16

This Part Completes Volume II. See back pages

1s/3d

HARMSWORTH'S WIRELESS ENCYCLOPEDIA

For Amateur & Experimenter

MAR—OSC

CONSULTATIVE EDITOR

SIR OLIVER LODGE, F.R.S.

THIS PART CONTAINS

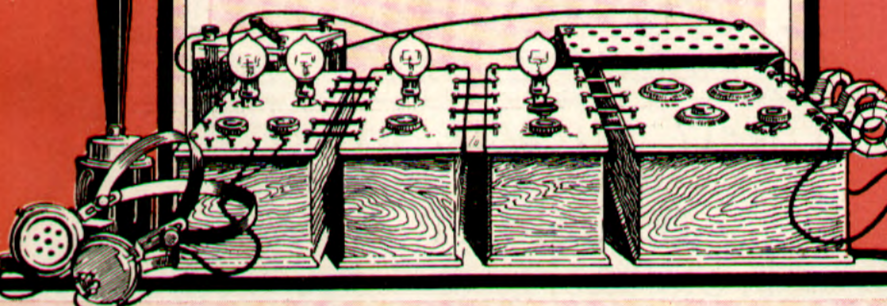
186 New Photos & Diagrams with 158 'How-to-Make' & Other Articles

MICROPHONES
MILLING AND MILLING CUTTERS
MODULATION AND MODULATING
NUTS AND BOLTS
OMNIGRAPH

Special Articles by Sir O. Lodge, F.R.S.
OHM, OHM'S LAW, OSCILLATIONS

PLATE IN PHOTOGRAVURE:
NEUTRODYNE RECEIVER

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



The Only A B C Guide to a Fascinating Science-Hobby

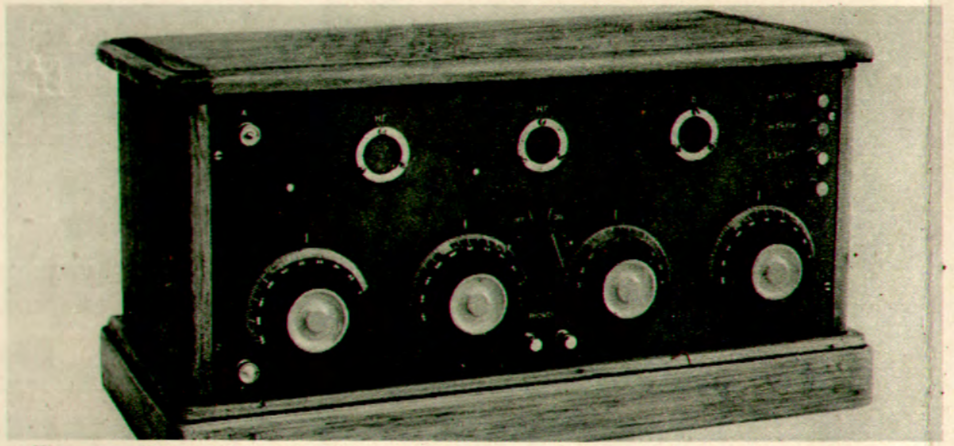


Fig. 10. External appearance of the receiver. Terminals on the right allow low-frequency amplification to be added

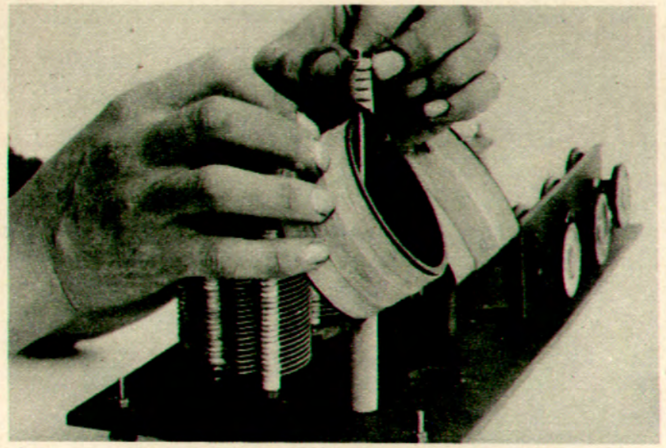


Fig. 11. Mounting the H.F. transformers, using 2 B.A. rod and slant cut ebonite tubing

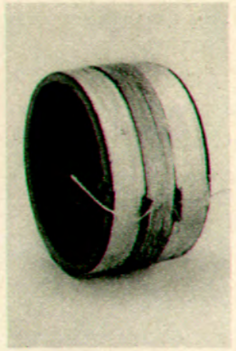


Fig. 12. H.F. transformers completed, winding ends fixed

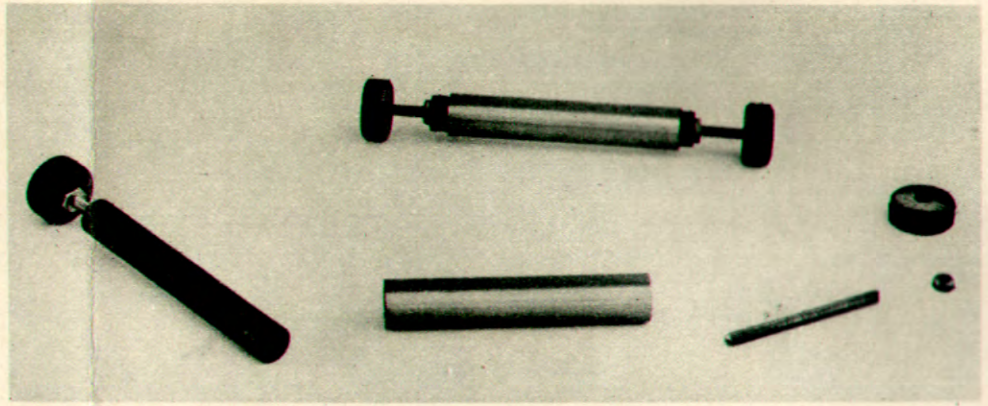


Fig. 13. At the back is a finished neutrodyne condenser, and in the foreground is the unassembled set of parts

