coil (*q.v.*) and in certain other kinds of transformers (*q.v.*). Another method is to wind the two (or more) coils upon a closed iron ring: the permeability of the iron is so much higher than that of the air that practically no lines of force leave the ring, the whole flux remaining within the substance of the ring and therefore threading any coils which may be wound upon the ring. This is the principle of many types of transformer, particularly for comparatively low-frequency alternating current, such as alternating current power supply, and also for the audio-frequency speech currents in telephone and wireless circuits (Fig. 18). The core usually consists of a bundle of iron wires or strips.



MAGNETIC FIELD OF A COIL

Fig. 13. Through the centre of a coil is a sheet of paper with iron filings. The coil is carrying a current, and the magnetic field is revealed by the position in which the filings have arranged themselves



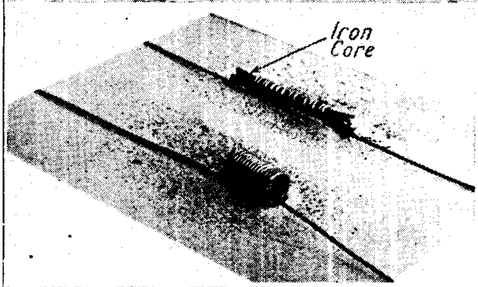


Fig. 15 (top). Concentrated in a magnetic substance—iron—is the magnetic field, the flux in it being greater than in the air

Fig. 16 (left). This photograph shows how an iron core in a current-carrying coil increases the magnetic concentration

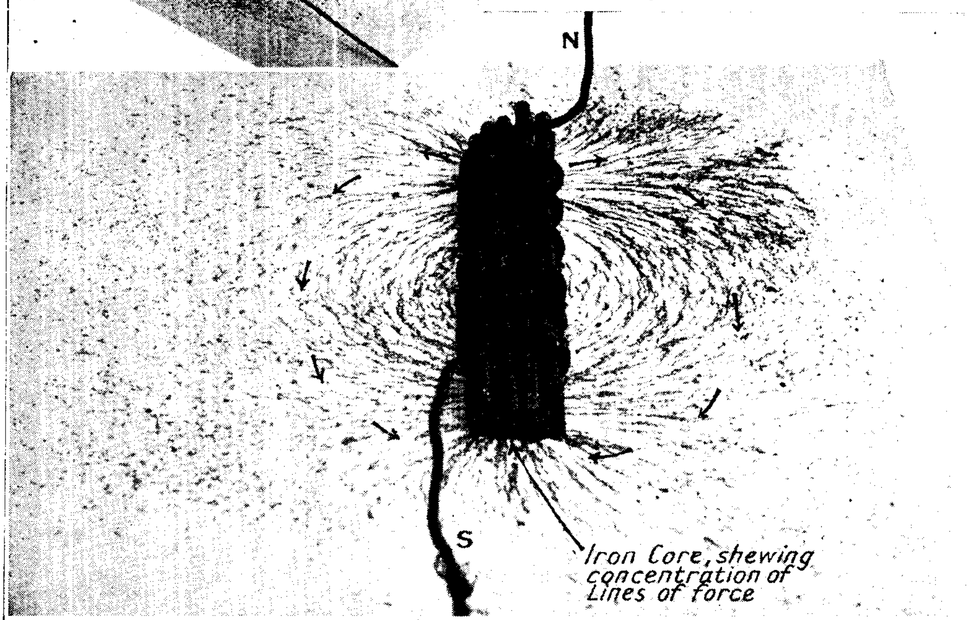
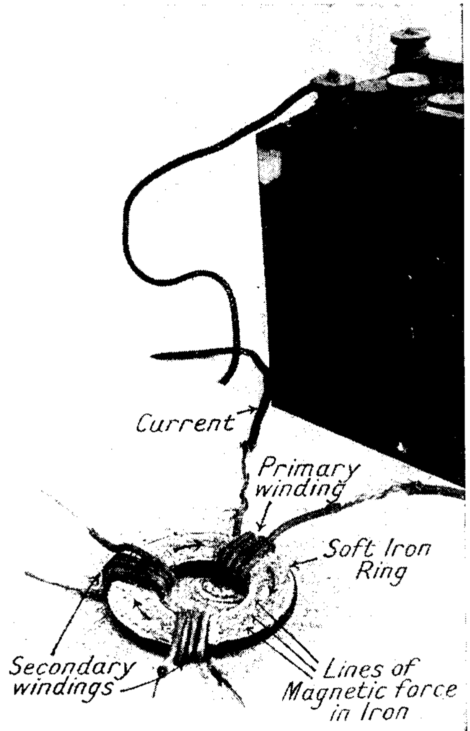


Fig. 17. Here the iron core, as seen in Fig. 16, is shown in a near view, and the concentrated lines of force will be seen quite distinctly

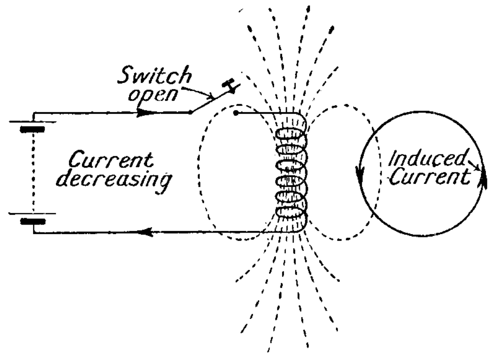
MAGNETIC CONCENTRATION IN MAGNETIC SUBSTANCES

A substance of high permeability may be employed as a magnetic shield. For many purposes, particularly in wireless work, it is desirable to shield apparatus from stray magnetic fields, which, by induction, may produce disturbing effects. The way in which the magnetic shielding is effected is by interposing a fairly thick sheet of iron, or a number of thin sheets (the latter for preference, when alternating fields are to be screened off). The lines of magnetic force crowd into the iron, and so are conducted away from the apparatus to be shielded. A method of this kind is



PRINCIPLE OF THE TRANSFORMER

Fig. 18. Lines of force due to the current-carrying coil are conducted by the iron core into the other coils which are wound upon the core



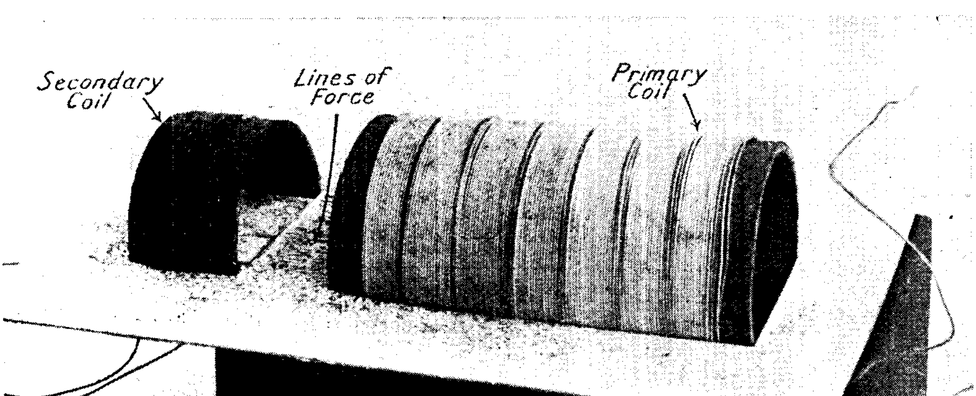
MAINTENANCE OF MAGNETIC FIELD

Fig. 20. How induced current produced by changing magnetic flux is in such direction as to tend to keep the magnetic field constant

sometimes used for certain forms of galvanometer, the instrument being almost completely enclosed in a thick iron shell or sphere. Where alternating currents are used, however, eddy current shields may sometimes be used (*see* Eddy Currents).

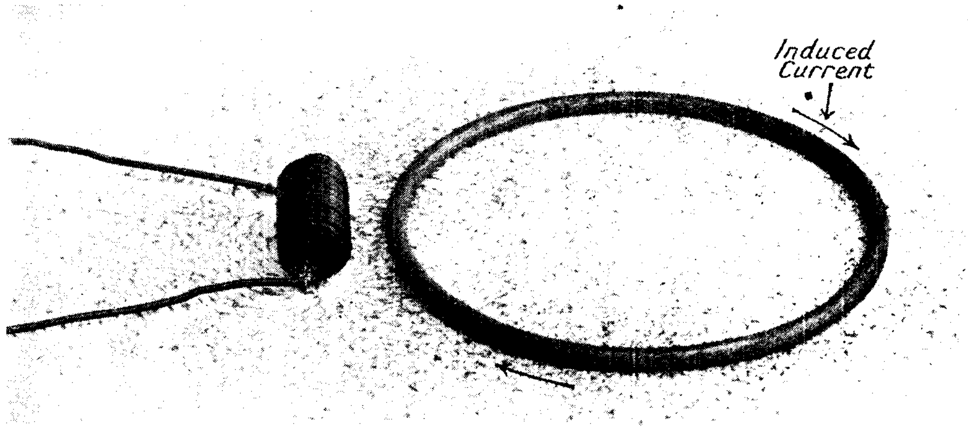
We have seen that the establishment of an electric current produces a magnetic field, and the creation of a magnetic flux in a neighbouring coil will cause the production of an induced current in that coil.

Similarly, since a magnetic field is set up in the first coil, a current is induced in the first coil also. The magnetic interaction of two coils is called mutual induction (*q.v.*), and the inductive effect of a coil upon itself is called self-induction, or more usually inductance (*q.v.*). The currents induced in coils of wire by the making or breaking of currents will themselves produce magnetic fields, and it is found that the direction of the induced current is such as to produce a magnetic field tending to compensate for the magnetic change which gave rise to the induced current. Thus, if a current is started in a circuit the magnetic field is increasing, and there is an induced current in the coil in the opposite direction



DEMONSTRATION OF THE TRANSFORMER PRINCIPLE

Fig. 19. Flux from the first coil is indicated entering the second coil in this photograph, which shows in a different way from the method in Fig. 18 the principle of the transformer



PRINCIPLE OF ELECTRO-MAGNETIC INDUCTION

Fig. 21. Lines of force from left-hand coil enter right-hand coil (fine wire wound on iron ring) and cause induced current : lines shown by iron filings

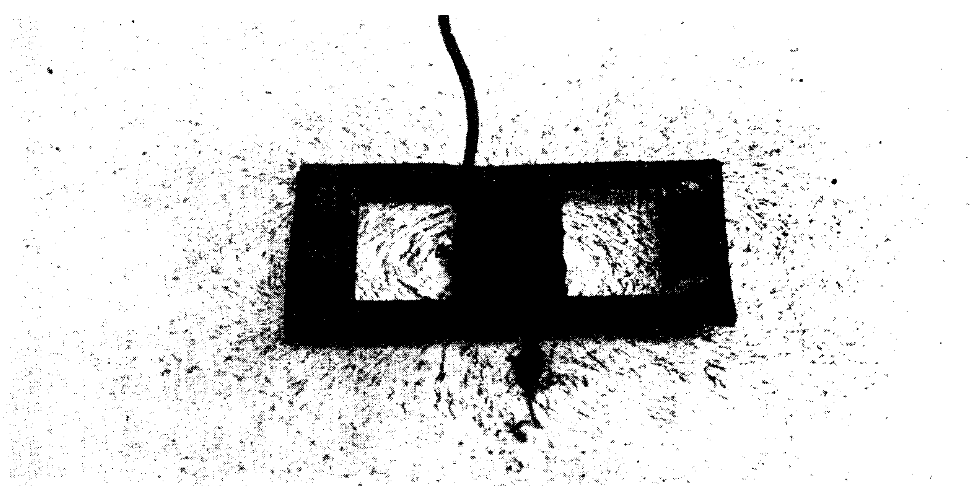
to the original current, that is, tending to oppose the establishment of the magnetic field (Figs. 19, 20).

The presence of inductance in a circuit has a choking effect upon alternating current, this effect usually being greater the higher the frequency, or periodicity, of the alternating current. Self-induction coils with large inductance and small ohmic resistance are sometimes employed to impede alternating current, and are called choke coils or impedance coils.

The phenomenon of electro-magnetic induction is made great use of in electrical engineering, and particularly in wireless. By its aid, and the employment of alternating currents, we are enabled to transfer electrical energy from one circuit to another without any direct electrical connexion existing between the circuits : this is very useful for a variety of purposes.

A telephone transformer is a good example of such an arrangement, where it is impossible for any direct current to pass through to the secondary of the transformer : the only energy which can be transferred to the telephones in such a case is that corresponding to the variations of the current in the primary (Fig. 21).

Moreover, by suitable adjustment of the ratio of the number of turns of wire in the primary and secondary of a



MAGNETIC FLUX IN A WIRELESS TRANSFORMER CORE

Fig. 22. In the above photograph is a portion of a transformer core, as actually used in wireless. The coil wound upon the central portion is producing a magnetic flux, and the distribution of the flux is indicated by the filings

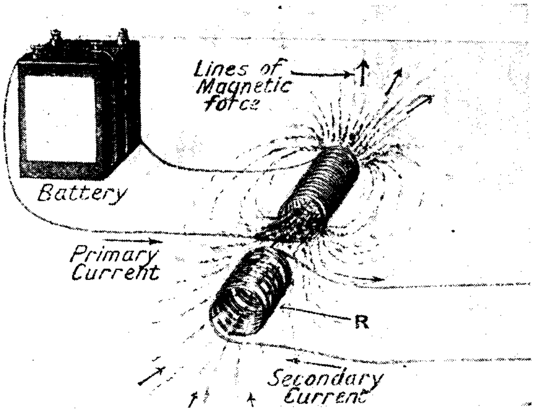


Fig. 23. Coils are arranged in this illustration for a large amount of the flux from the one to enter the other

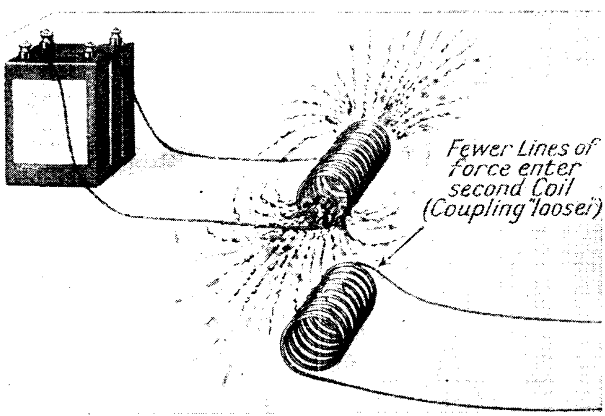


Fig. 24. Compare this with Fig. 23. Here the position of the coils is such that a smaller proportion of the flux from the one enters the other. The coupling is said to be "looser"

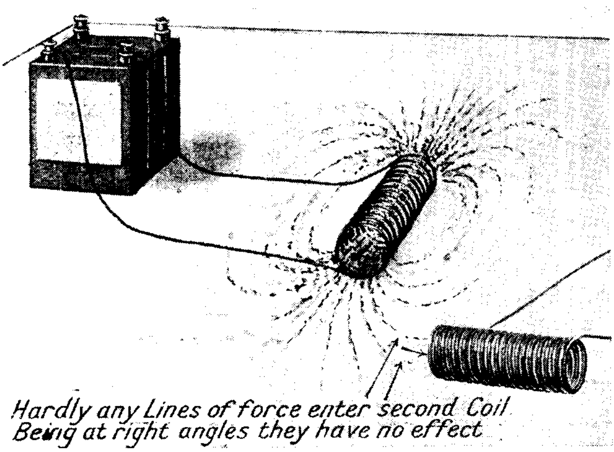


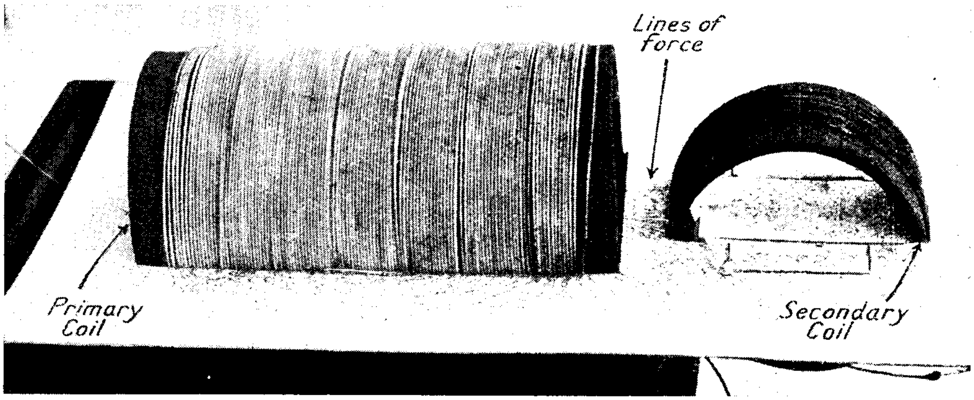
Fig. 25. In this position (compare with figures above) the coupling is very loose, almost nil, since practically none of the flux from the first coil enters the second

PRINCIPLE OF VARIABLE MAGNETIC COUPLING

transformer, the voltage in the secondary may be made to bear any desired ratio to the voltage in the primary. Roughly speaking, the voltages produced are proportional to the numbers of turns of wire. This is very convenient for many purposes (*see* Spark Coil, Transformer). A telephone transformer with a high-resistance primary and low-resistance secondary may be introduced into a high-resistance circuit, and permits the use of low-resistance telephones in the secondary circuit. Intervalve transformers (*q.v.*) also make use of the same principle (Figs. 22–26).

The disposition of two coils in relation to one another (other things being equal) obviously determines the number of lines of magnetic force from the one coil which will pass through the second coil for a given current in the first. The magnetic relation of two coils to one another is called "coupling," and is of fundamental importance in wireless circuits. If the arrangement of the coils is such that a very small proportion of the magnetic flux from the one passes through the area of the other, the coupling is said to be "loose"; if a larger proportion of the flux from the first is encompassed by the second, the coupling is said to be "close" or "tight."