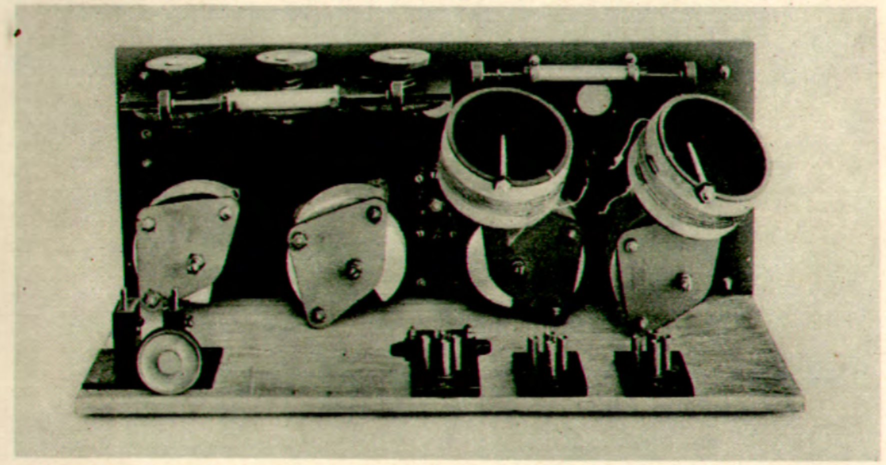


Fig. 14. Mounted at the back of the panel may be seen the components before wiring is commenced. Note the two special condensers

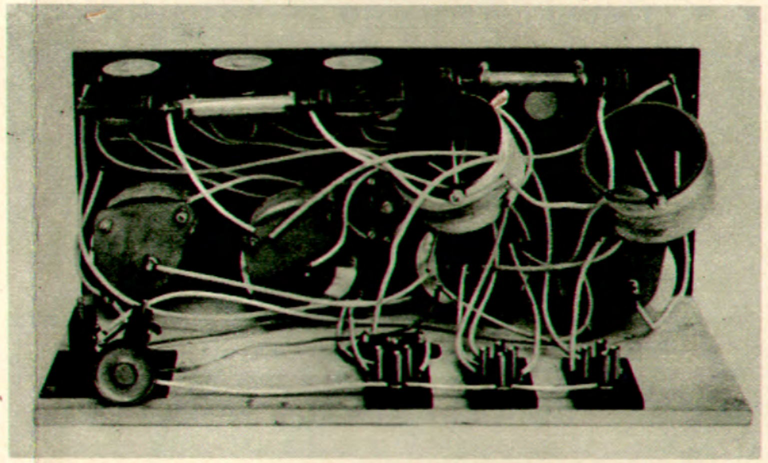


Fig. 15. Back view of the completely wired set, illustrating the position occupied by the filament resistance panel

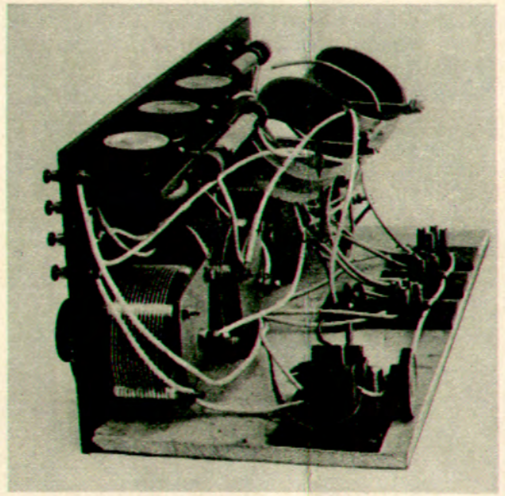


Fig. 16. Right end view of set showing wiring and transformers set at an angle

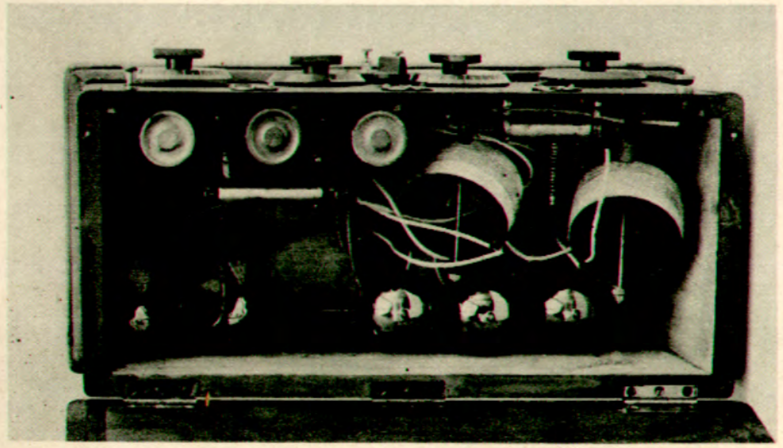


Fig. 17. This illustration shows the set in its cabinet with valves and coils in position ready for operation

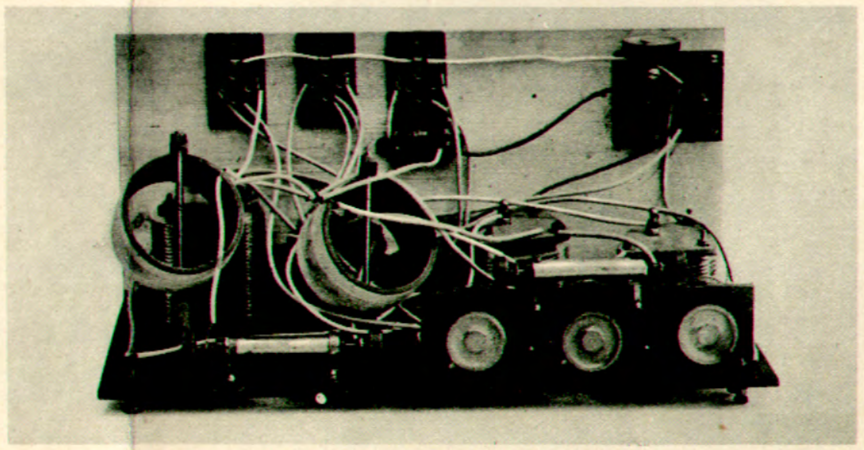


Fig. 18. Interior of set from above, showing clearly the positions and methods of fixing the neutrodyne condensers