The usual method of varying the coupling between two coils (in wireless apparatus) is to mount the coils so that they may be moved further apart or closer together, and at the same time rotated in relation to one another. It will be seen that both the variation of distance and the rotation will produce a change in the coupling. Sometimes only the change of distance is employed for variable coupling, and sometimes only the rotation. In some cases—

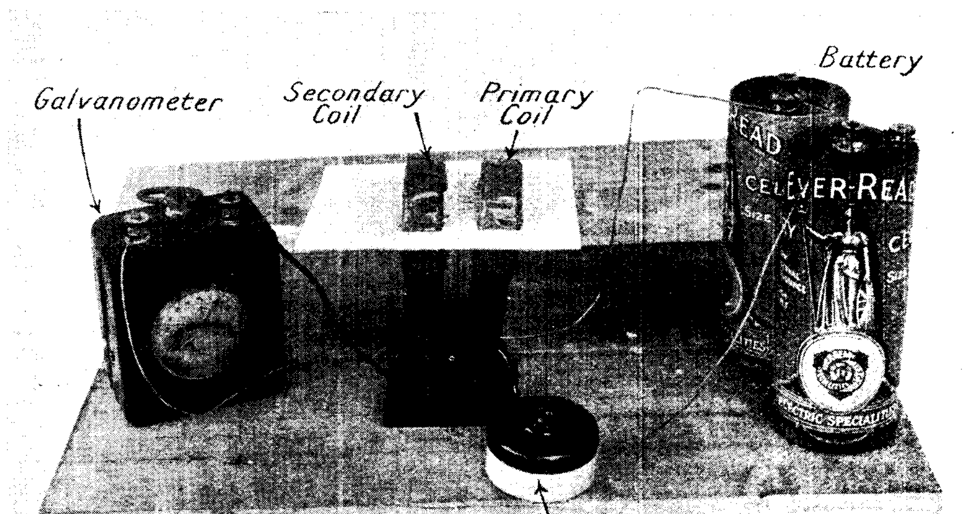


MAPPING OUT OF MAGNETIC FLUX BY FILINGS

Fig. 26. This is an actual photographic representation of the mapping out of the magnetic flux by filings. The photograph illustrates in a remarkable way the reality of the magnetic coupling as used in wireless

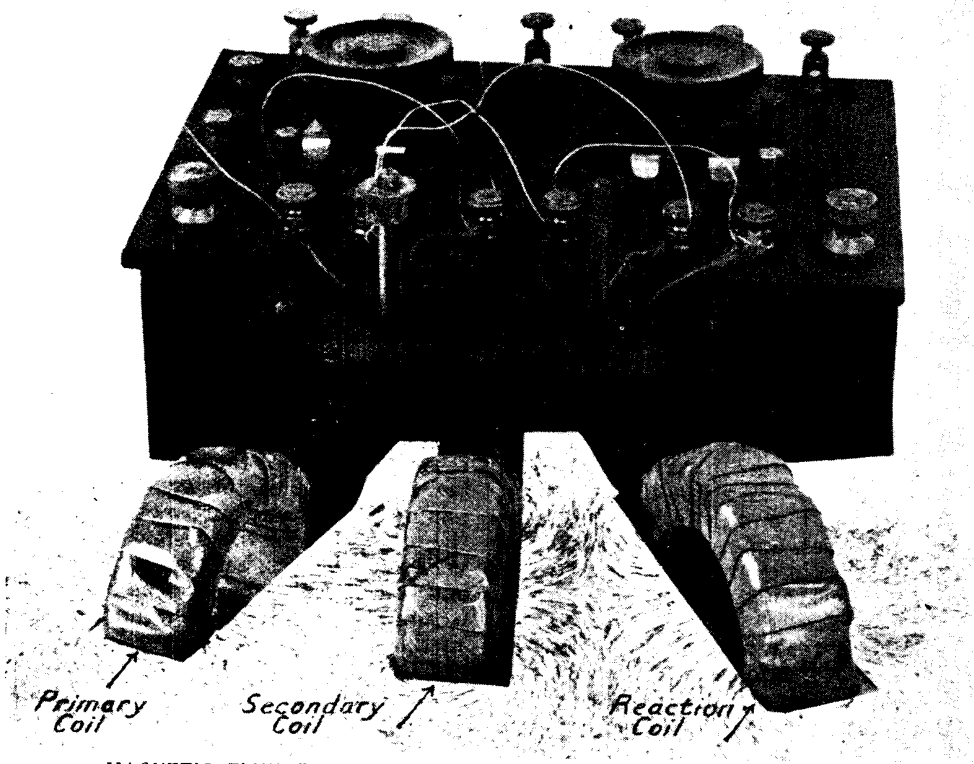
for example, in the aerial circuit of a wireless receiver—an arrangement is used consisting of two coils electrically connected in series, and mounted so as to be capable of rotation with relation to one another. Such an arrangement is known as a variometer. If the two coils are placed with their axes parallel, and so that the magnetic fields produced by them (when current flows) are of the same polarity, they will assist one another, and the inductance of the circuit will be a maximum. If one coil is turned through 180° its magnetic field will be directly opposed to that of the other coil, and the net inductance of the system will be a minimum. At any intermediate position the inductance of the system will have a value intermediate between the maximum and minimum values. The variometer is thus a very convenient and sensitive method of tuning (Figs. 27–29).

There are other methods of tuning, depending upon adjustment of inductance or capacity (or both), and various methods of coupling, known as resistance-capacity and inductive coupling, but in all cases where tuning or coupling depends upon



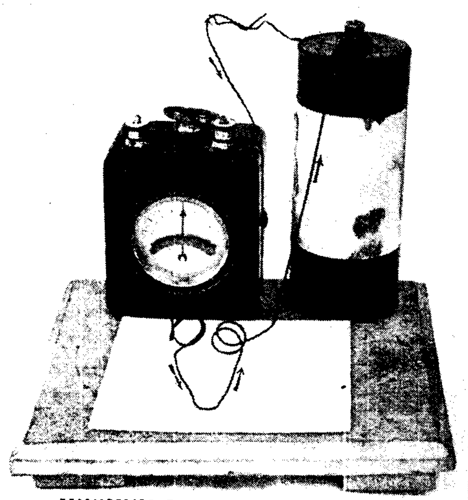
COUPLING FLUX OF TWO PLUG-IN COILS

Fig. 27. Two coils actually in use in wireless apparatus are photographed, and the coupling flux is shown mapped out by the filings on the card attached to them



MAGNETIC FLUX PRODUCED IN COUPLED COILS OF A RECEIVING SET

Fig. 28. This very remarkable photograph shows actual wireless inductance coils, somewhat loosely coupled, with direct current flowing through them. The filings indicate the magnetic flux between the coils. A most valuable mental picture of what occurs in the coupled coils may be gained from this photograph

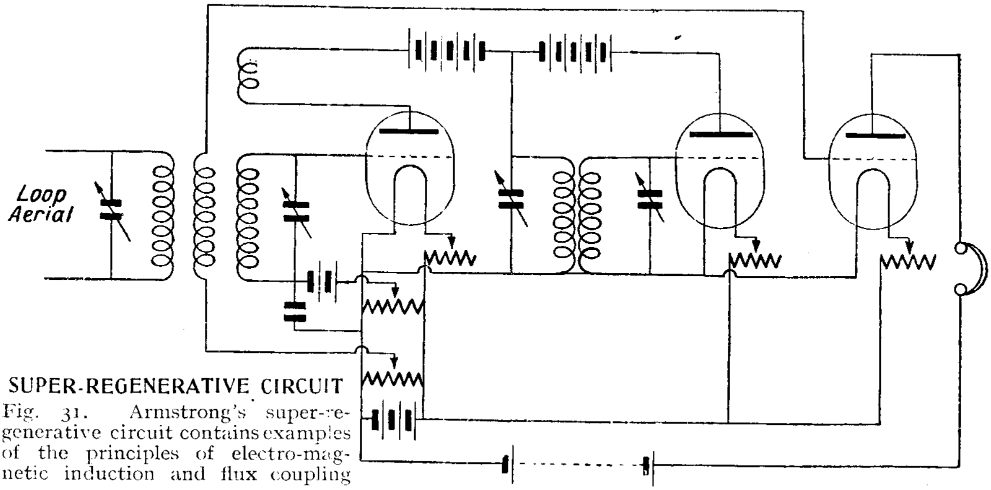


MINIMUM POSITION OF COUPLING

Fig. 29. Two coils are reversed so as to oppose one another. This corresponds to the minimum position of coupling of a variometer

inductance the principle is the same as that which we have been considering, namely, the production of an induced current in a coil of wire by the variation of the magnetic flux through the coil (or vice versa).

The various ways in which inductive couplings are used in wireless transmitting and receiving circuits are too numerous to mention here. But there is a special case of such coupling which is of great interest and importance, and which may be given as an illustration, namely, the regenerative coupling usually attributed (as applied to receiving circuits) to E. H. Armstrong. It is well known that the variations of potential impressed upon the grid of the first valve of a receiving circuit by the oscillations in the aerial circuit cause the precipitation of currents in the anode circuit much larger than those in the aerial (or grid) circuit, a source of



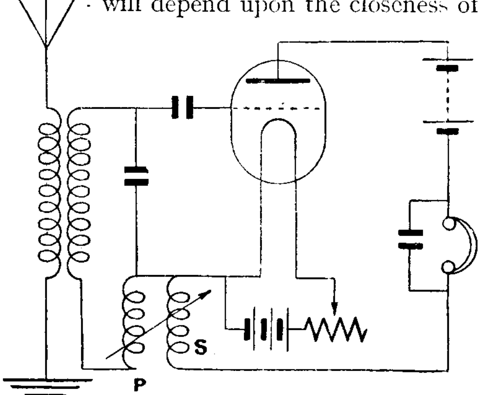
SUPER-REGENERATIVE CIRCUIT

Fig. 31. Armstrong's super-regenerative circuit contains examples of the principles of electro-magnetic induction and flux coupling

energy being available in the anode circuit in the shape of a high-tension battery.

If, however, a coil be included in the anode circuit and placed so that there is mutual induction between it and a corresponding coil in the aerial (or grid) circuit, some of the energy in the anode circuit will pass over to the grid circuit and will increase the oscillatory current in that circuit, to its own ultimate advantage (Fig. 30).

The effect may be popularly illustrated by the analogy of a small man and a large man about to climb a series of rocks; the small man gives the other the first "leg-up," and the large man then hauls the small man up after him, and uses him similarly for the next stage, and so on. The amount of "feed back" of energy from the anode to the grid circuit will depend upon the closeness of the coupling of the two circuits, and may be adjusted by adjusting the coupling. This feed-back effect is usually called "reaction" in England, and the two coils employed for adjusting the coupling are called "reaction coils." If the reaction exceeds a certain critical amount, the circuit sets into self-oscillation and becomes a transmitting circuit. If, however, the reaction is brought near to, but not quite up to, the critical value, the circuit remains a receiving circuit, but of considerably enhanced sensitiveness. The two reaction coils comprise, in effect, a variometer.



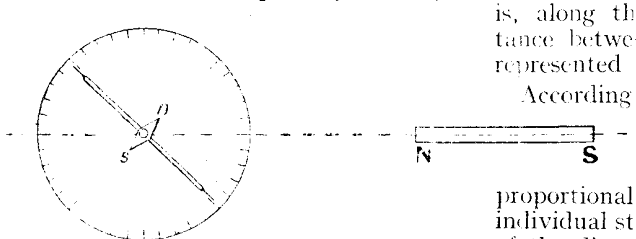
REGENERATIVE CIRCUIT

Fig. 30. Coupling flux as illustrated in preceding photographs may be pictured mentally in appreciating the action of this apparatus

By means of a special method Armstrong has also constructed what he calls a "super-regenerative" circuit (Fig. 31). In this the reaction is actually pushed a little beyond the oscillation-point, but extra oscillations of lower frequency (say 10,000 to 15,000 per second) are generated by a second valve and superposed upon the high-frequency oscillations, so that the oscillations which tend to be produced by the first valve are alternately checked by those of the second. The Armstrong super-regenerative receiving circuit is extraordinarily sensitive for very feeble signals. A full account of it would, however, be out of place here. *See* Armstrong Circuits; Regeneration; Reaction.

MAGNETITE. This is another name for the mineral which forms a natural magnet and is more popularly known as lodestone (*q.v.*).

MAGNETO. Small machine used for generating electricity. Essentially, it comprises a permanent magnet, between the poles of which is rotated the armature (*q.v.*). A contact breaker or distributor forms part of the armature, and is used to regulate the time and nature of the electrical output from the machine. It is not used extensively in wireless work, but forms a necessary part of most internal combustion engines, as it supplies the high-tension current required for the ignition system by means of an induction coil of the normal type. The circuit includes a mica and tinfoil condenser to damped induced currents in the primary winding.



PRINCIPLE OF THE MAGNETOMETER

Fig. 1. Degrees of arc are shown on a graded scale traversed by a pointer, and the strength of the magnetic field N S is being measured

The wireless worker in possession of a petrol electric generating set will find that the usual type of magneto is similar to that employed in automobile engineering. Another application of the magneto is in the form of a hand-driven generator used in telephone circuits for the local ringing circuits. *See* Dynamo.

MAGNETOMETER. The magnetometer is of great convenience and utility as an instrument for taking quick readings of field strength, and is used to take comparative readings between the fixed field strength, due to the earth's magnetism, and the field, due to the magnet under test.

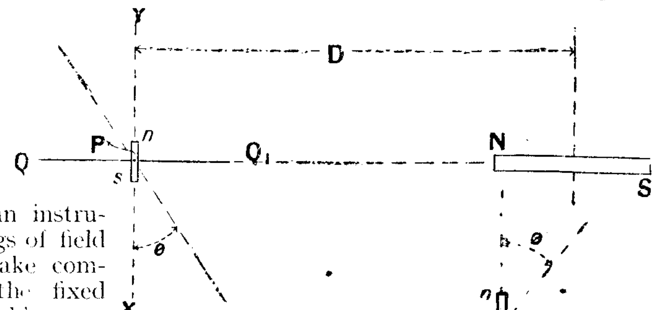
The principle of the magnetometer is illustrated in Fig. 1, where the strength of the field along the axis of the magnet, N S, is being measured, deflections being caused upon the short needle, *n s*, to which is attached a long pointer, traversing a scale graduated in degrees of arc. A more accurate instrument takes the form of a reflecting mirror attached to the needle, *n s*, upon which a beam of light is thrown from a distant lamp and reflected again on to a scale, after the manner of a reflecting galvanometer.

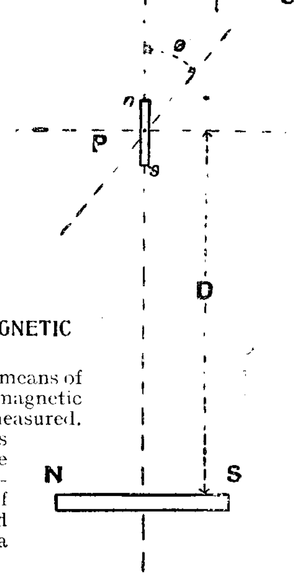
A method of measuring the magnetic moment of a magnet by the magnetometer is illustrated in Figs 2 and 3. The magnet whose moment is to be determined is shown at N S, and is separated by a definite distance, D, from the middle region of another small magnet, *n s*. It is supposed that the strength of the horizontal component of the earth's magnetic field at P is known, when removed from the influence of N S, and that its direction, X Y, is perpendicular to the axis of magnet N S, that is, along the direction Q Q_1. The distance between the two poles of N S is represented by l.

According to elementary laws of magnetism, the force exerted between two poles of strengths m and m' respectively is proportional to the product of their individual strengths divided by the square of the distance separating them. Therefore the pole at N in Fig. 2 produces a field at the point P in the direction P Q of strength

$$\frac{m}{\left(D - \frac{l}{2}\right)^2}$$

and the pole at S produces a field at point





MEASURING MAGNETIC MOMENT

Fig. 2 (above). By means of a magnetometer, magnetic moment is being measured. Fig. 3 (right). This shows the principle of the magnetometer method of measuring the field strength of a magnet

P in the direction P Q_1—that is, opposite to P Q, of a strength equal to

$$\frac{m}{\left(D + \frac{l}{2}\right)^2}$$

The deflecting field acting on *n s* will be the difference of these two forces, namely

$$F = \frac{m}{\left(D - \frac{l}{2}\right)^2} - \frac{m}{\left(D + \frac{l}{2}\right)^2}$$

$$= \frac{2Dml}{\left\{D^2 - \left(\frac{l}{2}\right)^2\right\}^2} = \frac{2DM}{\left\{D^2 - \left(\frac{l}{2}\right)^2\right\}^2}$$

since $M = ml$.

From what has been said earlier, it is known that a deflecting field F acting on a magnetic needle controlled by a field H, at right angles to F, will experience a deflection θ, where $F = H \tan \theta$. Therefore

$$\frac{2DM}{\left\{D^2 - \left(\frac{l}{2}\right)^2\right\}^2} = H \tan \theta$$

and $$M = \frac{H\left\{D^2 - \left(\frac{l}{2}\right)^2\right\}^2}{2D} \tan \theta$$

When $\left(\frac{l}{2}\right)^2$ is small compared with D^2 the expression can be reduced to

$$M = \frac{HD^3}{2} \tan \theta \text{ approximately.}$$

If the magnet N S is placed with its centre in line with the axis X Y in Fig. 3 and the deflection produced is θ', then

$$M = H\left\{D^2 + \left(\frac{l}{2}\right)^2\right\}^{\frac{3}{2}} \tan \theta'$$

which can be further reduced to

$$M = HD^3 \tan \theta' \text{ approximately,}$$

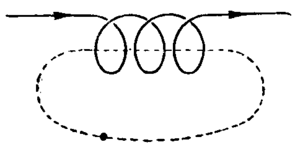
provided $\left(\frac{l}{2}\right)^2$ is small compared with D^2.

The field of a magnet varies inversely with the cube of the distance, at any considerable distance from it. This is an easily remembered fact and an important one. That is also why the intensity of the field of a magnet falls off so very rapidly. If at a distance of 1 cm., for example, the strength of the field is unity, at 2 cm. it has dropped to only one-eighth of its strength, and at 3 cm. to only one twenty-seventh of its strength. *See* Flux; Magnetism.

MAGNETO-MOTIVE FORCE. The similarity existing between the two phenomena of electric current and magnetic flux has led to the conception of a magnetic "circuit," the laws of which closely resemble those governing the electric circuit.

For example, everyone knows that a difference of electrical pressure or potential must exist between the two ends of a conductor before any current can flow along it. The magnetic case is analogous in the essential point that before a magnetic flux can come into being there must be a difference of magnetic potential, or, as it is generally called, "magneto-motive force."