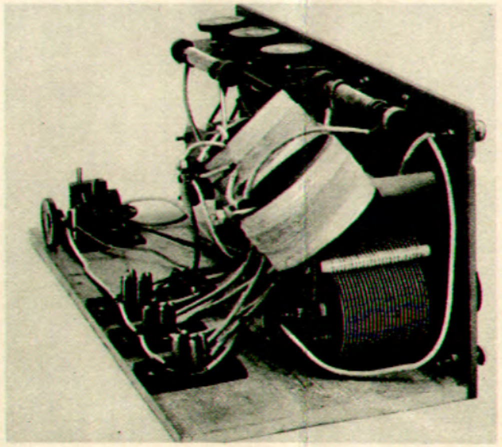


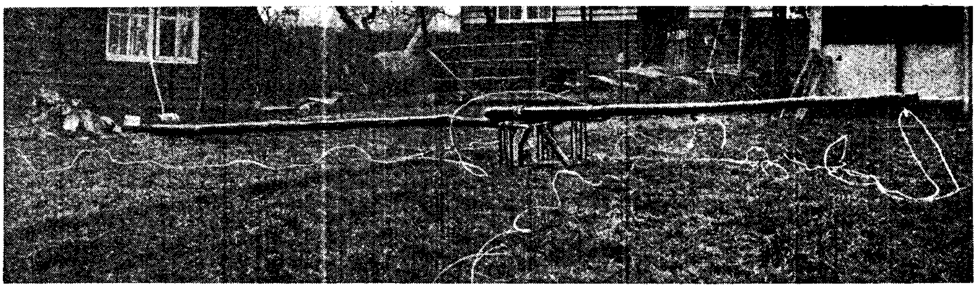
Fig. 19. Side view showing H.F. transformers staggered to minimize interaction

Fig. 20. Neutrodyne receiver in operation. Rheostats are easily accessible by opening top of cabinet

NEUTRODYNE RECEIVER WITH TWO STAGES OF HIGH-FREQUENCY AMPLIFICATION EMBODYING HAZELTINE-TYPE CONDENSERS TO NEUTRALIZE VALVE & VALVE-HOLDER CAPACITY

To face page 1468

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



SIMPLE MAST READY FOR ERECTION

Fig. 1. Two stout scaffold poles are here seen lashed together to form one mast. At the head is a pulley for hoisting the aeria when the mast is erected and the guy-ropes are attached ready

MARRIOTT, ROBERT HENRY. American wireless authority. Born in 1879, he was educated at the Ohio State University, where he first made a study of wireless. In 1901 he entered the service of the American Wireless Telephone and Telegraph Company, to whom he was responsible for erecting wireless stations at Breille, Galilee, etc. Appointed chief engineer of the Pacific and Continental Wireless Telephone and Telegraph Company, he erected stations in California, San Pedro, etc. He was afterwards concerned in the building of wireless stations in various parts of the United States for the United Wireless Telegraph Company, and in 1911 he was appointed Radio Inspector for the United States Government, and is a fellow and former president of the Wireless Institute.

MASSICOT. This is a form of litharge or lead monoxide. It is produced at temperatures below the fusing point of lead monoxide. The term litharge is often confined to that produced above the fusing point. Massicot is the raw material used in the manufacture of red lead or minium. *See* Litharge ; Red Lead.

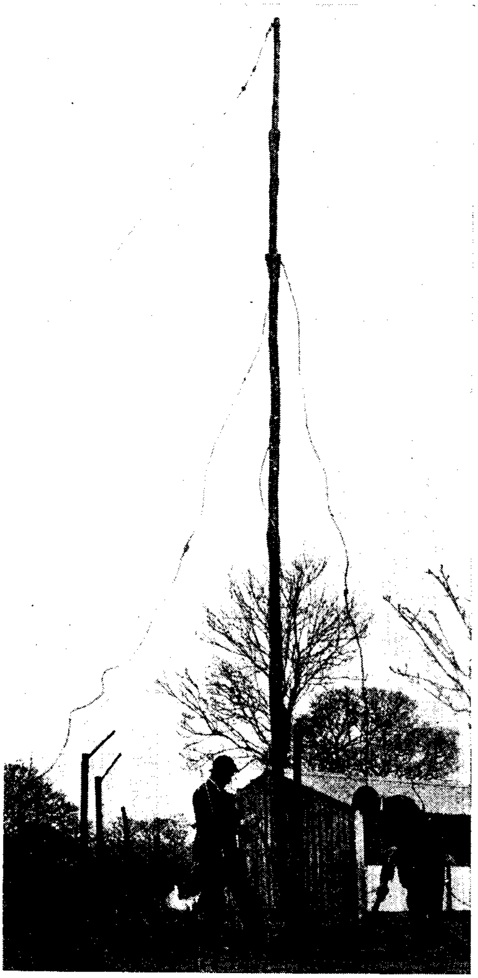
MAST. Term used in wireless work to describe generally any structure used to raise and support the aerial wires. Wireless masts are made up in a great many different ways. The simplest is merely a rough pole embedded in a deep hole dug in the ground. Some elaborate structures are made up of prepared timber in two or three lengths and suitably supported with guy wires and stays. Masts at large commercial stations may reach heights of 300 to 400 ft. or more. One method of construction is to use rolled steel plate in the form of a tube built up in sections and well stayed with steel guy-ropes. Such a mast is illustrated in Fig. 2 as used at the Chelmsford Marconi Station.

STEEL MAST AT CHELMSFORD

Fig. 2. The Marconi station at Chelmsford is equipped with a steel mast, shown in the above photograph. This is a tubular mast several hundred feet high, and supports a cage aerial, which is seen on the ground ready to be hoisted

ERECTING A DOUBLE MAST

Fig. 3. Two of the men helping to erect the double mast in the photograph are making use of the guy-ropes. By this means the mast is prevented from swaying



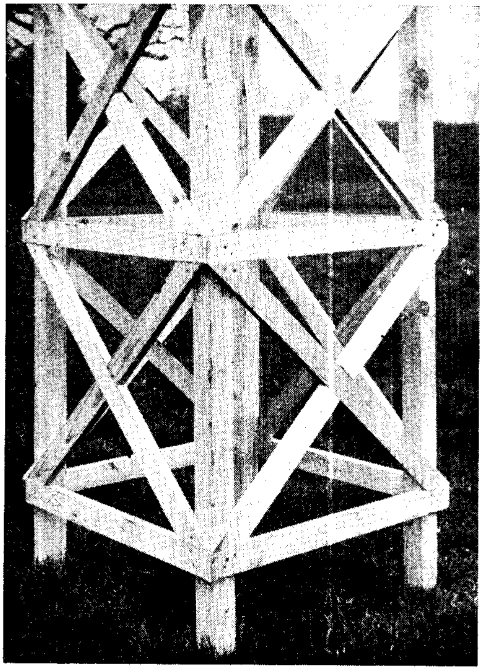
MAKING THE BASE FIRM

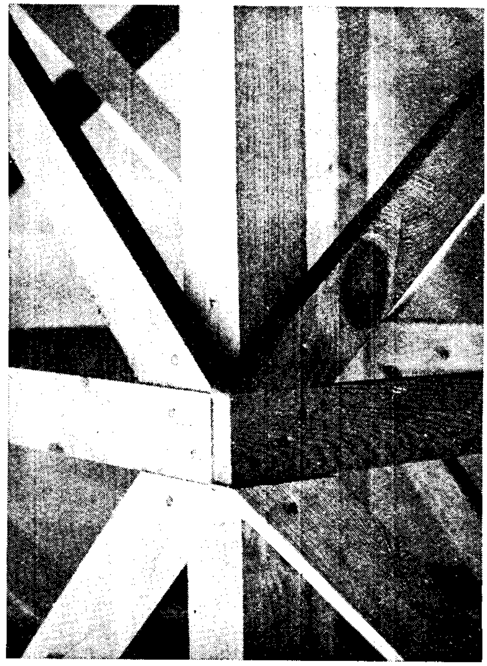
Fig. 4. Earth is being rammed around the base of the mast in order to hold the pole firm. Guys are then tightened up to take the lateral strain

The amateur will not require a mast more than 30 to 40 ft. in height, and such a mast can very readily be constructed from two good stout scaffold poles, or even from ordinary rough poles such as those which are obtained from growing trees. Such poles are often obtainable about 25 to 30 ft. in length, and sufficiently straight for practical use. An excellent mast is made by taking such a pole, and selecting a second, rather lighter one about 12 ft. in length, and securely lashing this to the top of the lower mast (Fig. 1). If the lashing is carried out with strong galvanized iron wire, with an overlap of about 4 ft., the whole mast will be quite strong and stable.

To erect a pole-mast it should be laid on the ground and the joined part rested upon a box or some other support. It should be placed in line with the intended direction of the aerial. A hole from 3 to 4 ft. in depth is then dug, and the foot of the mast laid over it, as shown in Fig. 3. The next step is for two assistants to take a guy-rope each, while two others take up the pole, keeping the foot of it in the hole, and raise the mast as far as possible, the assistants with the guy-ropes meanwhile pulling in unison. This operation is continued until the mast is in an erect position, when the earth is quickly shovelled into the hole by one of the workers, while the other steadies the mast and the third the guy-ropes.

The erection of a 40 ft. pole-mast is not a task which should be attempted by the amateur without plenty of assistance.



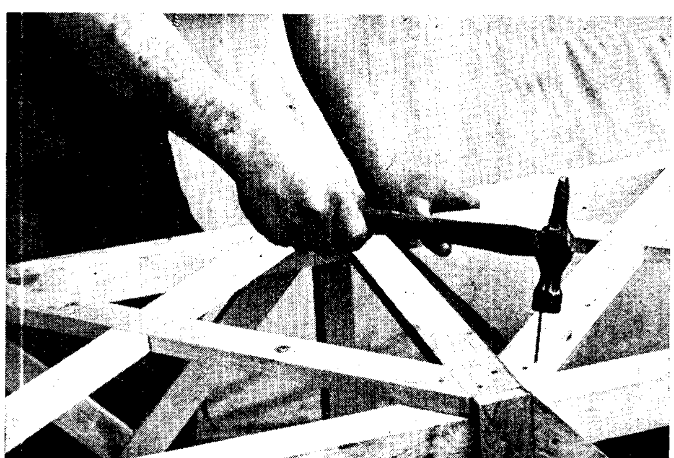


CONSTRUCTIONAL DETAILS OF HOME-MADE TIMBER MAST

Fig. 5 (left). Considerable strength is obtained by building a mast with cross members and diagonal braces. Fig. 6 (right). Careful inspection of the method of construction will convince the amateur that very little skill is required to make this kind of mast, and no difficulties will arise if the instructions for building are exactly carried out

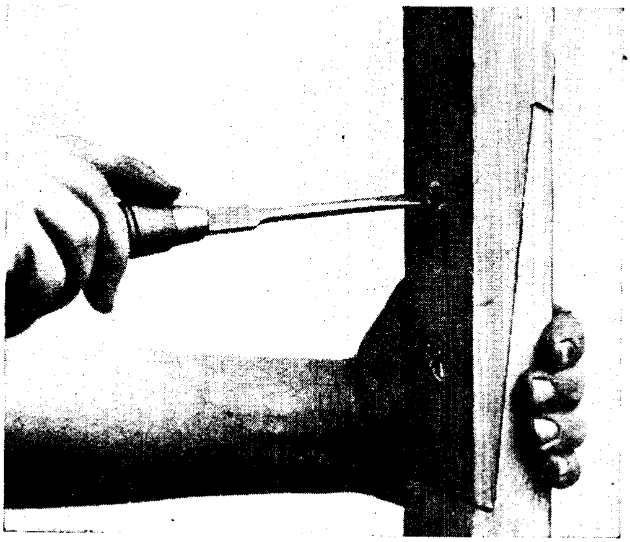
The earth should be well rammed around the foot of the pole, as shown in Fig. 4. If the mast is set up on a calm day there will be no risk of falling, but if there is a wind blowing the assistants must constantly hold the guy-ropes and watch the swaying of the mast, and check any tendency for it to fall by pulling upon the guy-ropes. When the earth has been well rammed home the guy-ropes are tightened up and everything made secure.

Another type of mast which the amateur can construct is shown in Fig. 5, and consists of four corner posts, which may be 2 in. square for a 25 to 30 ft. mast, spaced about 3 ft. apart at the bottom, tapering to practically nothing at the top. The corner posts are tied together with horizontal cross members and braced with diagonal braces. These may be ½ in. thick and securely nailed to the corner posts or side pieces, as shown in Fig. 7. The details for the joints of this type of mast construction are shown in Fig. 6, and the scarfing



HOW THE JOINTS ARE MADE

Fig. 7. All the joints are simple and easy to make. The cross-pieces are nailed to the upright sections, as shown in this illustration



CORNER POSTS OF TIMBER MAST

Fig. 8. How the corner posts of a timber mast are scarfed and screwed together is shown in this photograph

joints for the corner posts in Fig. 8. This type of mast may also be built up on the site, gradually working upwards by climbing up the lattice work, or be made in two side sections and be erected and then braced together with the cross-pieces and diagonal braces.