Magneto-motive force, therefore, is the impelling power that generates the magnetic lines of force, and causes the magnetic region surrounding every current-carrying conductor, whether it be a straight wire or coil. It may be said also that magneto-motive force, or the power to magnetize, is a measure of the work which has to be expended on a unit magnetic pole carrying it through one complete circuit round a



THEORY OF MAGNETO-MOTIVE FORCE
Interlinked with electric current is a magnetic field. The direction of current is indicated by the arrows

closed magnetic path against the magnetic forces of the system. Such a path may lie, according to circumstances, either wholly in air, or partly in air and partly in iron or other substances, but the definition is entirely unaffected thereby.

The definition of a unit magnetic pole is that it is of such strength that when placed at unit distance from a similar pole in air (that is, at 1 centimetre distance) a repulsion effect of 1 dyne (unit force) is experienced. Now this repulsion effect may take place in any conceivable direction with regard to the pole position. In other words, if the unit pole is situated at the centre of an imaginary sphere of one unit radius, or 1 centimetre, a second similar pole will be repelled with unit force if situated on any portion of its surface. Since the surface of a sphere expressed in terms of its radius is $4\pi r^2$, and in this case $r = 1$, it is clear that every unit magnetic pole must emit 4π

lines of force, which radiate from the centre in every direction, resulting in unit flux density at the surface of the sphere, that is 1 line per square centimetre.

If this unit pole, with its 4π lines of force radiating from it, is passed along a closed path, such as indicated by the dotted circuit in the figure, from a given point through the spirals of wire to the same point again, each turn of the coil will cut each of the magnetic lines once, and the work done will therefore be

$$W = 4\pi CS/10,$$

where W is the work, C the current, and S the number of turns. This being expressed in amperes, division by 10 is necessary to reduce it to absolute or C.G.S. units.

Since $4\pi = 12{\cdot}257$, and this and the divisor 10 are constants, the expression may be further simplified by stating it

Magneto-motive force (M.M.F.) $= 1{\cdot}257 \times$ ampere-turns.

We are thus provided with a means for producing a field of any requisite strength, since the lines produced per unit area only depend upon the ampere-turns. When a wire carrying a current is coiled in the shape of a long thin hollow tube it is called a solenoid, and the above formula gives the strength of the magnetic field at its centre. The magnetometer may be used to obtain the strength of its field, as it is to obtain the strength of the field round a magnet, as explained under the heading Magnetometer.

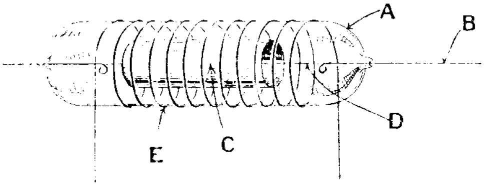
The strength of the magnetic field is greatly increased by the introduction of an iron core in the solenoid, increasing the flux many hundreds of times, depending upon the quality of the iron core and the degree of magnetization to which it has been pushed. The reader should consult such articles as Flux and Permeability in the Encyclopedia for further information on the subject. *See also* B. H. Curve.

MAGNETRON. The magnetron is either a two-electrode or a three-electrode valve in which a magnetic field is employed to give the valve action.

The field may be produced by placing a winding round the bulb of the valve and passing a current through it, or in some cases the field produced from the current flowing in the actual valve filament is sufficient to produce this action, but this is not the case with valves having ordinary filaments, as the current passing through the filament of an ordinary valve is not sufficient to produce a powerful enough field.

An excellent paper on the magnetron was read by A. W. Hall before the American Institute of Electrical Engineers, and was reported in the Journal of that society in September, 1921. Much of the following is extracted from this paper.

The magnetron depends to a very great extent on the exactitude of its symmetry,

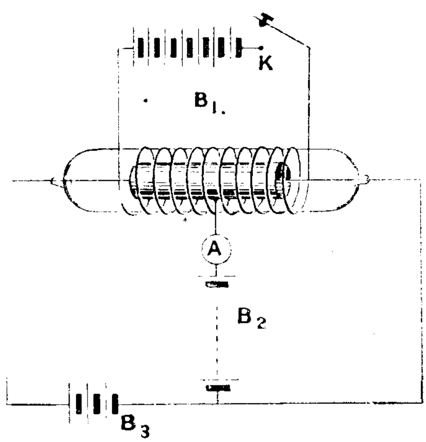


CONSTRUCTION OF THE MAGNETRON

Fig. 1. A is a glass tube in which a filament lead, B, is inserted. C is the anode, D the filament, and E the field winding

in fact, unless its construction is exact, so that the filament, anode, and field winding are concentric and symmetrical, it will not have the correct characteristic of the magnetron. It must be so constructed that the magnetic field is parallel to the axis of the valve.

The field, as already explained, may be produced by an external winding (*see* Fig. 1). The evacuated glass bulb, A, is similar to that used in other types of valves. Mounted within it is a slotted cylindrical anode, C, great care being taken that this is truly central within the glass tube. Passing down the centre of the anode C is the filament or cathode, D.



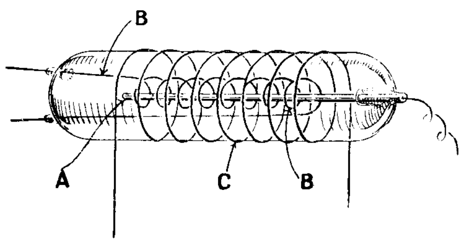
MAGNETRON CIRCUIT

Fig. 2. B_1 is a field battery and B_2 the anode battery. B_3 is the battery which supplies the filament

There may also be a grid, but, as the action of the magnetic field replaces the grid in the ordinary valve, a two-electrode magnetron may be used to replace a three-electrode ordinary valve.

The action of the magnetron is easier to follow by considering it connected in the simple circuit, Fig. 2. Here B_3 is a battery supplying current and lighting the filament and B_2 is a high-tension battery with its positive pole connected to the anode of the valve through an ammeter, A. So far the valve is a simple rectifier, and a current will flow through the circuit A, B_2, B_3, as soon as the filament is alight. Now the magnitude of the current which can flow through the valve is limited by either the temperature of the filament or the voltage of the anode, but the addition of the solenoid winding, together with the battery B_1 and key K, produces a third limitation.

If the field is weaker than a certain critical value the full current will flow



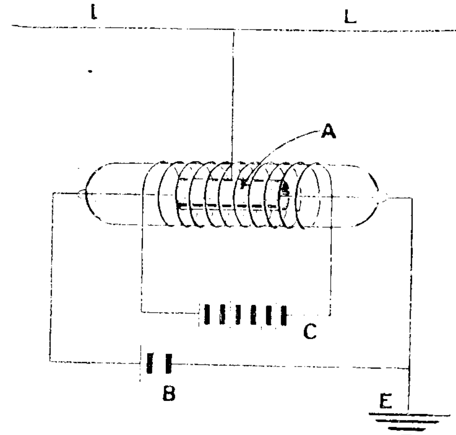
SENSITIVE TYPE OF MAGNETRON

Fig. 3. In this more sensitive type of magnetron A is a rod anode, B a spiral filament, and C the outside field winding

from the battery B_2 with K either open or closed, but if the field strength is raised beyond this critical value, by increasing the battery B_1, then when K is closed no current will flow from B_2, whilst with K open the full current will flow. The magnetic field thus controls the valve action. The value of the field necessary to produce this cutting off action will depend on the diameter of the anode and on the potential between the anode and the filament. It will be inversely proportional to the anode diameter and directly proportional to the square root of the voltage between the anode and the cathode.

From this example it will be seen that this type of valve may be used in place of an ordinary three-electrode valve, in almost any circuit, by making suitable modifications.

A more sensitive type of magnetron is obtained when the anode is placed inside



MAGNETRON AS LIGHTNING ARRESTER

Fig. 4. Used as a lightning arrester, L is the overhead line in danger because of high potential due to lightning

the cathode, instead of in the more general way with the anode outside.

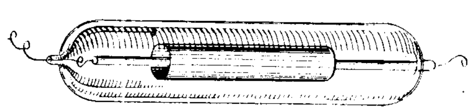
This type of valve is illustrated in Fig. 3, where A is the anode, which may be a wire, a rod, or a slotted tube, whilst the filament is shown as B, in the form of a spiral surrounding the anode, whilst the field winding is, as before, wound on the outside of the glass tube.

Again, in this case, a grid may be added, which will make a three-electrode valve with the addition of the magnetic control. The valve may therefore be used for the same purposes as the ordinary four-electrode valve.

In all cases it should be noticed that the anode should be slotted, or, otherwise, harmful eddy currents will be set up in it due to the action of the powerful field from the external winding.

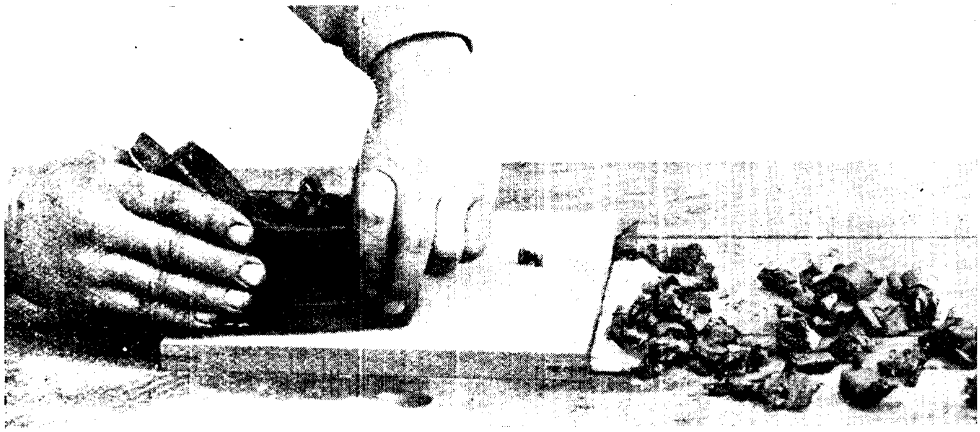
A practical use which has been suggested for this type of valve is that of a lightning arrester.

If it is connected, as Fig. 4, with the anode A to any overhead line, L, which is in danger of high potential due to lightning, if the filament is then lighted from the battery B, and the field excited from the battery C, the field may be adjusted so that at normal high potentials no current will flow through the valve, but should



MAGNETRON WITH VERY LARGE FILAMENT

Fig. 5. This magnetron depends on a field from the filament current



SMOOTH PLANING A MAHOGANY PANEL

Fig. 1. Mahogany, being a hardwood, is particularly suitable for many purposes associated with wireless, and has the additional advantage of good appearance when properly treated. Here a panel is being planed to give it a smooth surface before polishing

the line become charged the valve will open, the current will flow from the line to earth, and once the line potential is normal the valve will close again.

In October, 1923, a second paper was read before the American Institute of Electrical Engineers, showing how the magnetron might be worked without the addition of any external field winding, and depending for its action solely on the field produced by the current in the filament.

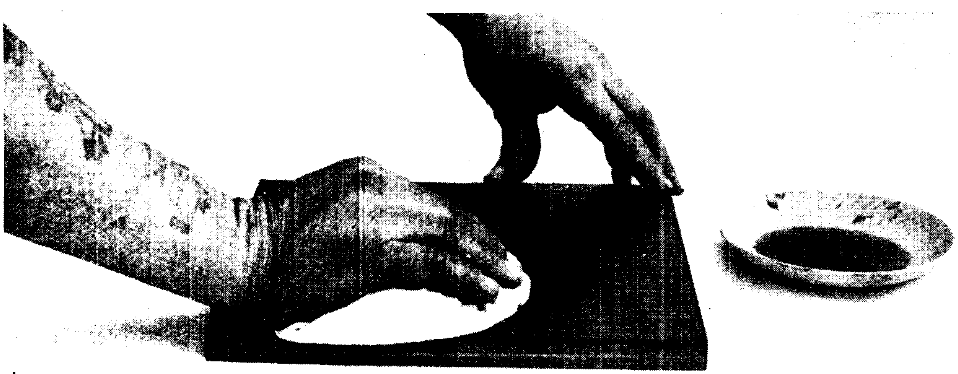
The valve in this case becomes similar to a simple symmetrically-arranged rectifier valve having a very large filament (Fig. 5).

A case is mentioned of a valve having a filament 2 cm. in diameter and 1 metre in length. The anode was 8 cm. in diameter. A current of 4,400 amperes was passed through the filament.

The normal electron emission of this size of filament with that current would be 170 amperes. This current produced a sufficiently strong field to make the magnetron a non-conductor from anode to filament when 200,000 volts were applied between these two points.

MAGNIFIER. This term is sometimes used for amplifier, and appears in such expressions as note magnifier, etc. *See* Amplifier.

MAHOGANY. The hard, evenly-grained reddish-brown-coloured wood of *Swietenia mahogani*, extensively employed in cabinet-making. There are a variety of other woods similar in appearance, colour, and structure which are loosely termed mahogany, and for the purposes of wireless are quite satisfactory in everyday use.



IMPROVING THE COLOUR OF MAHOGANY

Fig. 2. Finished wireless cabinets of mahogany may be given a handsome appearance by staining and polishing, or oiling. The operator is here shown applying stain

Mahogany is utilized considerably in wireless work for cabinets and cases, and for the baseboards of all manner of wireless apparatus. It can be obtained in boards from the timber merchants, and these usually measure about 10 to 12 in. in width and 1 in. or $1\frac{1}{4}$ in. in thickness. It is most economically purchased in board, and is sawn up into various scantlings, or sizes, that are likely to be serviceable. For example, the board, which may measure some 15 ft. in length, may be sawn across about 6 ft. from one end, and this cut into squares and rectangular sections from 2 in. to 3 in. in width and 1 in. in thickness.

The remainder of the board may be sawn into three or four pieces varying in width and finished from $\frac{1}{4}$ to $\frac{1}{2}$ in. or thereabouts. If these are machine planed, the material will be in a good state for the amateur to work upon.

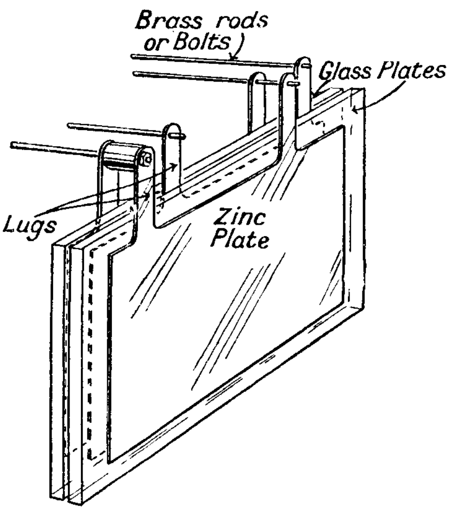
Thinner mahoganies are obtainable in the form of fretwood of about $\frac{3}{16}$ or $\frac{1}{8}$ in. in thickness, and may be used for panels, sides for some light cases, and other similar work. The operative processes connected with mahogany are similar to those for other woods. When planing to obtain a final finish it is necessary to use a very keenly sharpened smoothing plane, as shown in Fig. 1, using the plane with care and watching the grain of the wood so as not to tear or roughen the surface.

After the mahogany has been prepared it is frequently polished. The timber is prepared for this process by sandpapering and filling, and the polish applied with a rubber in the manner illustrated in Fig. 2. Some workers prefer to improve the colour of mahogany by darkening it with a suitable water stain. This is entirely an optional matter, but by many it is considered that a dark-coloured mahogany gives a better appearance to small apparatus. *See* Cabinet.

MAIN BATTERY. Name given to the battery which operates the main circuit of a receiving or transmitting set. *See* Local Battery.

MAIN CONDENSER. Name given to the condenser used on ship transmitting sets. This condenser has to stand up to high voltages, and it has a dielectric of the best flint glass. The diagram shows the arrangement of the glass plates and zinc plates which are used. For the $1\frac{1}{2}$ kilowatt set there are 72 glass sheets and 70 zinc sheets, while in the $\frac{1}{2}$ kilowatt set two sheets of glass are placed between each pair of zinc plates. In this latter set the plates are smaller and fewer. In the $1\frac{1}{2}$ kilowatt set the condenser consists of two equal banks of plates in a lead-lined teak container. Each bank is placed in a zinc cradle so that it can be removed for inspection and repair. In the $\frac{1}{2}$ kilowatt set there is only one bank.

The zinc plates are connected through their lugs by brass bolts, and as each set of plates is fixed in this way by two lugs a rigid connexion is made. In the larger set the container lid has four terminals. Two are marked 17 and one 36, while the fourth is a false terminal, having no internal connexion. The 17 terminals are joined to the centre of one of the brass bolts which connects to each set of 17 zinc plates. The 36 terminal is connected to



ARRANGEMENT OF A MAIN CONDENSER
Suspended from brass rods and bolts are zinc and glass plates arranged alternately

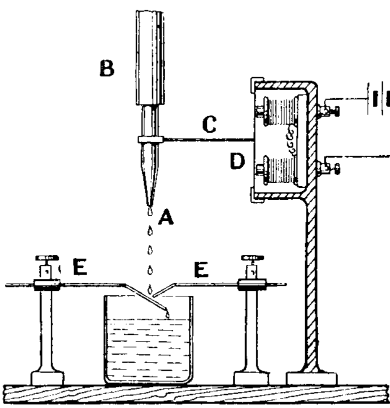
the middle of one of the brass bolts joining a set of 18 zinc plates. By a suitable switch the two banks of condensers may be placed either in series or parallel, so lessening the total capacity of the banks or increasing it as required. In series the total capacity is ·0162 mfd., and in parallel ·065 mfd.

The plates of glass used in these types of condensers are tested up to about 30,000 volts.

The main condenser for the 5 kilowatt sets is considerably bigger than either of those described. There are four banks of plates, and each plate is double the size of the $1\frac{1}{2}$ kilowatt set. By means of a controlling device known as a Swiss commutator (*q.v.*) the four banks may be connected up in a number of different ways, so varying the capacity of the condenser as a whole. *See* Condenser, page 482.

MAJORANA'S MICROPHONE. Form of liquid microphone due to Majorana, who made use of the well-known effect of sound waves on a jet of liquid issuing from a small hole. Bell, in 1886, found that if a liquid issues from a small opening a disturbance near that opening causes the liquid stream to break it up into isolated beads.