To facilitate working at an altitude, a couple of stout planks can be rested on the cross-pieces and lashed in position, thus forming a platform from which to work. All the timber for this type of mast ought to be thoroughly well creosoted or treated with some form of wood preservative before it is put up. *See* Aerial; Box Mast; Lattice Mast.

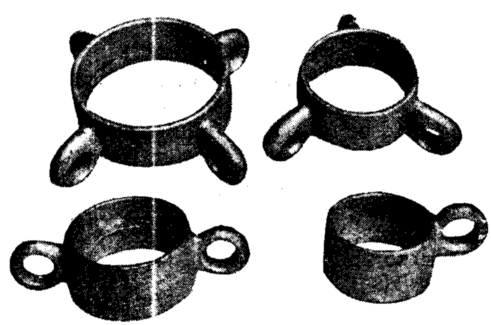
MAST BANDS. Name given to a metal fitting forming a means of attachment for the guy-wires of an aerial mast. Such fittings are made in considerable variety of sizes and shapes. Four useful patterns are illustrated, from which it will be seen that the fitting consists essentially of a malleable or wrought iron ring, having formed upon it one or more projecting eyes.

The bands are usually fitted to the mast by slipping them over the small end of the mast and driving them down to the tapered portion until they fit closely. In some cases they are secured with three or four screws, but this is not necessary if the bands are fitted properly on to a tapered portion of the mast. Connexion between the guy-rope or wire and the eye of the mast band is generally effected by a wrought or malleable iron shackle. On the score of durability it is preferable that these fittings be of galvanized iron, but if expense is no object, they may be of phosphor-bronze.

MAXWELL. Name given to the unit of magnetic induction in the practical system of electrical measurements. *See* Units.

MAXWELL'S CORKSCREW RULE. This is a rule due to Clerk-Maxwell which provides an easy method of remembering the relative directions of current and lines of force. If it be imagined that a corkscrew is being screwed in the direction of the flow of current, then the corkscrew rotates in the direction of the magnetic lines.

McLACHLAN, NORMAN W. British wireless authority. Born at Longtown, Cumberland, in 1888, and educated at Carlisle Grammar School and the George Watson and the Heriot-Watt Colleges, Edinburgh, and Liverpool University, he was appointed lecturer in Engineering and Mathematics at Newcastle-on-Tyne in 1909. In 1913 McLachlan was appointed supervisor of classes in engineering subjects in the Liverpool Technical Institutes, and after the Great War, during which he was engaged in aeronautical research and the study of anti-submarine devices, he made a special study of magnetos at the National Physical Laboratory, Teddington.



MAST BANDS

Four patterns of mast bands are illustrated; these are used to attach guy wires to aerial masts

DR. N. W. McLACHLAN

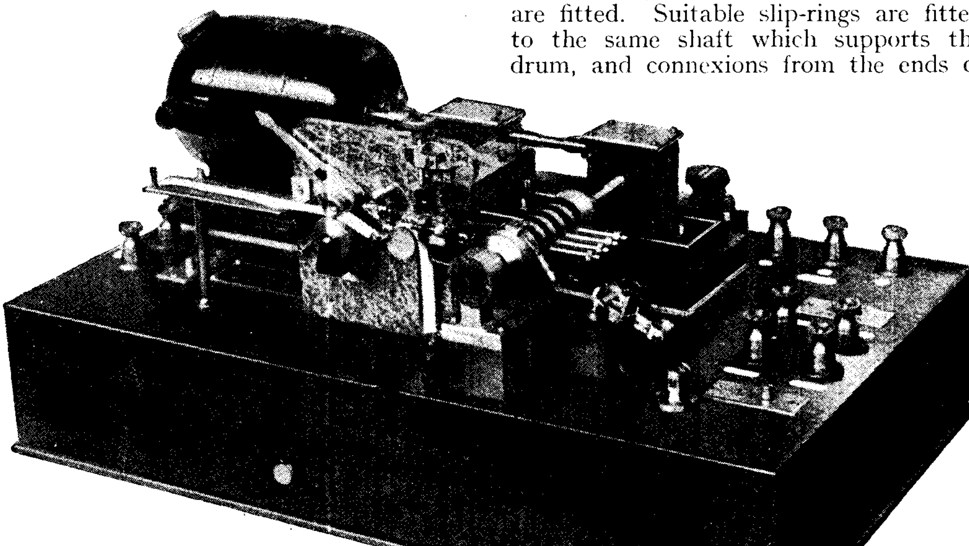
This well-known engineer, scientist and lecturer has served for a number of years as research engineer to the Marconi Company, and has written many valuable papers on wireless subjects. He is a contributor to this Encyclopedia

Photo Elliott & Fry

Appointed research engineer to the Marconi Company, he is the author of many papers on wireless and electrical subjects in the journal of the Institution of Electrical Engineers and other scientific journals, including those on Characteristic Curves of a Poulsen Arc; the Magnetic Behaviour of Iron at Very High Frequencies; and Theory of Iron-cored High-frequency Transformers. He is the author of several patents in wireless. Dr. McLachlan wrote the article Radio Wonders of the Future for this Encyclopedia, which appears on page xxix.

McLACHLAN RECORDER. A form of syphon automatic Morse recorder upon which very high speed messages may be received and recorded upon a paper strip. It is the invention of Dr. McLachlan, of Marconi's Wireless Telegraph Co., Ltd., and is manufactured by that company. A photograph of the instrument is given below, and an example of the paper strip record which the machine produces appears in Fig. 4, under the heading High Speed Reception, page 1126.

The principal feature of this device lies in the methods used to cause the received currents to operate the recording mechanism. A drum composed of soft Swedish iron is made to rotate by the small electric motor shown in the photograph. This drum has an annular recess turned in it, into which coils of fine wire are fitted. Suitable slip-rings are fitted to the same shaft which supports the drum, and connexions from the ends of



MARCONI-McLACHLAN HIGH-SPEED MORSE RECORDER

This high-speed magnetic drum recorder is one of the most sensitive automatic message-recording devices made. It will work with a current of 25 micro-amperes at 150 words per minute

Courtesy Marconi's Wireless Telegraph Co., Ltd.

the coils in the drum are taken to the slip-rings. A number of cast-iron rings are fitted to the outside diameter of the drum. These have to be exceedingly accurate, and are, in fact, machined true to a maximum error of ·0001 of an inch. Suspended over the rings is a small steel shoe, which is fitted between brass guides in order to prevent any possibility of side-play.

The guide pieces terminate at their ends in the form of a hook, one of the latter being connected to a simple piece of mechanism consisting of a light metal rod and a duralumin lever, which is pivoted, and is free to rotate in a horizontal plane. The duralumin lever has a very light tubular silver syphon passing through it, the upper end of which rests in an ink-well and whose lower end rests lightly on the paper strip. The latter is clearly shown in the illustration. A strong spring, the tension of which may be varied at will, is attached to the other end of the duralumin lever. This adjustment is carried out by means of a threaded tensioning screw and locked by a nut. The remaining hook on the guide is fitted to a lighter spring, which prevents side movement.

Current from the wireless receiver is conveyed to the coils in the drum via brushes and the slip-rings previously mentioned. The passage of this current causes the drum to become magnetic and to attract the shoe to it. This tends to cause a side movement of the shoe. A very large pull indeed is required to prevent this side movement, and it is this pull which is utilized to give lateral motion to the syphon. The paper passes with a continuous, even motion under the tip of the syphon and the latter moves transversely across it ; the result of combining these two motions is to produce rectangular formations on the strip. The top lines of these rectangles represent the dots and dashes of the Morse code, according to their length.

The instrument is extremely sensitive. The machine will work with a current of only 25 micro-amperes, at a speed of 150 words per minute. This renders great amplification on the receiver unnecessary.

McMICHAEL, H. LESLIE. British wireless expert. Born at Birkenhead in 1884, and educated at Ackworth and Mason College, Birmingham, he was apprenticed to Duckett & Brown, the electrical engineers. McMichael early took an interest in wireless, and was one of the earliest to hold a receiving and transmitting licence in London. He made a special study of crystal detectors and, in collaboration with R. H. Klein, invented

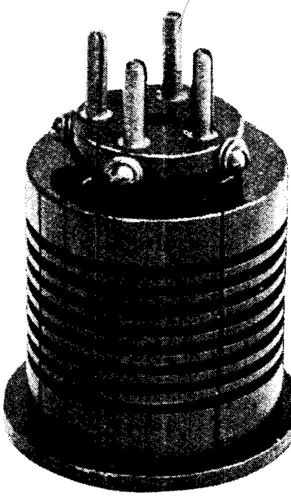
H. LESLIE McMICHAEL

Mr. McMichael was one of the founders of the Radio Society of Great Britain (formerly Wireless Society of London), and has acted as its honorary secretary for a considerable period. He was one of the earliest amateurs to hold a receiving and transmitting licence in London

the synthetic crystal Radiocite. He was one of the founders of the Wireless Society of London, and for some years has acted as its honorary secretary. He is a managing director of L. McMichael, Ltd., the well-known wireless firm, and a member of the Institute of Radio Engineers. Mr. McMichael compiled the list of Call Signs: Amateur Transmitters, for this Encyclopedia

McMICHAEL PLUG-IN TRANSFORMER. A type of high-frequency transformer of the plug-in variety. The illustration shows a typical transformer of this type where the primary and secondary windings, instead of being wound in a single deep groove with one winding over the other, as is common in the majority of patterns, are wound in alternate grooves along a solid ebonite core or former.

The former seen in the illustration has a series of eight slots, four being occupied by the primary winding and the remainder by the secondary. In order to prevent accidental contact between windings, four saw cuts are arranged round the face of the former and form a trough in which the wires connecting the alternate grooves are placed. The ends of both windings are brought out through the saw cuts to valve legs, which enables the transformer—which, in common with all types of high-frequency transformers, has an efficiency limited to a comparatively small wave-length band—to be withdrawn rapidly from the circuit and replaced by another. The arrangement of the valve legs enables them to fit the standard valve holder. The ends of each transformer winding are attached to opposing valve legs, so that the valve legs normally corresponding to the grid and the anode form one winding and the filament valve legs the other.



McMICHAEL TRANSFORMER
Both windings of this high-frequency plug-in transformer are laid in slots cut along the face of an ebonite former

The manufacturers make a feature of pairing or matching two or more specimens of this transformer so that they may be used to the best efficiency in multi-stage high-frequency amplification.

MEGA. This is a Greek prefix used in the C.G.S. system of units for one million times, or 10^6. In some words it becomes contracted to meg, and its usual abbreviation is M. Thus megohm is one million ohms. *See* C.G.S. ; Units.

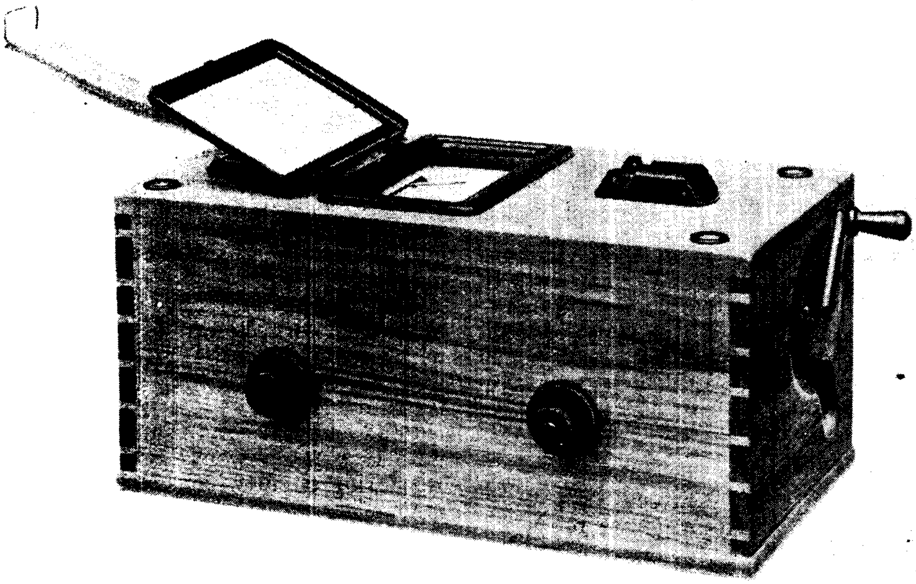
MEGGER. There are few instruments of greater general utility in electrical testing than the one which goes by the name of the " megger." It is as essential to be able to read the insulation resistance of a circuit or wiring system as it is to read pressure and current in volts and amperes, and although resistance values can always be arrived at indirectly by an application of Ohm's law—that is to say, the resistance in ohms is found by dividing the potential difference at the ends of the circuit by the current passing in amperes—it involves taking two readings, and often the instruments available are not sufficiently sensitive or of a suitable range.