The way Majorana made use of this property of a jet of liquid is shown in the diagram. A is the jet of liquid, which is



MAJORANA'S LIQUID MICROPHONE

In this diagram may be seen the working principle of the liquid microphone due to Majorana

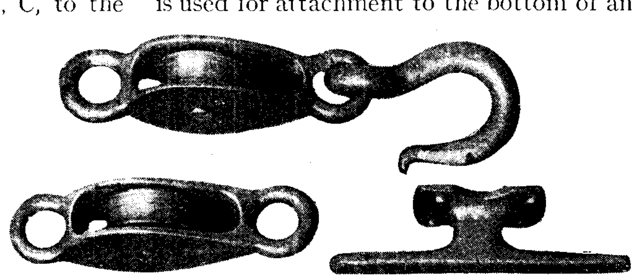
allowed to fall on two electrodes, E, E, in such a way that the drops of liquid bridge the gap between the electrodes. The electrodes are connected as shown to two terminals, and thence to the transmitting circuit.

The liquid drops from a container, B, which is connected by an arm, C, to the diaphragm, D. The latter is vibrated through electro-magnets controlled through a local microphone, M, and a battery. As the diaphragm vibrates, due to speech or other sound, so the jet of liquid is broken up and varied, and this in turn modifies the flow of liquid across the two electrodes and the resistance in the circuit between the two terminals. This, of course, modifies the radiated wave, and so enables speech or music to be transmitted. *See* Jervis Smith Microphone; Liquid Microphone; Sykes's Microphone; Transmission; Vanni Microphone.

MAKOWER, W. British wireless expert. Born December 6th, 1879, he was educated at University College School, University College, London, and Trinity College, Cambridge. Here he entered the Cavendish Laboratory and made a study of radioactive materials, afterwards becoming a Research Fellow at Manchester University. Makower has made a study of thermionic valves, and since the end of the Great War he has been engaged in research at the Air Ministry Laboratory in the Imperial College of Science and Technology. Makower has written a considerable amount on radioactivity, and in 1909, in collaboration with Dr. S. Russ, he discovered the radioactive recoil, for a thesis on which he received his doctor's degree at London University. He is a Fellow of University College, London, and recorder of section A of the British Association.

MALLEABLE IRON. Term applied to iron which is capable of being wrought or hammered without excessive liability to fracture. More particularly the term is associated with cast iron, which is normally too brittle to be hammered successfully, but after a suitable heat treatment the crystalline structure of the metal is changed, and it becomes practicable to hammer the casting, and, if necessary, to bend it a small amount without the risk of fracture. When possessing this property cast iron is generally known as malleable cast iron, or simply as malleable.

Three typical examples of malleable iron fittings for wireless purposes are shown in the figure. On the right is a cleat, which is used for attachment to the bottom of an



MALLEABLE IRON FITTINGS FOR MASTS

Three examples of malleable iron fittings for wireless purposes are shown: a cleat, and two different types of halyard pulley

HOW TO USE THE CARPENTER'S MALLET

Fig. 1. Mortise work is carried out, as in this photograph by the aid of a carpenter's mallet,

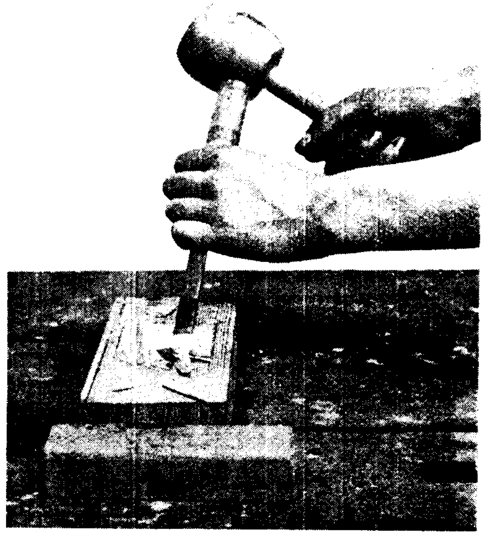
aerial mast, and upon which the halyard rope should be wound. The cleat should be fixed by four screws, passed through the holes shown. The height at which it is fixed should be determined by the owner to suit his convenience.

Two different types of halyard pulley are also illustrated, one being fitted with a hook, thus rendering it suitable for direct attachment to any projecting loop from a mast band.

All malleable iron fittings such as these should be galvanized in order to render them immune from rust due to exposure to the weather.

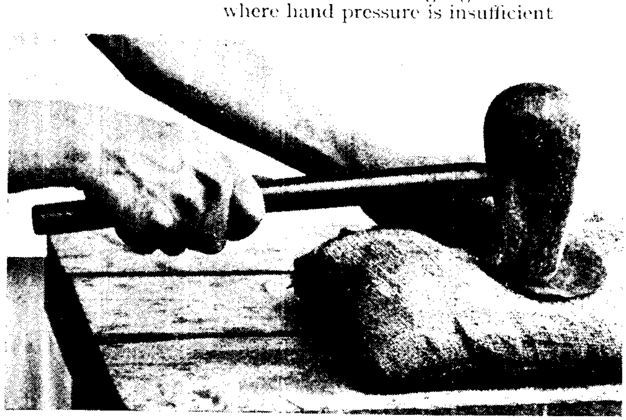
MALLET. A hammer-like implement used by wood and metal workers. A most useful form of the implement for amateur use is that known as the joiner's or carpenter's mallet, which comprises a rectangular block of hardwood, known as the head, through the centre of which is fitted a hardwood handle. This handle is tapered and inserted until the end is through the head of the mallet, so that when the implement is in use the action tends to tighten it.

The tool is used by grasping the handle in the right hand and striking a blow fair on the centre of either of the end faces of the head. These faces are cut to a slight angle, so that when correctly manipulated the face is parallel to the object struck at the moment of impact. The method of use is shown in Fig. 1, which shows a carpenter's mallet used in an early stage of cutting out a mortise. Such a mallet should always be used when driving a chisel, and not a hammer, which only



RECESS CUTTING WITH CARVER'S MALLET

Fig. 2. Carvers' mallets are largely used to cut recesses in wood, and with gouges for hardwood where hand pressure is insufficient



USING A TINMAN'S MALLET

Fig. 3. Sheet metal is here shown being shaped by using a tinman's mallet. The metal is held on a cushioned surface for this purpose

results in the handle of the chisel spreading and splitting. This is one of the commonest mistakes made by the amateur woodworker.

Another type of mallet is known as the carver's mallet, and has a circular-sectioned head with a central handle. It is used principally for driving wood-carver's tools, and is illustrated in Fig. 2. It is very useful for driving gouges or other tools in the depth of recesses, especially in hardwoods, where pressure of the hands alone is insufficient to make the tool cut properly.

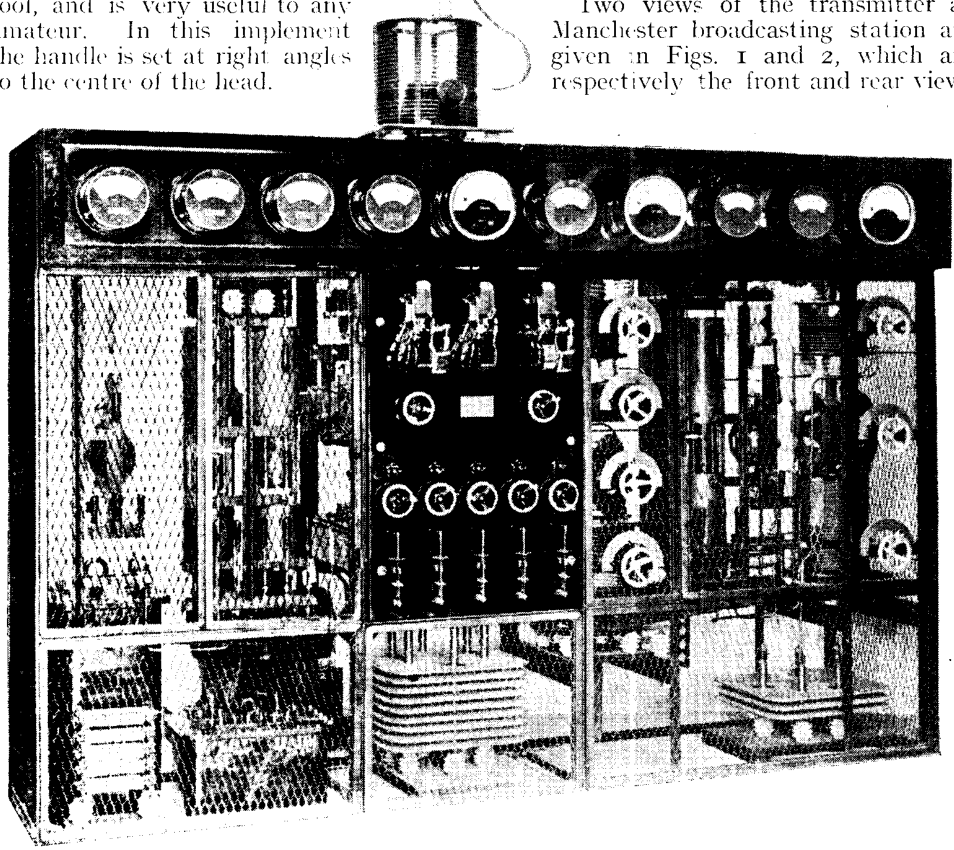
For sheet-metal working and plumber's use another type of mallet has some advantages. This is known as a tinman's mallet, and is illustrated in Fig. 3. It has many applications for the shaping of sheet metal, beating out shallow troughs and bowls, and in the working of sheet lead and other plumber's work. It is an inexpensive tool, and is very useful to any amateur. In this implement the handle is set at right angles to the centre of the head.

Other varieties of mallet include those with a raw-hide head having a central handle at right angles to it, and used by metal workers, the value of the raw hide being that it does not bruise or indent the metal.

Another variety of mallet has a very large hardwood head, bound with metal straps to prevent it splitting, and a long handle, some three or four feet in length, and is used for driving in stakes for the support of aerial guy-ropes and similar work. The tool is variously known as a tenter's mallet or beetle. *See* Hammer.

MANCHESTER BROADCASTING STATION. Call sign, 2 ZY; broadcasting wave-length, 375 metres. This station was opened on November 15th, 1922, in the research department of the works of the Metropolitan - Vickers Co., Ltd., Trafford Park, Manchester.

Two views of the transmitter at Manchester broadcasting station are given in Figs. 1 and 2, which are respectively the front and rear views



FRONT VIEW OF MANCHESTER B.B.C. STATION TRANSMITTING GEAR

Fig. 1. From left to right the three divisions show, first, the modulating valves and circuits, second, controlling switch panel and third, the oscillating valves and their circuits

Courtesy Radio Communication Co., Ltd.

of the installation. It will be seen that the whole apparatus is mounted upon a metal framework which is 9 ft. long by 6 ft. high. The apparatus as a whole employs a main oscillating system. This is served by one OC/2·5 silica valve. B.B.C. specifications demand a "drive" circuit which excites the grid circuit of the main oscillating system. A valve of the O/500 watt type is used for this purpose. Modulation is effected by the choke-control method, and this circuit is also served by one O/500 glass valve and two special O/2·5 silica valves.

A 5,000 volt D.C. generator is used to supply the H.T. current. Wave-length control over maximum and minimum wave-lengths of from 300 to 500 metres is provided.

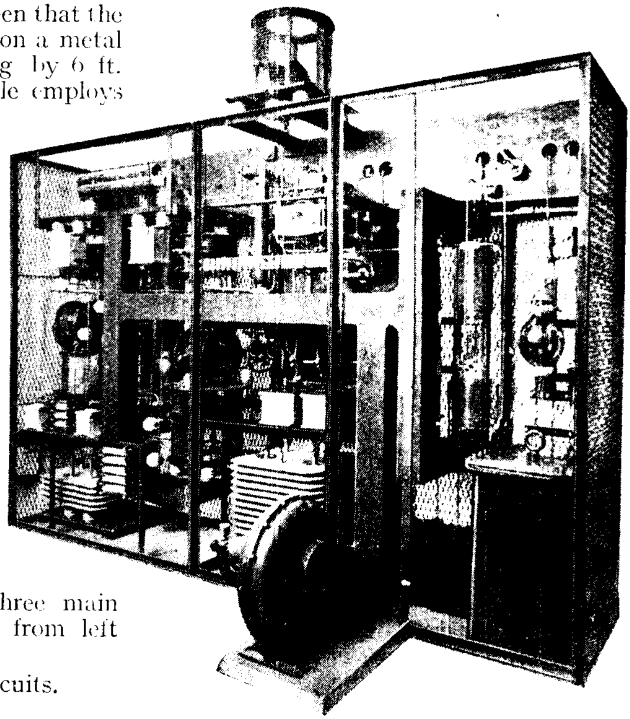
The set is divided into three main divisions, which are, in Fig. 1, from left to right, as follows:

(*a*) Modulating valves and circuits.
(*b*) Controlling switch panel.
(c) Oscillating valves and circuits.

Taking the first division, which is the control or modulating circuit. on the left will be seen the 500 watt glass valve, which stands well away from other apparatus, and underneath which is placed the intervalve transformer. From this the circuit is extended to the two special silica valves, which may be seen behind the expanded metal cage. This compartment contains also the control choke and grid-biasing battery.

The centre division is known as the controlling switch panel. Polished and enamelled slate is used as a base. The controlling handles and switches are for H.T. and L.T. supply. Besides these there are push-button switches for the voltmeters. Circuit breakers are applied to the H.T. circuits, and there is a starter for the air-blast motor, which drives the centrifugal blower seen in Fig. 2. The air blast is for cooling the silica valves, which would otherwise get seriously overheated and burn themselves out.

The back of this panel may also be seen in Fig. 2. Here are smoothing chokes and condensers for the H.T., filament rheostats for the L.T., and the main terminal board. Immediately behind the blower is the closed circuit air condenser, while above,



BACK VIEW OF MANCHESTER GEAR

Fig. 2. Behind the panel in Fig. 1 is seen the centrifugal blower, here shown in the foreground. An air blast is used for cooling the silica valves

Courtesy Radio Communication Co., Ltd.

on top of the framework, the aerial tuning inductance is situated.

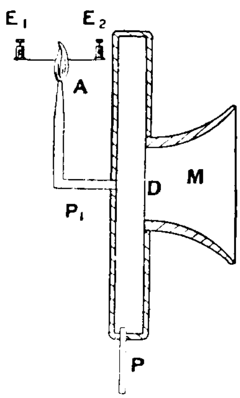
The right-hand division is the drive circuit and main oscillating system. Both photographs should be studied in conjunction with one another, in order to follow the lay-out of the components which form these circuits. The subsection devoted to the drive circuit comprises a 500 watt valve, together with its switches. A tuning inductance and variometer are fitted, as well as a grid condenser and leak. The main valve of the oscillating circuit is of the 2·5 silica type, and this also is connected to a grid condenser and leak. Close inspection of Fig. 1 will reveal the tuning inductance and variometer, and the aerial coupling can be seen.

The instrument board extends right across the top of the transmitter. The first two instruments from the left are the sub-control and control ammeters. These are followed by the control indicator and filament voltmeter. The next instrument is the aerial ammeter, which is a H.F. instrument, and the H.T. voltmeter is situated on the right of this. Two ammeters follow this, these being for the oscillator and closed circuit. The two last instruments are for the drive section, and are the drive anode ammeter and oscillating circuit ammeter respectively. All the H.T. ammeters are of the hot-wire type, while the others are moving coil instruments.

MANGANESE. One of the metallic chemical elements. Its atomic weight is 54·93, taking oxygen as 16, and its chemical symbol Mn. It is widely distributed, and forms many valuable compounds and alloys. The permanganates, for example, are widely used in the preparation of many disinfectants. As an alloy with copper and nickel it forms the well-known resistance alloy manganin, extensively used in electrical work. *See* Manganin.

MANGANIN. An alloy from which standard resistances are made. It consists roughly of 84 per cent of copper, 12 per cent of manganese, and 4 per cent of nickel, though there are considerable variations in its composition. It is valuable in the manufacture of wire for rheostats, since it has a very low temperature coefficient of resistance. It is difficult to work, however, and suffers in annealing. It must be soldered with silver solder, and not soft-soldered. The fact that it hardly changes its resistance with temperature makes it valuable in the manufacture of resistance boxes for careful measurements of resistances.

MANOMETRIC FLAME MICROPHONE. Early form of microphone which depends for its action upon the effect of sound waves upon a flame. The diagram gives a simple representation of the action of the manometric flame microphone. M is a microphone and D its diaphragm. An inflammable gas fed through a pipe P to a pipe P_1 is lighted at A so that it passes between two electrodes, E_1, E_2 to form a variable resistance. The resistance to the passage of a current between the electrodes varies with the size of the flame, and this depends upon the vibrations of the diaphragm, D, causing pulsations of gas to the mouth of the pipe, P_1. This form of microphone has been extensively experimented with to obtain speech reproduction at a distance, but it is not reliable, and has been superseded by other forms of microphone. In another form a flame is made to rise and fall by means of sound waves. The light of the flame is concentrated on a selenium cell, and the variations of resistance of the cell enable sound to be transmitted electrically. *See* Microphone.



Action of the flame microphone

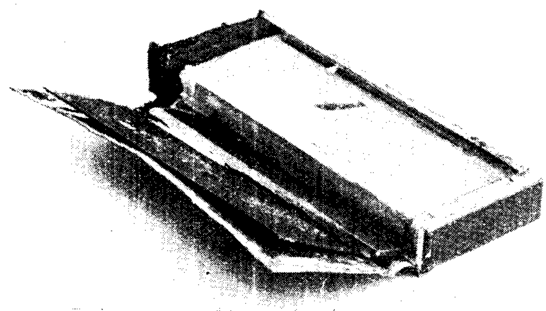
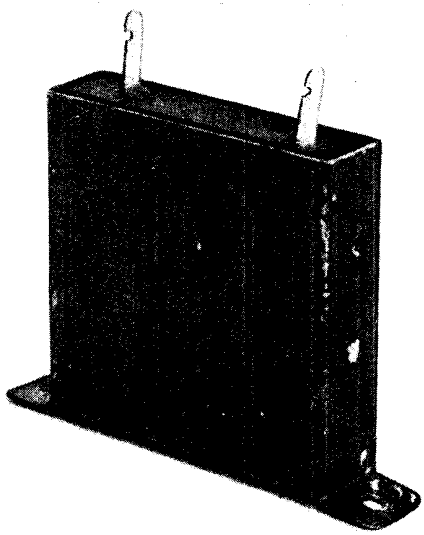

CONSTRUCTION OF MANSBRIDGE CONDENSER

Fig. 1. Opened out, the solid block of waxed-up plates is seen separated from the tinned iron case by waxed cardboard slips. The lugs connecting the opposing plates are set in a top of solid insulating compound

MANSBRIDGE CONDENSER. A type of fixed condenser differing from the multi-plate condenser in that the required capacity is obtained with only two plates. These plates are made of thin sheet tinfoil, and are separated from each other by specially prepared and waxed paper. In construction a long strip of tinfoil is overlapped with a similar strip of paper having a rather greater width.

On top of these another strip of foil is laid so that it rests exactly over the previous strip. This is followed by another strip of insulating paper laid over the first sheet. Keeping the four strips in position, they are folded round each other, the insulating strips always keeping the opposing plates from touching. The strips are pressed well together in order to secure maximum capacity, and freedom from shortage or leakage by the entrance of dirt or damp. The capacity of the resulting condenser is dependent upon the width



MANSBRIDGE CONDENSER WITH LUGS

Fig. 2. Mansbridge condensers are often fitted with lugs as shown, rendering them suitable for panel mounting or attachment to a wooden base. This is a convenient size for bridging H.T. batteries

and length of the plates, provided the insulating paper is of fixed dielectric value.

When all the foil has been wound on, a few extra turns of the insulation are wrapped round, after which the condenser is immersed in a bath of paraffin wax. A well-waxed sheet of cardboard is wrapped round the condenser when it is placed inside a tin case. Connexion to the opposing plates is made by thin wire, which is brought out to lugs. These are secured in a block of insulating compound, which effectually seals the condenser in its tin case.

Fig. 1 shows a typical Mansbridge condenser with case open, showing the condenser block and cardboard sheet insulating it from the case.

Fig. 2 shows another condenser of this type largely used in wireless work. This illustration shows the clean appearance and compactness of these condensers.

The condenser shown is suitable for panel mounting. It is fitted with lugs at either end of the bottom sides by which it may be bolted or screwed in any desired position.

Care should be taken in soldering that the lugs are not made too hot, as there is a possibility of unsoldering the connexions on the inside of the lugs.

MANTISSA. The name given to the figures to the right of the decimal point of a logarithm. In the logarithm tables these decimal parts of the logarithms only are given. *See* Logarithm.

MARCHANT, EDGAR WALFORD, British wireless expert. Born in 1876, he was educated at University School, Hastings, and Central Technical College and London University. In 1897 he was appointed superintendent of the laboratory and workshops of Lord Blythswood at Renfrew, where he carried out many experiments in wireless telegraphy. He became chief assistant at Finsbury Technical College, 1900, under Professor Silvanus P. Thompson, and the following year was appointed lecturer in electro-technics at University College, Liverpool. In 1903 he was appointed the first professor of electrical engineering at the university.

Marchant was for some time closely associated with W. Duddell in developing the oscillograph, and the two read a joint paper on the study of the electric arc by the aid of oscillographs to the Institution of Electrical Engineers, of which institution Marchant became vice-president. He is also a vice-president of the Radio Society of Great Britain. He has written many papers on wireless subjects, and contributed an article to the proceedings of the Royal Society on the magnetic behaviour of iron under oscillatory discharge of a condenser.

MARCONI, GUGLIELMO. Irish-Italian wireless pioneer. Guglielmo Marconi was born at Bologna, April 25th, 1874, and was educated at the Leghorn Technical School, under Professor Rosa. From his earliest years he was keenly interested in communication by means of Hertzian waves, and began his brilliantly successful series of experiments in June, 1895. These first experiments were carried out on his father's estate near Bologna.

Marconi soon found that the Hertzian form of resonator gave only feeble signals at a distance, and he substituted a vertical wire, with the result that in 1895 he was able to transmit signals to a distance of one and a half miles. About the same time he improved the Branly coherer, which he was using as a detector, and invented an electric tapping device to decohere the filings.

This early apparatus of Marconi, from which has sprung the far-flung wireless chain of to-day, consisted of a coherer, a

SENATORE GUGLIELMO MARCONI

In 1896 Marconi took out the first patent in this country for a practical system of wireless telegraphy. He was the first to establish wireless communication across the Atlantic, and his name is associated with the well-known companies making wireless apparatus and conducting wireless communication services

relay, a decoherer, and a Morse printing instrument, all working from accumulators. Between the coherer and the relay Marconi interposed choke coils, and this had a very marked effect on the receptivity of his set. By close attention to the details of his system he was able to carry on his signals at greater ranges than had up to that time been accomplished by other experimenters.

The transmitting apparatus used by Marconi in these early efforts consisted of a large spark gap to which the aerial and earth wires were connected. The high-tension current for the spark was provided through an induction coil from batteries. The spark gap consisted of a ball discharger comprising four brass balls. The two middle balls were separated by a small space filled with vaseline oil, the actual spark jumping from the two end balls to the middle ones and through the vaseline, producing a high-frequency spark.

Marconi came to England in 1896, where he took out the first patent ever granted for a practical system of wireless telegraphy. He made a number of experiments at Westbourne Park, and demonstrated his system before Sir William Preece and other high officials at the Post Office. In the following year he increased the range of his set to nine miles, using a 20 in. spark coil and kites to raise the vertical aerials. In July, 1897, in demonstrating before the Italian government, he covered 12 miles between warships, and he began to instal a number of his sets for lighthouses, and the success of his experiments led to stations being erected for the corporation of Trinity House.

In 1899 the first proof of the advantages of wireless over other forms of communication came with the saving of the lives on board the ship R. F. Matthews, which ran into the East Goodwin lightship. The latter was equipped with one of Marconi's transmitting sets, and was able to communicate with the South Foreland lighthouse and summon assistance.

From that time onwards Marconi was continually increasing the distance at which he could communicate, and also the speed of telegraphing. Until 1901 he had only used half a kilowatt of power, but in 1901 he erected his famous wireless station at Poldhu, and increased the power he was using to 12 kilowatts. On December 12th, 1901, he received signals in Newfoundland from the Cornwall station, and for the first time the Atlantic was bridged by wireless, over a distance of some 2,200 miles. From that time Marconi rapidly extended his stations and employed the best scientific brains of the day to suggest improvements, so that, step by step, he has reached the stage where not only wireless telegraphy, but wireless telephony has become possible.

The genius of Marconi lies not so much in his inventions, as in his far-sightedness in being the first man to realize the immense commercial possibilities of wireless, and to make the best use of all the scientific effort of his time to further the object he had in view. Undoubtedly to him is due the great advance that has been made, and to his unceasing efforts in the face of ridicule and criticism in his early experiments.

Marconi has received innumerable honours from all countries. He holds the honorary degrees of universities all over the world, and the freedom of a large number of cities. In 1909, with Professor Braun, he was awarded the Nobel Prize for Physics, and in 1914 he was given the Honorary Knighthood of the Grand Cross of the Victorian Order. He has been awarded the Albert Medal of the Royal Society of Arts, the Gold Medal of the Institute of Radio Engineers of New York, the John Fritz Gold Medal for the invention of wireless telegraphy, and the Franklin Gold Medal of the Franklin Institute. He was the Italian delegate to the Peace Conference, and signed on behalf of Italy. He is chairman of the board of directors of the Marconi Company.

MARCONI BEAM. This is a popular name for a system of directional wireless along a beam of light due to Marconi. The system is really a short-wave transmitting system, and is described under Short Wave.

MARCONI COHERER. The Marconi coherer (Fig. 1) consists of a glass tube, B, bound on to a bone support, A.

Within the tube B are two cylindrical-shaped plugs, C, C, each of which has one end turned down so that it becomes a smaller cylinder, whilst the surface of the other end of the big cylinder is cut at a slight angle, as shown, so that when the two plugs are mounted in the glass tube there is a wedge-shaped space left between their adjacent faces.

The filings mixture is introduced into the space between these two silver plugs before the tube is sealed off. A mixture which Marconi found both sensitive and reliable was made from fine filings of hard nickel, with the addition of 4 per cent of silver filings. He found that if the percentage of silver is increased the coherer may be made more sensitive, but that it becomes less reliable in its action. He also found that these coherers worked best when the surface of the silver plugs was slightly amalgamated with mercury.

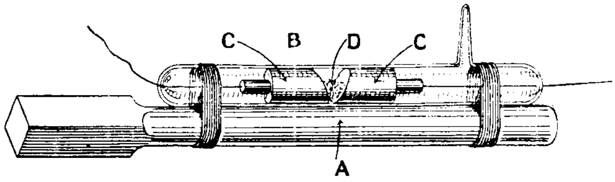
When all the component parts have been assembled in the tube, the air is removed till a pressure of $\frac{1}{1000}$ of an atmosphere is left in the tube, and at this pressure the tube is sealed off. Rough adjustment of the coherer is first made by turning the whole tube on its bone support A. Finer adjustment is then made by means of a hand-screw which turns the bone support A, and carries with it the glass tube.

Both adjustments act in the same way, on the one hand by causing the filings to fall into the more open part of the wedge-shaped space between the two plugs, or on the other by causing them to come in close contact as they are shaken to the bottom of the V groove and wedged between the silver plugs.

Under normal conditions the coherer offers a certain resistance to the passage of an electric current, but when a high-frequency current (a wireless signal) passes through it the filings cohere or stick together, the electrical resistance is reduced, and the current from a local dry-cell battery flows through it. This current passes through a sensitive relay, which closes another battery circuit through a Morse printing telegraph, which records the signal.

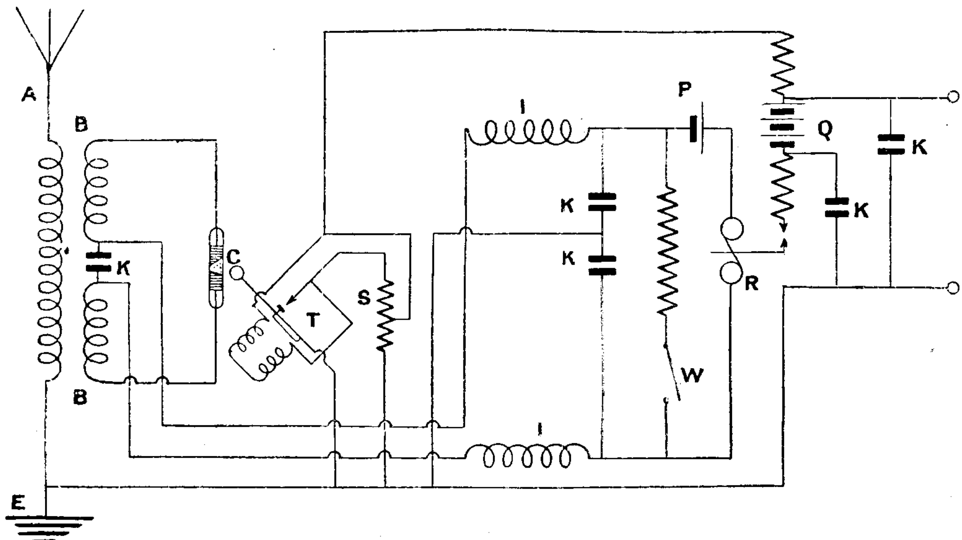
A special form of electric vibrator, somewhat similar to an electric bell, is used to vibrate the tube, thus causing the filings to shake apart after the signal has passed, so that it is once more in a sensitive condition and ready to receive the next signal. Provided that heavy currents are prevented from passing through the filings, the coherers remain sensitive and work with reliability over long periods.

The coherer has its uses even to-day, when valves are so generally used. When working with moderate signals, it is reliable



HOW THE MARCONI COHERER IS CONSTRUCTED

Fig. 1. Supported on a bone rod, A, is a glass tube, B. Silver plugs are at C, C, and at D are nickel and silver filings



HOW THE MARCONI COHERER MAY BE USED FOR SHORT-DISTANCE SIGNALS

Fig. 2. Given above is a theoretical circuit diagram in which is included a Marconi coherer at C. The bell tapper which decoheres it is at T, a non-inductive shunt being connected across its coils to prevent it acting on the coherer

as well as simple. Its primary advantage is, however, that when standing ready for reception it does not take an appreciable amount of current.

The coherer has been employed in conjunction with its relay for operating a calling-up bell, and over short distances it may be employed for this purpose, as well as for operating fog signals, and other audible or visible signals, placed on rocks at sea which are difficult of access for replacement of batteries.

The current for the coherer itself is supplied from a single dry cell, whilst another dry cell battery is employed to ring the bell or work the Morse printer.

Fig. 2 illustrates a coherer circuit, where A is the aerial and the aerial coil of the "jigger," B, B, the secondary coils of the "jigger," K a small fixed condenser, C the coherer tube, T the bell type of tapper, and E the earth connexion. S is a non-inductive shunt, part connected across the tapper coils and all connected across the contacts of the tapper. This shunt prevents the tapper from causing the coherer to recohere. I, I, are high-resistance choke coils. P is the single cell battery for working the relay through the coherer. W is a small key in series with a high resistance, which may be employed for testing the relay. Q is the battery for working the bell, Morse printer, fog signal, or other apparatus. K, K, are fixed condensers.—*R. H. White.*

MARCONI DOUBLE CONDENSER. A type of double condenser in which two sets of electrically connected moving plates revolve between two corresponding sets of fixed plates which are insulated from each other.

The illustration shows a typical double condenser complete with calibrated dial and knob. The two sets of fixed plates are held in position between three ebonite pillars attached to stout brass top and bottom plates by countersunk screws.

Both sets of moving plates are set in a common spindle consisting of a thick brass tube. Ebonite bushing at top and bottom of the spindle insulates it from the main body of the condenser.

This condenser is made in different capacities, two common sizes being those of ·00025 and ·0005 mfd. The advantage of this type of double condenser is found in circuits requiring simultaneous tuning, such as are found in two stages of tuned anode coupling.

It is also suitable in two-stage high-frequency transformer coupling, where its application is in tuning the primary windings of the transformer.

In order to secure exact wave-length in both circuits, both sets of plates are carefully balanced in capacity.

MARCONI FILAMENT RESISTANCE. A novel type of variable resistance suitable for valve filament regulation. The frame of the instrument shown in the figure consists of a stamping of sheet brass having two vertical pieces at front and rear which support an insulated former and the controlling spindle. Four projecting lugs are arranged at each corner of the base by which the resistance may be secured in position to a baseboard.

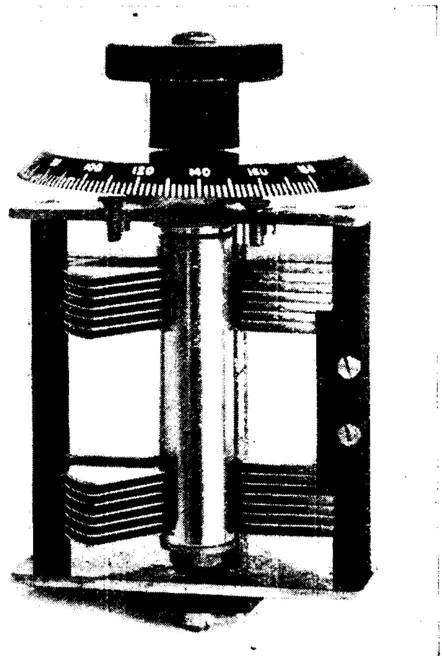
An alternative method of mounting is provided in the vertical piece forming the front. This is suitably drilled and tapped to permit the insertion of three countersunk fixing screws. This method of mounting is suitable where attachment to a vertical panel is required.

The regulating or controlling spindle rotates in bearings at either end in the vertical sides of the instrument. To this spindle is wound and soldered a thick copper wire, so that in the length of the spindle it makes one complete turn. A stop peg is provided at the back end to prevent overturning. The spindle is rotated by means of an ebonite knob fitting the spindle, which is made square-ended at this part.

A small screw fitting over the face of the knob and screwing into the spindle prevents the knob from being pulled off. At the end of the knob a pointer is provided indicating the position of the contact on the resistance wire. The latter is wound in grooves cut in an oblong former of ebonite or similar composition, and secured rigidly to it at either end.

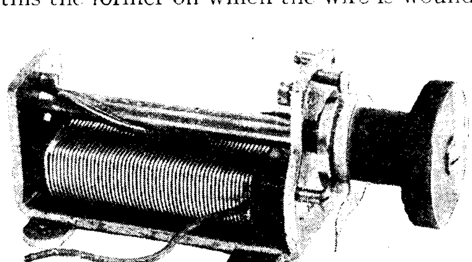
Differing from the great majority of filament resistances of this type, the controlling arm or spindle, although rotatable, is fixed, and the requisite spring between the wire and its contact is supplied by an entirely separate spring. In order to obtain this the former on which the wire is wound is pivoted at one edge, thus allowing it to move up or down in a direction parallel to the controlling spindle. At the opposite end of the former to the pivoting end a spring is attached, the other end of which is held by a pin at the top of the front of the instrument.

It will be seen, therefore, that the tendency of the spring is to pull one side of the wire-wound former in contact with the helical wire attached to the controlling spindle. As the latter is rotated a different part of the contact touches the resistance wire, and also in a different place. In this way the resistance is varied with an extremely smooth action. Connexion from the instrument is taken from any part of the brass case and a flexible lead attached to the front end of the resistance wire. This type of resistance has the advantage over the ordinary type of filament resistances in that its contact is the lightest possible in conjunction with electrical connexion, and that the least possible effort is required to adjust it. The increased resistance is much more smooth than that of the usual variety of rheostat. *See* Filament Resistance.