The megger is really a development of an older form known as the ohmmeter, which required for its use a generator as well, the outfit consisting of two separate instruments.

Conducting circuits usually count their resistance in ohms or fractions of an ohm. Insulating circuits have resistance values amounting to thousands or millions of ohms. The megger is intended for measurements of the order of millions of ohms, hence its name, the prefix " meg " meaning one million times.

The general appearance of a standard megger insulation testing set will be gathered from Fig. 1. The working principle of this set is illustrated by the diagram in Fig. 2. A is a high-voltage generator armature driven from an external handle, seen in Fig. 1 at the end of the case, by means of multiplying spur gearing, and the armature revolves between the pole pieces N S at one end of the permanent magnet fields B.

At the opposite end of these fields is another pair of pole pieces containing the coils constituting the ohmmeter movement, one being a fixed coil and the other a moving coil, attached to which is a pointer which traverses a graduated scale visible from the outside of the case, and marked to read direct in megohms or fractions. The current generated by A has two circuits open to it, one through the fixed coil and one through the movable coil. When the external or line terminals E C are disconnected and there is " infinity " resistance, the current from the generator has only one path open to it, through one of the coils, the effect of which is to swing the needle over to the " infinity " end of the scale. When the external line terminals are connected up to a circuit whose insulation resistance is not perfect, a certain amount of the



MEGGER USED FOR MEASURING INSULATION RESISTANCE

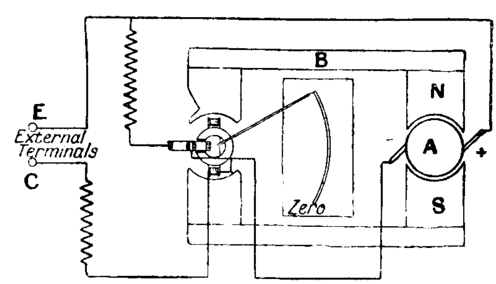
Fig. 1. An instrument of general utility in electrical work, the megger is particularly useful in the experimenter's workshop. By means of it the insulation resistance of a circuit can be read directly. The above photograph shows the general appearance of a megger

Courtesy Evershed & Vignoles, Ltd.

current generated by A is shunted off through the second ohmmeter coil, which is acting in a plane at right angles to the first one, and the combined result of the two magnetic effects causes the pointer to take up a position which is the resultant of the two forces and in proportion to their relative magnitudes. If the leakage between E and C is considerable, the second coil will become the more powerful, and the needle will be deflected towards that end of the scale which is calibrated in the lower values of ohms.

Since the same terminal voltage is applied to the ends of both circuits, instrument and line, the accuracy of the readings is not impaired by the exact rate at which the handle of the generator is turned, both coils being affected equally by any rise and fall of volts. But for certain testing work it is desirable to apply considerably higher pressures than with other work, since the apparatus on test may be called upon to withstand more strenuous working conditions. Hence various testing voltages can be obtained, such as 100, 250, 500, and 1,000 volts, by varying the windings on the hand-driven generator armatures.

Meggers are obtainable in two distinctive types—the variable-pressure and the constant-pressure form. In the variable-pressure type the drive from the handle to the armature is direct, hence the voltage generated will be proportional to the speed at which it is driven. In the constant-pressure type, however, an ingenious form of slipping clutch is used



PRINCIPLE OF THE MEGGER

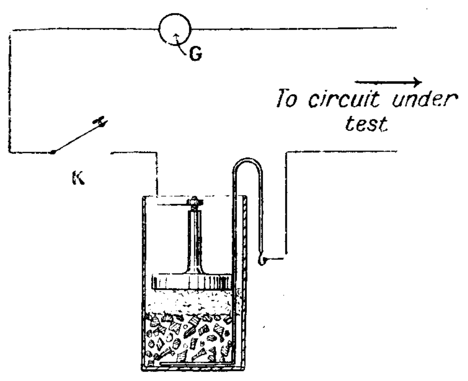
Fig. 2. The circuit arrangement of the megger is shown in this diagram, which indicates the principle of the instrument

with a free-wheel attachment, so that the armature can only be run up to a certain speed. Above this the slipping centrifugal clutch operates, and above a critical speed the volts are found to remain extremely constant. *See* Insulation; Resistance.

MEGOHM. One million ohms. Large resistances are always measured in megohms, and small resistances in microohms. The resistances of grid leaks, for example, are generally given in megohms. *See* Ohm; Units.

MEISSNER, ALEXANDER. Austrian wireless expert. Born at Vienna, 1883, he was educated at the Technical High School and University of Vienna. He joined the Telefunken Company in Berlin, 1907, and is one of the leading authorities in Germany on wireless. To him is due a large number of wireless inventions, including the Telefunken compass, musical quenched sparks, interference preventers, the direct current cathode valve relay for the reception of Morse, etc. In 1913 he invented the generation of oscillations by means of the three-electrode valve. He holds many patents, including spark gap for impulse excitation, quenched-spark signalling in conjunction with G. von Arco, etc., and he is the author of many papers for scientific journals and societies on the subject.

MENOTTI CELL. Form of Daniell cell which is largely used for testing purposes. It consists of a glass container, at the bottom of which is a copper cup containing crystals of copper sulphate. Above is a packing of damp sawdust, upon which rests the zinc element. The cell is chiefly used for testing the continuity of circuits. The cell has a resistance of 30 ohms, and its voltage is practically unity. The diagram shows how the Menotti cell is connected to a circuit undergoing test for continuity. *See* Daniell Cell.