MARCONI DOUBLE CONDENSER

Simultaneous tuning of two balanced circuits is possible with the Marconi double condenser, shown above. It is of considerable use with two stages of high-frequency amplification



MARCONI RHEOSTAT

Novel type of variable filament resistance. Adjustment is positive and extremely smooth

MARCONIPHONE RECEIVING AND AMPLIFYING SETS

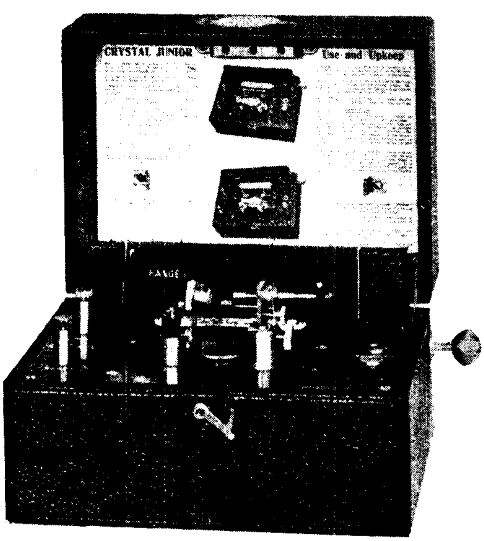
An Interesting Set of Instruments Described in Detail for the First Time

In the following article are described some of the receiving sets, from the crystal receiver to the six-valve receiver, manufactured by Marconi's Wireless Telegraph Company, Ltd. The tuning of these sets is unique, and the circuit diagrams are given here for the first time, specially for this Encyclopedia. These sets should be compared with those described under such headings as Amplifier and Crystal Receivers

Marconiphone is the name given to a variety of wireless receivers. They incorporate a number of unique and interesting features. Connexions to aerial, earth, batteries, etc., are in all cases made by means of non-interchangeable, non-reversible plugs and sockets, thus eliminating the possibility of incorrect connexion and short circuiting of the high- and low-tension batteries with each other.

In all sets up to and including the four-valve model, tuning is accomplished by the spade system, which has several advantages over the more conventional methods.

In this system the inductance of the tuning coil is varied by moving a flat copper plate or spade over the face of the coil, which is of the basket or duolateral type, the effect of the spade being to lower the inductance of the coil in proportion to the area of the coil covered by the spade. Remarkably sharp tuning is obtained by this method, whilst with a correctly designed spade the efficiency is higher than that obtained with variometer tuning.

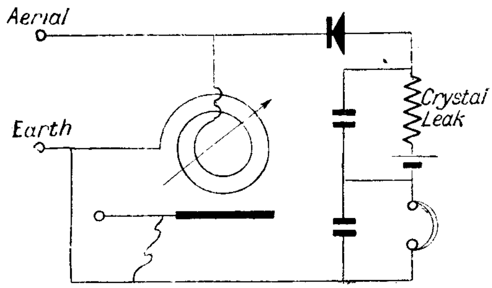


MARCONIPHONE CRYSTAL JUNIOR

Fig. 1. Galena or a carborundum crystal and dry battery may be used with this receiver, which has the spade method of tuning

The system has the additional advantage of being extremely stable and entirely free from hand-capacity effects, even when working near the point of oscillation.

The reflex circuit which is employed on all the valve models was devised some years ago by Captain Round, chief of the Marconi research department, and the full equivalent of an extra valve is obtained by its use.



CIRCUIT DIAGRAM OF MARCONIPHONE CRYSTAL RECEIVER

Fig. 2. Wiring of the Marconiphone Crystal Junior, shown in Fig. 1, is made clear by this circuit diagram

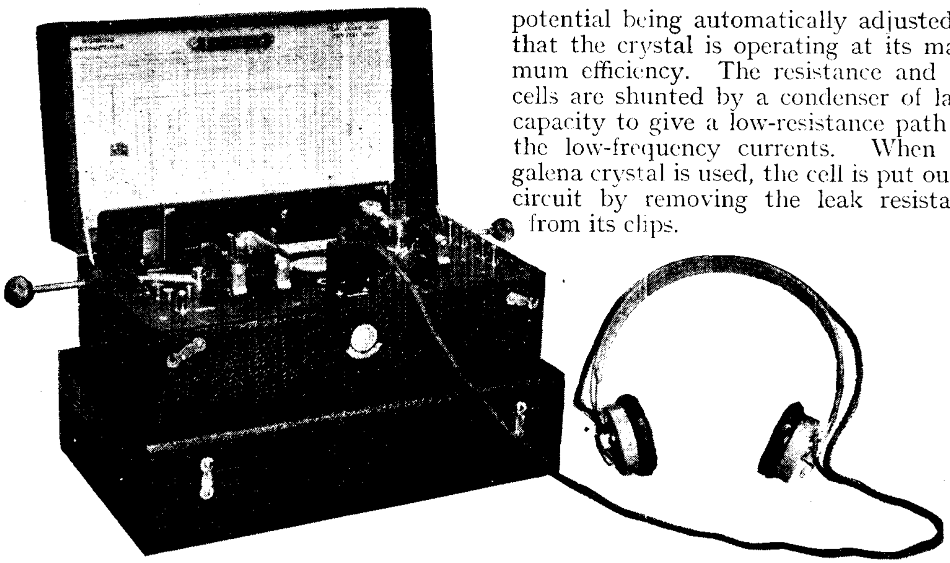
Fig. 1 shows the Marconiphone Crystal Junior. This receiver is one of the single circuit crystal detector type, tuning being effected by the spade method. The aerial tuning inductance is mounted in a detachable ebonite range block, a number of interchangeable range blocks being supplied to cover the range 300–3,000 metres.

These range blocks differ from the standard V.2 type in that they contain two alternative connexions to one coil, by means of which compensation is obtained for different-sized aerials.

The coil is changed by merely withdrawing the range block and replacing it upside down, one coil being used for long aerials and the other for short aerials.

A circuit diagram of the receiver is given in Fig. 2.

The crystal holder is arranged so as to permit of the use of either galena or carborundum crystals, the former giving greater sensitivity but being more difficult



potential being automatically adjusted so that the crystal is operating at its maximum efficiency. The resistance and dry cells are shunted by a condenser of large capacity to give a low-resistance path for the low-frequency currents. When the galena crystal is used, the cell is put out of circuit by removing the leak resistance from its clips.

MARCONIPHONE VALVE AND CRYSTAL RECEIVER

Fig. 3. One valve is used both for high and low frequency, and a crystal is used as detector, so that the receiver may be used in place of a three-valve set. The apparatus is shown complete with battery box

Courtesy Marconi's Wireless Telegraph Co., Ltd.

to adjust, whilst the carborundum crystal requires no adjustment, but is not quite as sensitive. The slight positive potential which is required by the carborundum crystal is supplied by a small dry cell and a series high-resistance leak, the

The set is mounted on an ebonite panel in a wooden box covered with black bookbinder's cloth, the lid being hinged. Sockets are provided for the use of one pair of telephones, a telephone adaptor being necessary if more pairs are required.

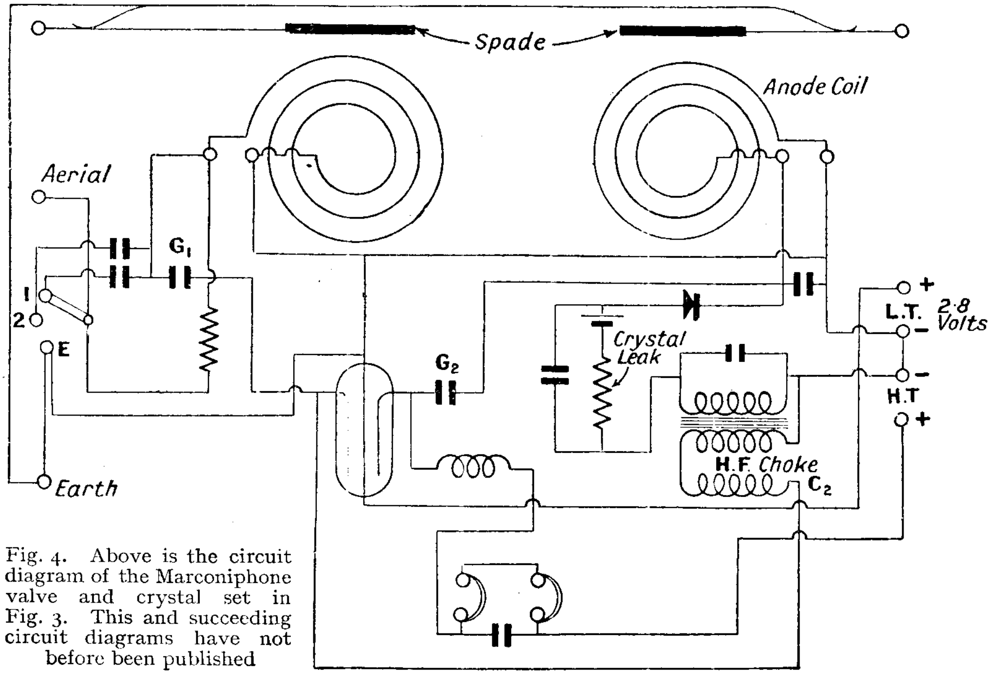


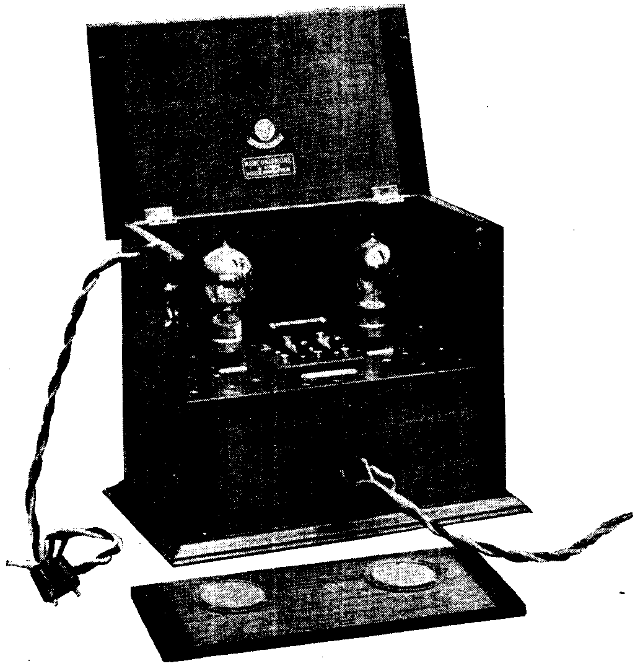
Fig. 4. Above is the circuit diagram of the Marconiphone valve and crystal set in Fig. 3. This and succeeding circuit diagrams have not before been published

The normal receiving range of the Crystal Junior, under average conditions, is approximately 20 miles, but under favourable conditions reception at greater distance is possible.

The Marconiphone valve-crystal receiver is shown in Fig. 3.

This receiver makes use of one valve and a crystal rectifier, the valve being used for high- and low-frequency amplification simultaneously by the use of a throwback arrangement. By this means the equivalent of three valves is obtained, and the amplification thus obtained enables the use of reaction to be dispensed with, resulting in exceptionally pure quality of reproduction.

The receiver is mounted in a wooden box covered with imitation leather, the lid being hinged. The valve, crystal detector, etc., are mounted on an ebonite panel.



MARCONIPHONE N.B.2 AMPLIFIER

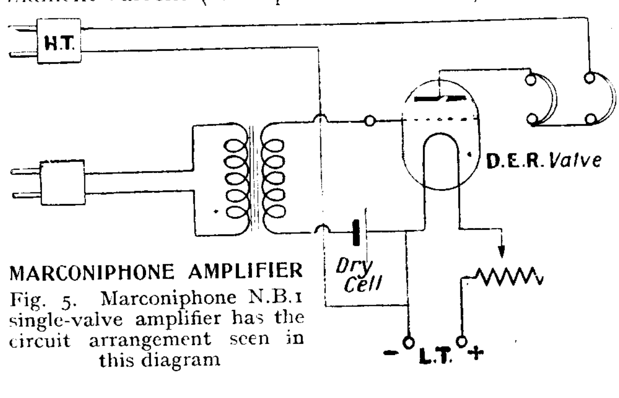
Fig. 6. Two stages of low-frequency amplification are added to the Marconiphone Crystal Junior by this apparatus when a loud speaker is desired

The circuit diagram is given in Fig. 4, and from this it will be seen that the throwback device is very similar to that employed in the V.2. The crystal detector is similar to the type fitted to the Crystal Junior receiver and allows of the use of either carborundum or galena crystal. The device for adjusting the potential on the carborundum crystal is also the same as in the Crystal Junior.

The anode circuit of the valve is tuned for high-frequency amplification, both the aerial and tuned anode coils being mounted together in a detachable range block.

The valve is of the D.E.V. type, the filament current (·2 ampere at 2·8 volts) being supplied by a dry battery which is contained, together with the high-tension battery (45 volts), in a box similar in appearance to that in which the receiver is mounted.

In the valve-crystal receiver only one socket is provided for the aerial plug, a three-position switch being provided to compensate for the use of different-sized aerials. In one position a condenser is placed in series with the aerial coil for use with long aerials, whilst the other position substitutes a larger series condenser for use with small aerials. The third position of the switch earths the aerial.



MARCONIPHONE AMPLIFIER

Fig. 5. Marconiphone N.B.1 single-valve amplifier has the circuit arrangement seen in this diagram

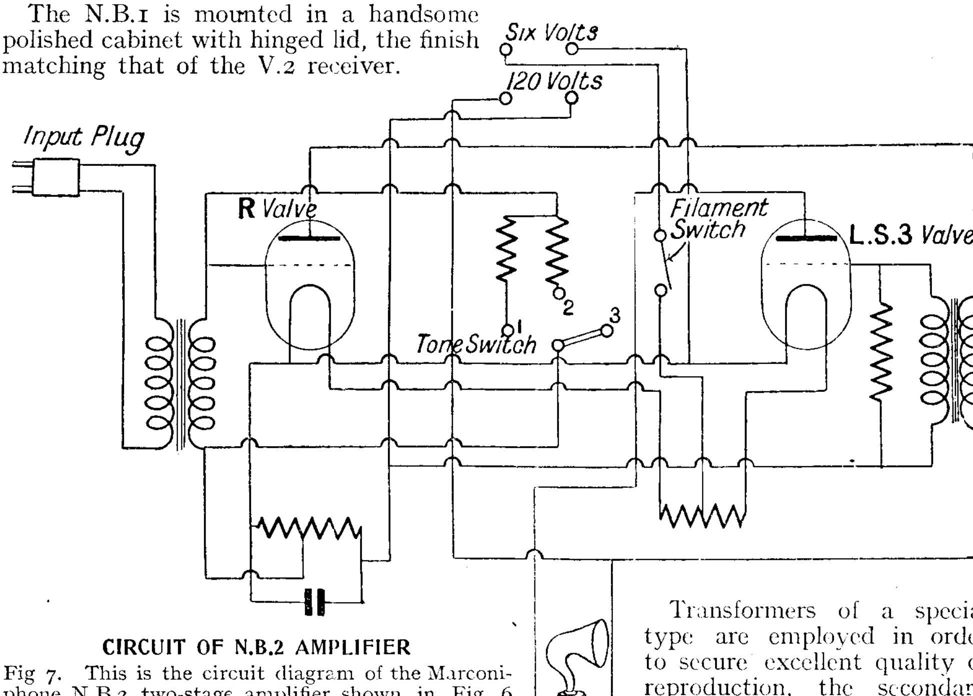
The Marconiphone N.B.1 is a single-valve low-frequency amplifier intended for use with the V.2, Crystal Junior, and valve-crystal receivers when it is desired to use a loud speaker.

A circuit diagram is given in Fig. 5, and from this it will be seen that the instrument is quite straightforward, transformer coupling being employed, and a D.E.R. valve used.

The instrument is largely used in conjunction with the V.2 receiver, and for this purpose a plug is fitted at the end of the high-tension battery lead for insertion in high-tension sockets on the V.2 receiver, so that the high-tension supply is drawn from the battery in the V.2. The two-volt accumulator used with the V.2 can also be used for lighting the valve filament, so that no additional batteries are required.

The negative potential which is required on the grid of the valve to ensure correct operation is supplied by a small dry battery, which is easily replaceable by means of a small detachable cover plate on the bottom of the cabinet.

The N.B.1 is mounted in a handsome polished cabinet with hinged lid, the finish matching that of the V.2 receiver.



CIRCUIT OF N.B.2 AMPLIFIER

Fig 7. This is the circuit diagram of the Marconiphone N.B.2 two-stage amplifier shown in Fig. 6

The Marconiphone N.B.2 amplifier, shown in Fig. 6, is a two-stage low-frequency amplifier intended for use with the V.2, Crystal Junior, valve-crystal, and R.B.7 receivers, when it is desired to use a loud speaker.

Extreme purity of reproduction rather than great volume of sound has been the guiding factor in the design, and the N.B.2 will give a volume of sound sufficient to fill an ordinary room, with a remarkable absence of the distortion and extraneous noise which is often present in loud-speaker reproduction. Another advantage of the amplifier is that it will pick up and amplify to a good strength very weak signals which are hardly audible in the head telephones, and which the majority of amplifiers would not be able to pick up, this result being obtained by the particular valves used.

The valves employed are one R and an L.S.3. The latter, which is used in the last stage, is a special valve capable of handling more power without introducing distortion. The potentials of the grids are maintained at the correct value, which gives maximum amplification and avoids distortion, by an automatic arrangement similar to that employed in the V.3 receiver.

Transformers of a special type are employed in order to secure excellent quality of reproduction, the secondary windings being shunted by high resistances to still further improve the quality.

In the case of the first transformer, a switch, marked "Tone," is fitted, which places different values of the high resistance across the secondary winding, thus giving a remarkably convenient control of the volume of sound.

The high-tension battery (120 volts) is supplied by three 42 volt units of large proportions, and a 6 volt accumulator of 40 ampere-hours' (actual) capacity is supplied for lighting the valve filaments.

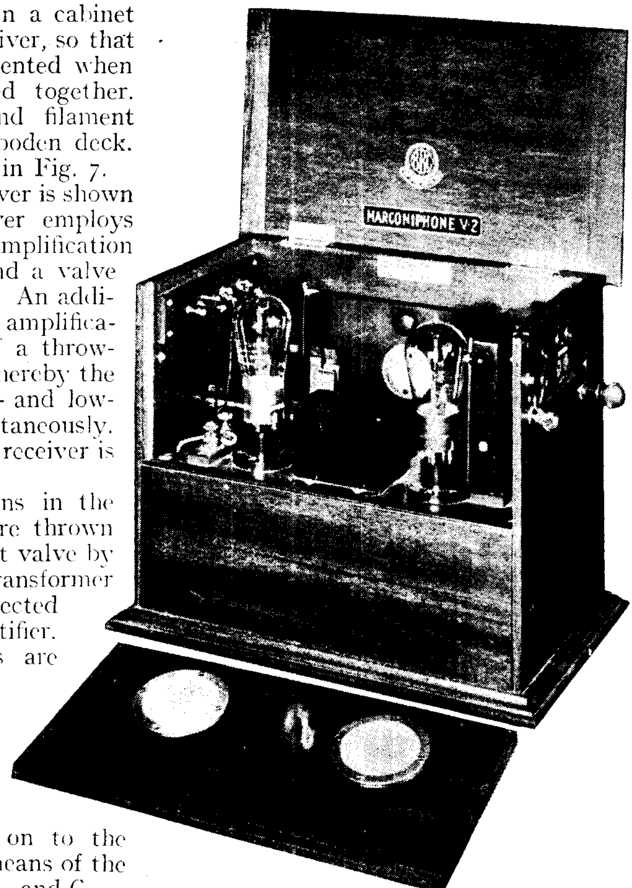
A fixed filament resistance is used in conjunction with an "On-Off" switch.

The amplifier is mounted in a cabinet similar to that of the V.2 receiver, so that a uniform appearance is presented when the V.2 and N.B.2 are used together. The valves, tone switch, and filament switch are mounted on a wooden deck. The circuit diagram is shown in Fig. 7.

The Marconiphone V.2 receiver is shown in Fig. 8. Briefly, this receiver employs one stage of high-frequency amplification with tuned anode coupling and a valve rectifier, employing grid leak. An additional stage of low-frequency amplification is obtained by means of a throw-back or reflex arrangement, whereby the first valve is utilized for high- and low-frequency amplification simultaneously. The circuit diagram of the V.2 receiver is shown in Fig. 9.

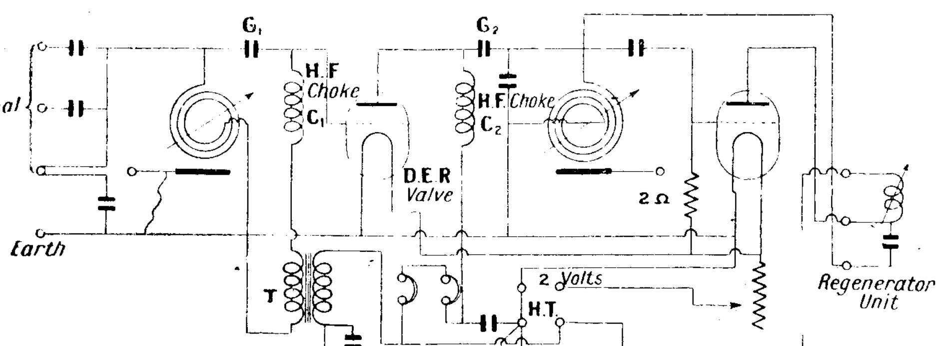
The low-frequency pulsations in the plate circuit of the rectifier are thrown back on to the grid of the first valve by means of the low-frequency transformer T, the primary of which is connected in the plate circuit of the rectifier. The low-frequency pulsations are prevented from passing on to the aerial and to the tuned anode coil by means of the blocking condensers G_1 and G_2. Similarly the high-frequency currents, before rectification, are prevented from passing on to the transformer and to earth by means of the high-frequency choking coils, C_1 and C_2.

Reaction on to the grid of the rectifier is obtained by a novel type of capacity reaction.



MARCONIPHONE V.2 RECEIVER

Fig. 8. Two valves are employed in this receiver, which has one stage of high-frequency with tuned anode coupling and a valve rectifier with reaction



CIRCUIT DIAGRAM OF THE MARCONIPHONE V.2 RECEIVER

Fig. 9. How the two stages of the receiver in Fig. 8 are wired and the arrangement of the circuit are shown in this diagram. Note the regenerator unit on the right, which employs a novel type of capacity reaction. This diagram is published for the first time

In the anode circuit of the rectifier is connected a coil, the inductance of which is varied by means of a copper plate which is arranged to swing over the face of the coil. The potential variation across this coil is communicated by means of a small fixed condenser to the tuned anode circuit, thus giving a regenerative action. The coil and condenser are mounted together in a regenerative unit (right-hand side of deck), a number of interchangeable units being supplied to cover the wave-length range from 300 to 3,000 metres, so that all British and many other broadcasting stations, as well as time signals from the Eiffel Tower, may be received.

There are three alternative connexions to the aerial, thus enabling approximately the same wave-length range to be covered with different-sized aerials. If the aerial plug is inserted in socket No. 1, a fixed condenser is inserted in the aerial circuit for use with long aerials. Socket No. 2 substitutes a larger series condenser for use with medium-sized aerials, whilst No. 3 puts a small condenser in parallel with the aerial tuning inductance for use with very short outdoor and indoor aerials. The earth connexion is made by pushing a protected socket on the end of the earth lead on to a pin mounted on the instrument. The aerial pin and earth socket are made to fit each other, so that when the instrument is not in use the aerial may be earthed by connecting together the aerial plug and earth socket, thus protecting the set from lightning and static electricity.

Spade tuning is employed, the aerial and tuned anode coils being mounted together in a removable ebonite range block, a series of interchangeable range blocks covering from 300 to 3,000 metres being available. The spades are moved by means of sliding rods which project from the sides of the instrument.

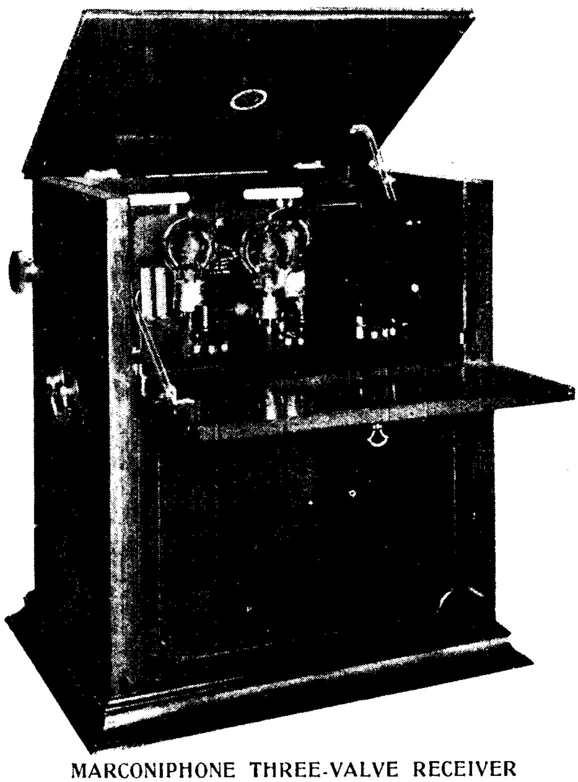
The two valves are of the dull-emitter D.E.R. type.

A 2 volt accumulator of 40 ampere-hours' (actual) capacity is supplied for lighting the valve filaments, through a variable resistance, recharging being thus required only once for each 50 hours of actual working.

The high-tension battery (42 volts), of large capacity, is contained in the bottom of the cabinet.

The set is mounted in an attractive well-finished cabinet, which is obtainable in teak, mahogany, walnut and satinwood. The lid is hinged, and the top part of the front of the instrument is removable, exposing a deck on which are mounted the valves, throw-back transformer, etc. The cabinet may be closed when the instrument is in use, ventilation of the valves being provided.

Owing to variations in local conditions it is impossible to give a definite figure for the range of reception of the receiver, but under average conditions it is possible to receive all the British broadcasting stations, as well as the Eiffel Tower, Radiola, etc., whilst there are many localities in which the reception of much more distant telephony stations, such as Konigswusterhausen, Lyngby (in Denmark), etc., is possible. During the transatlantic tests in 1923 so many reports of the reception of American broadcasting stations were



MARCONIPHONE THREE-VALVE RECEIVER

Fig. 10. This is similar to the V.2, with an additional stage of low-frequency amplification. This set brings in all the British broadcasting stations on a loud speaker

received from owners of the V.2 receiver, that such reception is no longer out of the ordinary.

Broadcasting from the London station has been received at places as far apart as Geneva, Copenhagen, Barcelona, and St. Vincent, making this receiver one of the most efficient two-valve receivers yet constructed. Much of the credit for the circuit is due to the experiments of Round on behalf of the Marconi Company.

The Marconiphone V.3, shown in Fig. 10, is a three-valve receiver consisting essentially of the V.2, with the addition of a further stage of low-frequency amplification. Spade tuning is employed, as in the V.2, but the spades are moved by rotating two milled knobs, one on each side of the cabinet. Detachable range blocks and regenerator units similar to those in the V.2 are used.

The receiver is mounted in a handsome cabinet, somewhat similar in lay-out to that of the V.2, but more massively proportioned. The lid and the top of the front of the cabinet are hinged independently. The latter opens outwards and exposes a panel on which are mounted the three valves, filament resistance, etc.

The high-tension batteries are contained in the bottom of the cabinet, and are easily accessible by sliding the front upwards. Contact is made by brass spring strips on the batteries, which press against corresponding springs on the back of the cabinet, thus eliminating wire connexions, etc.

Two 60 volt units of unusually generous proportions are employed, giving 60 volts on the rectifier and 120 volts on the amplifier valves.

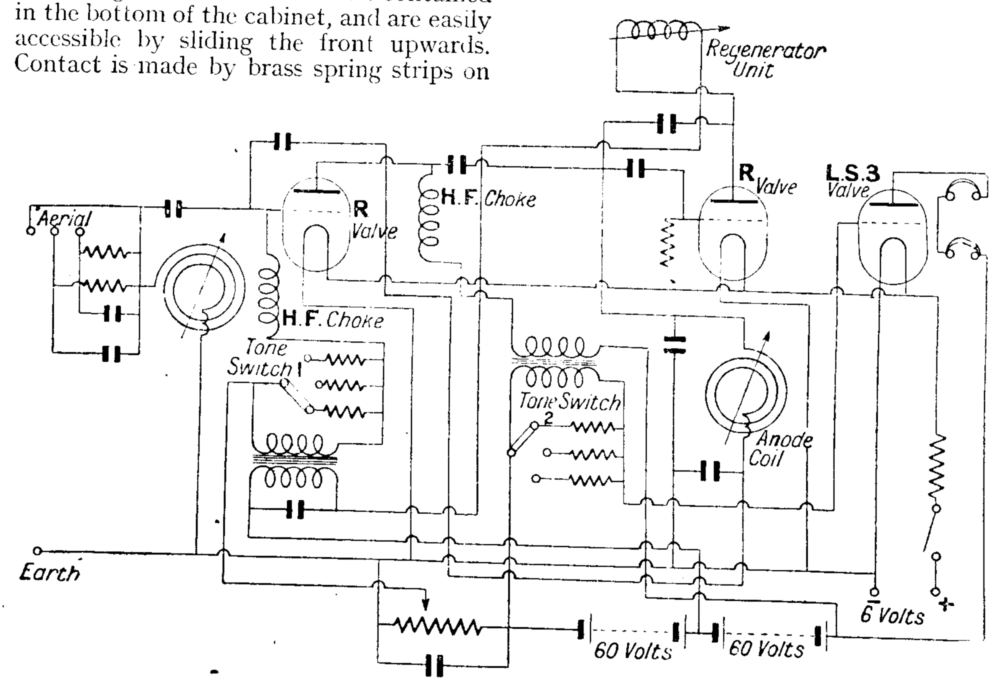
The valves employed are two of the R type and one L.S.3, the latter being a special valve which is capable of handling more power without introducing distortion.

A 6 volt accumulator of 40 ampere-hours' (actual) capacity is supplied for lighting the valve filaments. A fixed filament resistance is used in conjunction with an "On-Off" switch.

Three alternative aerial connexions are used, as in the V.2, to compensate for different-sized aerials.

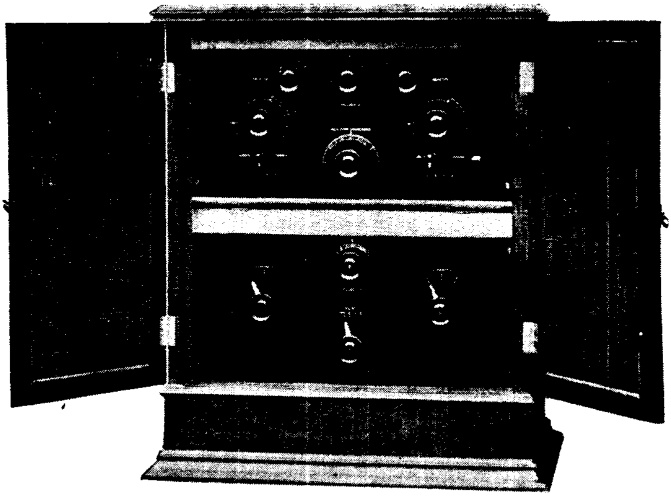
Two novel points in the V.3 which merit description are the method of obtaining negative potential on the grids of the amplifying valves, and the method of preventing re-radiation from the aerial when the set is oscillating.

In order to obtain the grid negative, a resistance is inserted in the plate circuit between the negative H.T. and the



V.3 MARCONIPHONE RECEIVER CIRCUIT DIAGRAM

Fig. 11. Novel methods are employed in this set for obtaining negative potential on the grids of the amplifying valves and, when oscillating, preventing re-radiation from the aerial



STANDARD PATTERN V.4 MARCONIPHONE

Fig. 12. Enclosed in a cabinet with double doors is a two-valve receiver with two stages of low-frequency amplification

great range of reception, freedom from interference, and great volume of sound with extremely good quality.

The first valve gives high-frequency amplification, and is coupled by means of a tuned anode to the rectifier. The low-frequency pulsations in the plate of the rectifier are then thrown back by a low-frequency transformer on to the grid of the first valve, amplification at low frequency then taking place.

Tuning is by means of the spade system, and the spades are of such a shape that straight-line tuning is obtained, *i.e.* the wave-length changes uniformly as the tuning knob is rotated.

negative L.T. As there is a continual fall of potential from the H.T. positive to the H.T. negative when plate current is flowing, the potential of points on the resistance will be negative with respect to the filament. Thus by connecting the grids of the valves via the transformer secondaries to appropriate points on the resistance, the correct negative potential is impressed on the grids.

The value of this grid negative will be to some extent self-adjusting, as the higher the plate voltage the greater will be the plate current, thus increasing the potential drop across the resistance and the value of the negative potential on the grid.

Re-radiation is prevented by a balancing condenser which neutralizes the plate-grid capacity of the first valve, thus preventing energy being fed back to the aerial when the tuned anode circuit is oscillating.

The range of the set for loud-speaker reproduction can be safely estimated as 100 miles, but under favourable conditions, however, all the British broadcasting stations and the Continental stations can be heard on the loud speaker. When using head-telephones the range of the set is, naturally, greater.

The circuit diagram is shown in Fig. 11.

The Marconiphone V.4 receiver, shown in Fig. 12, consists of a highly selective two-valve receiver, with a throw-back circuit which gives the equivalent of three valves and a two-stage power amplifier. The instrument gives a combination of

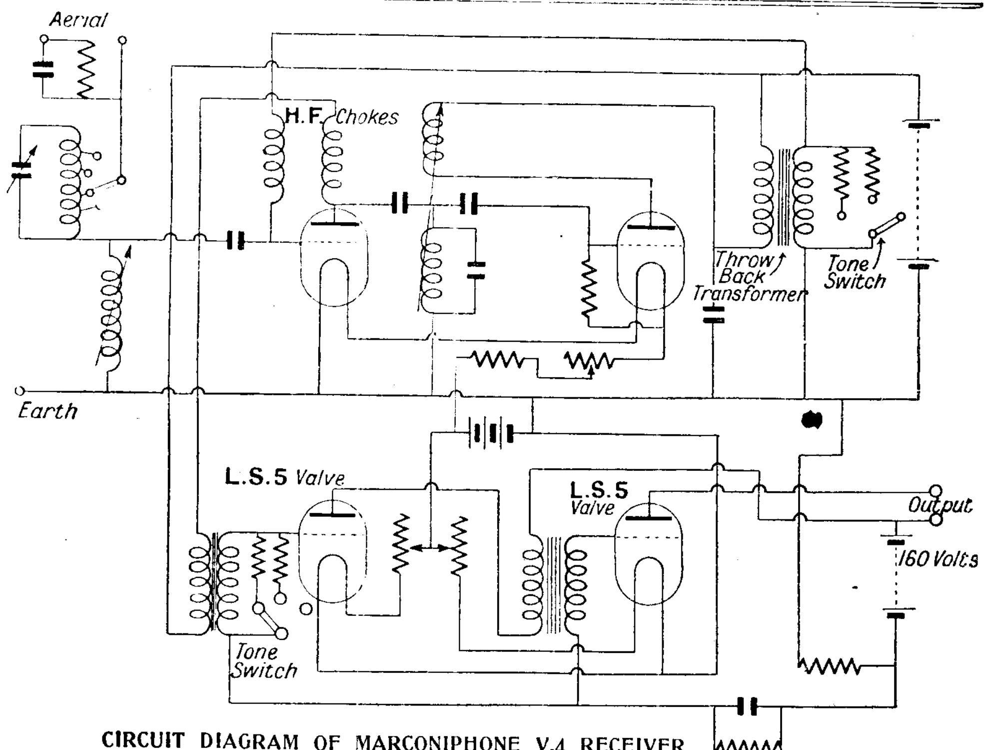
The wave-length range from 300 to 3,000 metres is covered without the use of interchangeable coils or range blocks by means of four coils and a four-position switch which connects the coils in series and in parallel, so that the set is self-contained for receiving broadcasting as well as the Eiffel Tower time signals and other long-wave transmissions.

For lowest wave-lengths the two smaller coils are used in parallel. The next stage is obtained by these two coils in series, and higher wave-lengths are covered by two larger coils, first in parallel and then in series. The same arrangement is used for both aerial and tuned anode circuits. This system gives extremely sharp tuning and high efficiency; no dead-end losses are experienced and no coil-changing is required.

Reaction on to the tuned anode is obtained by means of two coils, which are rotated together by a knob on the panel.

A tuned rejector circuit, consisting of a tapped coil shunted by a variable condenser, is fitted, and by tuning this circuit to an interfering station, the latter is eliminated. The rejector may also be used to cut out a near-by broadcasting station when it is desired to receive other stations.

The set, by means of the rejector circuit, is extremely selective and free from many of the defects of long-range instruments, which are unable to cut out Morse or tune out a local station.



CIRCUIT DIAGRAM OF MARCONIPHONE V.4 RECEIVER

Fig. 13. Three Marconiphone "Ideal" distortionless transformers are used in the V.4 receiver, of which the above is the circuit diagram

The use of the series rejector, combined with the sharp tuning of the aerial and tuned anode circuits, gives the instrument a selectivity and freedom from interference which are quite unprecedented in broadcast receivers.

The two valves employed are of the D.E.R. type, and the filaments are connected in series to economize in current.

The power amplifier consists of two transformer-coupled valves of the L.S.5 type (filament current ·85 ampere at 4·5 volts). These valves are of the low-impedance type, with a low-temperature filament, and they are capable of handling an enormous output whilst at the same time giving high magnification.

The three transformers employed in the V.4 are of the new Marconiphone Ideal distortionless type, in which uniform magnification has been obtained over the whole range of musical notes by means of a special patented arrangement of windings. Resonance being avoided, extraordinary good quality of reproduction is obtained, whilst the step-up of voltage is greater than is possible with the ordinary type of transformer.

Control of the volume of sound is obtained by switching different high resistances across the secondary windings of the first two transformers, whilst two, three or four valves may be put in circuit by means of a switch.

The grids of the L.S.5 valves are maintained at the correct negative potential by the same automatic arrangement as is employed in the V.3 and N.B.2 instruments.

High-tension supply is obtained from dry batteries of large capacity, which are fitted in the back of the cabinet, the voltage being 45 on the plates of the D.E.R. valves and 160 on the plates of the L.S.5 valves.

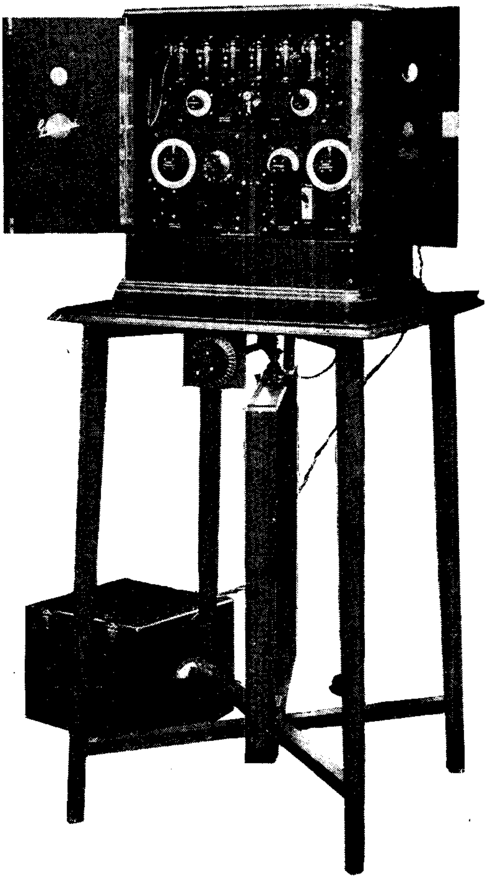
A 6 volt accumulator of 40 ampere-hours' (actual) capacity is supplied for lighting the filaments, two separate filament rheostats being supplied for the D.E.R. and L.S.5 valves respectively.

The instrument is contained in a handsome mahogany cabinet, with hinged doors, the receiver and amplifier being mounted on separate ebonite panels, which are covered with a veneer of highly polished ebonite, all controls being fitted with graduated dials and milled knobs. There is also a hinged door at the back to facilitate the replacement of high-tension batteries and to give easy access to the wiring.

The V.4 receiver can be also supplied with D.E.3 valves throughout.

The circuit diagram for this receiver is shown in Fig. 13.

The Marconiphone R.B.7 receiver is shown in Fig. 14. By its use it is possible to receive all the British broadcasting stations in any part of the country under any but the most adverse conditions, and it is usually possible to hear most B.B.C. stations with a frame aerial. Apart from this remarkable sensitivity, the receiver is outstanding on account of the unusually pure quality of reproduction which is



MARCONIPHONE R.B.7 MULTI-VALVE SET

Fig. 14. Six valves are employed in this set, which has a frame-aerial table. There are five stages of H.F., and a detector valve. One H.F. valve is also made to do duty as a L.F. amplifier, giving the effect of seven valves. The circuit diagram is given on the next page

obtained even when receiving the most distant stations, and the excellent selectivity, which enables interference to be largely eliminated.

The Marconiphone R.B.7 receiver employs six valves, but by means of the standard Marconiphone reflex circuit the equivalent of seven valves is obtained. Five stages of high-frequency amplification are used, followed by a valve detector and one stage of low-frequency amplification (obtained by means of the throw-back). The first four high-frequency stages are coupled by means of semi-aperiodic transformers, similar to those used in the Marconi series of "55" amplifiers. The last high-frequency amplifier valve is coupled to the rectifier by means of a tuned anode, and a low-frequency transformer then throws the low-frequency currents from the rectifier back on to the grid of the last H.F. valve, amplification at low-frequency then taking place.

The valves employed are low-capacity dull emitters, five D.E.V. type for amplification, and a D.E.Q. for rectifying (anode rectification being used). A 4 volt accumulator of 40 ampere-hours' (actual) capacity is used for lighting the filaments.

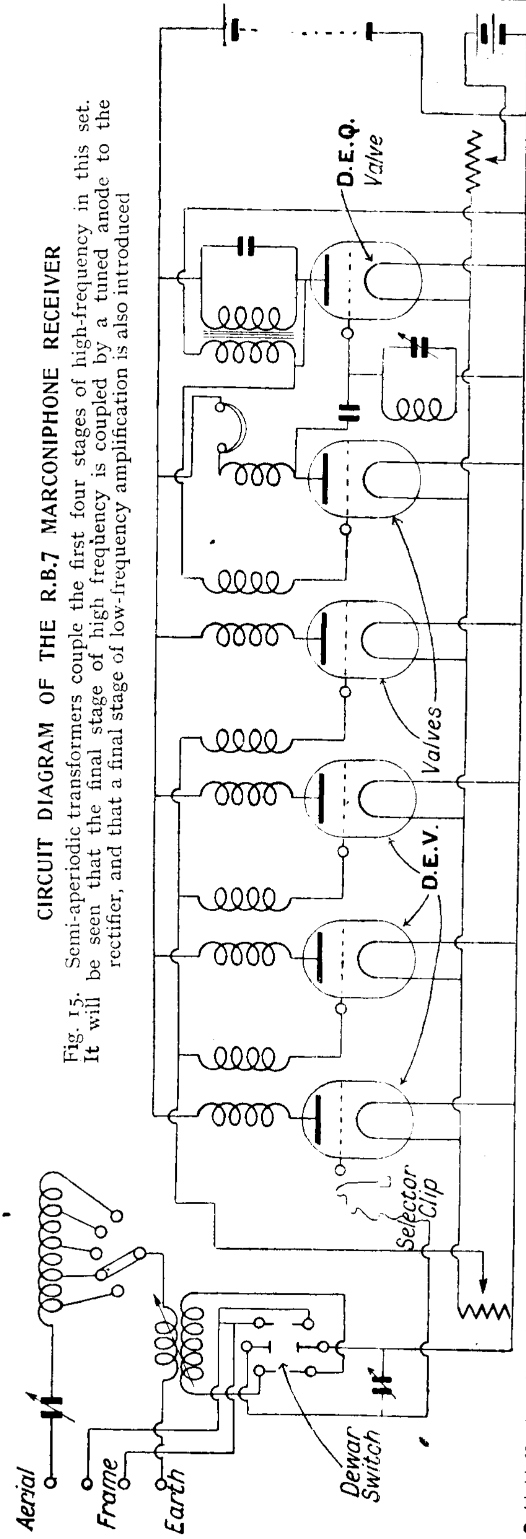
The high-tension supply (42 volts) is supplied by two paralleled units of large capacity fitted in the bottom of the cabinet. Any number of valves from one to the maximum may be put in circuit by means of a selector clip.

The aerial circuit is tuned by means of a series condenser and tapped inductance, and is loose-coupled to a secondary circuit, which is tuned by a condenser. The coupling is very loose, and this is partly responsible for the excellent selectivity of the receiver.

Reaction control is obtained by means of a potentiometer, which puts a variable positive potential on the grids of the amplifying valves. Oscillation is confined to the tuned anode circuit when the reaction is pushed up too far, so that there is no re-radiation from the aerial.

Separate connexions are available for an open aerial and a frame aerial, so that the two may be connected at the same time if desired, change over from one to the other being performed by a change-over switch. When the frame aerial is used, it is tuned by means of the secondary circuit tuning condenser.

Either one or two pairs of telephones may be connected to the instrument, a



CIRCUIT DIAGRAM OF THE R.B.7 MARCONIPHONE RECEIVER

Fig. 15. Semi-aperiodic transformers couple the first four stages of high-frequency in this set. It will be seen that the final stage of high frequency is coupled by a tuned anode to the rectifier, and that a final stage of low-frequency amplification is also introduced

Marconiphone telephone adaptor being required if it is desired to use more pairs.

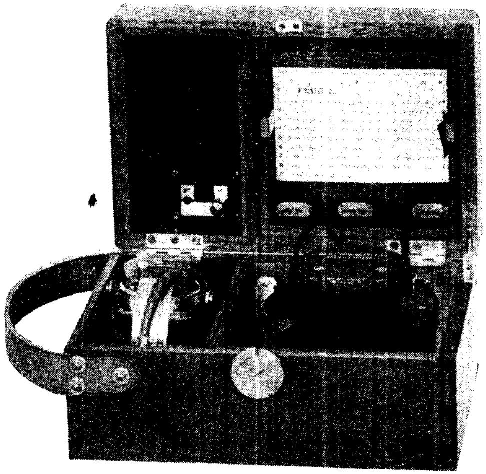
The instrument is mounted in a handsome polished mahogany cabinet with hinged doors, the valves, etc., being mounted on vertical ebonite panels. The circuit diagram is shown in Fig 15.—*R. B. Hurton.*

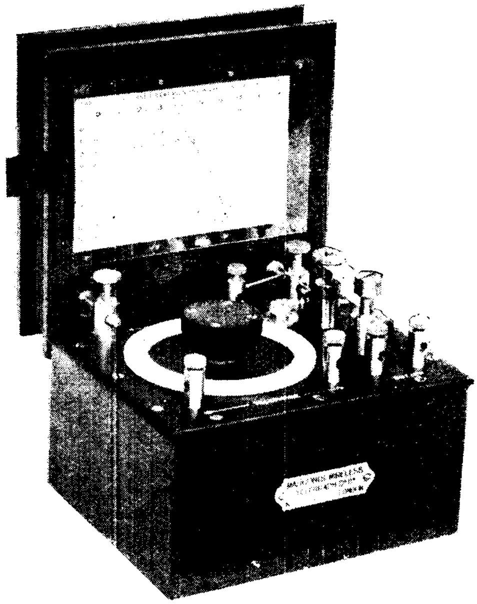
MARCONI WAVE-METER. A form of portable wave-meter having a range from 150 to 2,500 metres is shown in Fig. 1. The wave-meter here shown has an inductance coil tapped at an intermediate point, giving a double range of readings. Either a part or the whole inductance may be included in the tuning circuit by means of a brass plug and sockets, which are housed in a compartment to the left side of the hinged lid. The inductance coil is also placed in the lid, and occupies the right-hand side, being protected by the sides of the lid.

Detection is effected with a carborundum crystal wired in series with the telephones. A variable condenser is placed across the inductance, one side being connected to the beginning of the inductance coil, and the other to one side of the brass strip forming the sockets for the plug tap. In this way the condenser may be used either with the tapping or the whole inductance. Fig. 3, giving the wiring of the wave-meter, will help to make this clear. From this diagram the particular arrangement of the crystal will be noted. It is tapped early in the inductance winding, and consequently does not take the whole of the potential across the condenser. In this way the disturbing effects of the crystal are considerably minimized.

The crystal is fitted in a vertical spring clip behind the variable condenser in the middle of the box. A spare crystal box is supplied, and occupies a corner of the telephone compartment. A double calibration chart giving the wave-length readings corresponding to the condenser settings fits inside the inductance coil on the lid of the box. One side of this chart gives the wave-lengths appropriate to the tapped inductance, and the other side the readings for the full inductance.

In use, the operator, wearing the telephones, adjusts the instrument until signals are at maximum strength. By moving farther away from the transmitter a diminution of signal strength is observed until a point is reached when





MARCONI WAVE-METERS

Fig. 1. Above is a double-range Marconi wave-meter having a range from 150 to 2,500 metres. Fig. 2 (right). Another type of Marconi wave-meter is for use on broadcasting stations. The inductance is supported vertically by plugs fitting into terminals at the rear of the panel

Courtesy Marconi's Wireless Telegraph Co., Ltd.

the signal is very faint. A further critical adjustment of the condenser setting at this point will give the exact reading of the wave-length of the transmitter. The object of moving away from the generator of oscillations is to lessen the broadness of tuning experienced with the wave-meter.

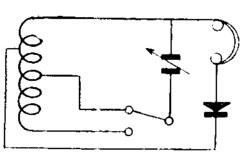


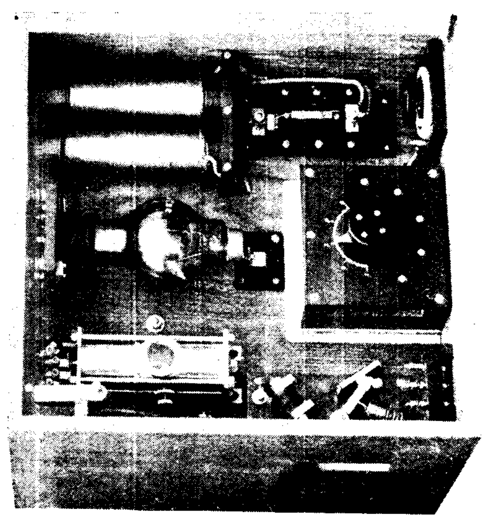
Fig. 3. In this diagram may be seen the method of wiring a Marconi wave-meter

Another type of Marconi wave-meter is illustrated in Fig. 2. In this design the inductance is fixed, and has a smaller wave-length range than the one described. It is particularly suited to broadcast wave-lengths. *See* Wave-meter.

MARCONI WIRELESS BELL. This is an automatic device operated by a distant transmitter which acts as a call bell of an ordinary telephone, and so announces when a particular station wishes to communicate. The device is insensible to all signals except those which are intended to operate it.

The principle of the instrument depends upon the transmission of a signal of definite duration on a definite wave-length. The signal is produced by modulating the outgoing wave at a steady low-frequency note.

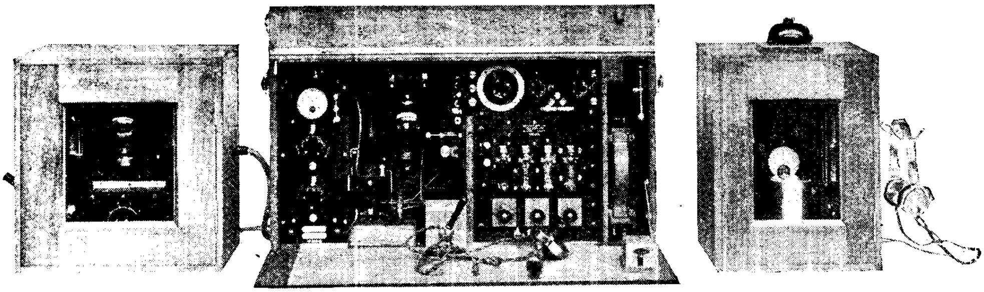
The call transmitter is fitted in a teak box, shown in Fig. 1. It is a self-contained unit, consisting of a valve and its oscillatory circuit, with the addition of a fixed resistance to cut down the high-tension supply if necessary. The valve circuit produces low-frequency oscillations, which may be varied by varying the capacity of a multiple condenser. This condenser



MARCONI WIRELESS BELL TRANSMITTER

Fig. 1. Any station can be called up by a wireless bell being rung, as in land-line telephony. The transmitter can send out on a number of different wave-lengths

Courtesy Marconi's Wireless Telegraph Co., Ltd



MARCONI CALL-BELL TRANSMITTER AND RECEIVER

Fig 2. Continuous watch is not necessary with this apparatus. The three units above are the Marconi 100 watt transmitter, the receiver, and the call bell. When a distant station calls the bell sounds, and reception is obtained as in normal wireless instruments. When the reply is transmitted the distant station is first warned by a bell at that end

Courtesy Marconi's Wireless Telegraph Co., Ltd.

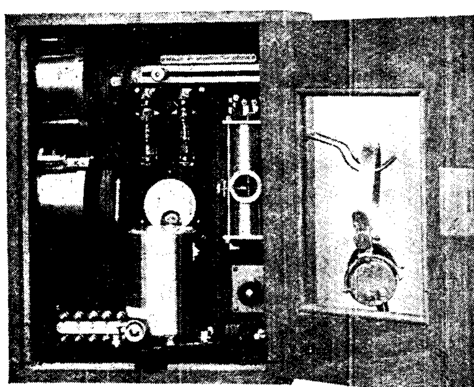
consists of a series of five units, each of which may be switched in at will. The switch is clearly shown in the centre of the bottom of the photograph, Fig. 1. Above it is the power valve.

Fig. 2 shows a transmitter, and receiver on the right. Fig. 3 shows the wireless bell receiver. In one type of this receiver there are two receiving valves with auxiliary circuits and condensers for amplification and tuning of the incoming signal. A reaction transformer increases the sensitivity, and the signal passes through a galvanometer and two relays to a bell. The telephones are hung on a rest, shown on the right, and this automatically puts the receiver in a stand-by position ready for registering a call. Once the bell has started to ring it continues to do so until the telephones are removed from the rest.

The Marconi wireless bell does away with the necessity of anyone being on the watch for any particular signal. It is intended for use in conjunction with the Marconi YB or YC types of portable and semi-portable installations. *See* Duplex Telegraphy.

HANDLED AND EYED MARLINSPIKES

Two marlinspikes are shown. These are largely used for splicing ropes and cordage, and are very useful to the wireless operator when erecting outside aerials



MARCONI WIRELESS BELL RECEIVER

Fig. 3. Until the telephone receivers are lifted off the hook shown on the right the bell continues to ring

MARLINSPIKE. Name given to a pointed steel instrument used chiefly in the splicing of ropes and cordage. Two patterns are illustrated; the smaller has a hardwood handle or knob, and the larger is pierced at the end. The wireless experimenter will find them of aid in the splicing of ropes and cords, especially when making eye splices and other splices, when they will be found to greatly facilitate the work.

The instrument is used to prise open the strands and work one strand beneath another, and so on in the splicing operations as explained under the heading Splicing. It is also used as a form of hammer to marle down the strands in ropes, and for serving or winding round a principal rope with thin cord or twine.

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