HOW A MENOTTI CELL IS USED

For testing a circuit the cell is used in this order. K is a key and G a galvanometer. Closing the key deflects the galvanometer if the circuit being tested is continuous

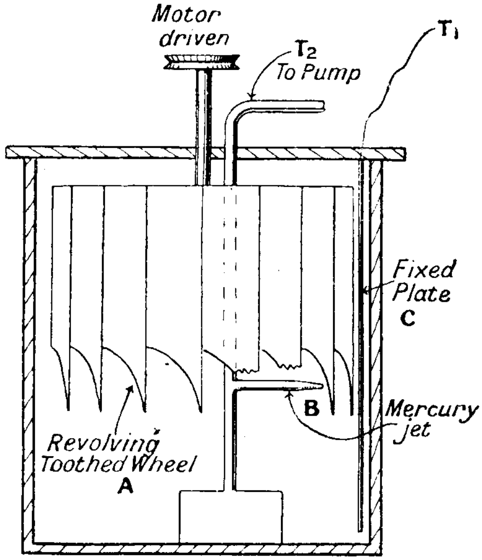
MERCURY. One of the metallic elements. Its chemical symbol is Hg, atomic weight 200, and specific gravity 13·59. It is not affected by air, oxygen, or carbonic acid gas at normal temperatures, and has the remarkable power of forming combinations with other metals known as amalgams. It is a silver-white in colour and is the only known metal which is fluid at ordinary temperatures.

Mercury is very largely used in electrical work. It is used in many cells for amalgamating one of the metal elements to reduce polarization and is one of the electrodes in the Castner and similar cells in the manufacture of chlorine and caustic soda. It has been used in the mercury vapour arc and in certain forms of valves, as the Lieben-Reisz valve (*q.v.*). Mercury is also largely used in the mercury jet interrupter, described in the following article.

MERCURY JET INTERRUPTER. When the primary winding of an induction coil is supplied with a continuous current it is necessary to interrupt the current more or less periodically in order that a secondary voltage shall be induced in the secondary circuit. There are a variety of methods by which this may be accomplished, and one of the most satisfactory is by means of a mercury jet interrupter. This method is largely used for operating X-ray bulbs from an induction coil connected to a direct current supply.

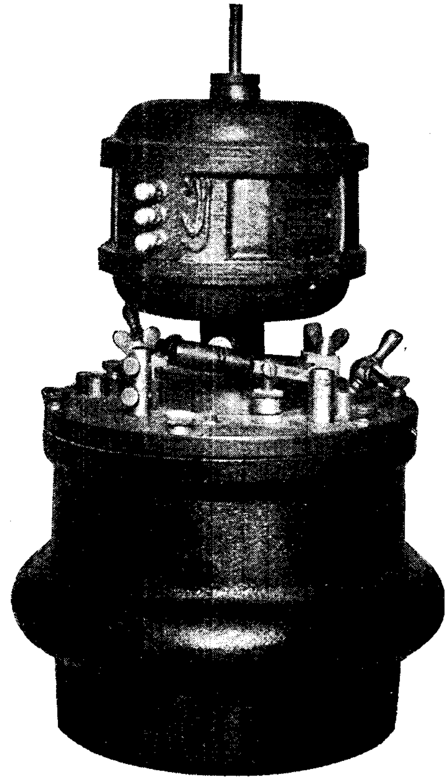
With this type of interrupter a stream of mercury is forced from a jet against a metal plate. The stream of mercury is interrupted by a toothed wheel of insulating material, so that periodically electrical continuity is made and broken between the mercury and the metal plate. In some forms of jet interrupters the jet itself revolves, the mercury impinging against a fixed metal plate.

The principle of one type of jet interrupter is shown in Fig. 1. A is a tooth-shaped wheel made of insulating material. This wheel is driven by a small motor, and the number of revolutions per minute can be varied between wide limits. A



HOW THE MERCURY JET INTERRUPTER WORKS

Fig. 1. In this diagram is shown the principle on which the instrument works. It is largely used in operating X-ray bulbs from an induction coil

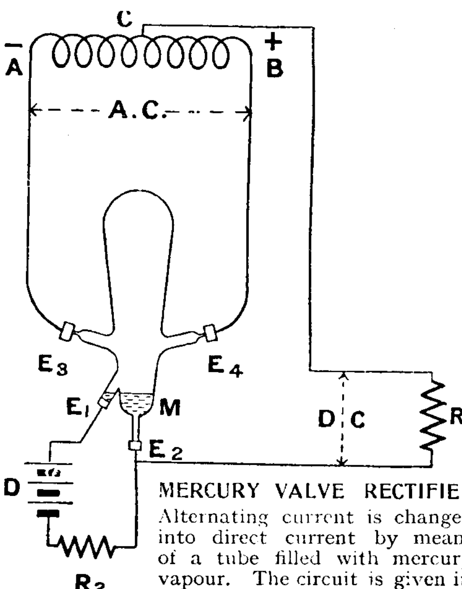


MERCURY JET INTERRUPTER

Fig. 2. Continuous current flowing to the primary of an induction coil is interrupted by this instrument, so that a secondary voltage may be induced in the secondary circuit

small centrifugal pump forces the mercury from the jet B, while the revolving wheel A interrupts the contact of the mercury with the plate C. The wheel A can be raised or lowered, thereby enabling the duration of contact of the mercury with the plate to be varied without altering the number of interruptions in a given time. The mercury can be covered with paraffin oil or alcohol to minimize oxidation, but after being in use for some time the mixture becomes worked up into a sludge and becomes non-conducting. To overcome this trouble, the vessel containing the interrupter can be filled with coal gas, which prevents oxidation and the working of the mixture into a sludge. Such an interrupter is shown in Fig. 2.

MERCURY VALVE RECTIFIER. An instrument for converting alternating currents into direct current. The mercury valve rectifier was invented by Cooper Hewitt, and consists of a glass vessel shaped as in the illustration. The glass vessel is pumped to a fairly high vacuum and a small quantity of mercury is placed in the lower part of the tube at M. There are two electrodes, E_1 and E_2, as shown,



MERCURY VALVE RECTIFIER

Alternating current is changed into direct current by means of a tube filled with mercury vapour. The circuit is given in this diagram and the level of the mercury is so adjusted that these two electrodes are just not in metallic contact. A slight tilting or rocking of the glass vessel allows contact to be made, and this is the usual way of starting the action of such a rectifier.

When the current has been started and the vessel is brought vertical so that the circuit is broken, a spark occurs. This sparking causes a state of high ionization in the tube, and high potential currents from the secondary of the step-up transformer, A C B, can flow from either electrode E_3 or E_4 to the electrode E_2. The mercury arc allows the current to flow from these electrodes to E_2, but does not allow the current to flow from E_2 to either of these electrodes. It is unilateral in its action, and the whole vessel is a rectifier, therefore, of A.C. currents.

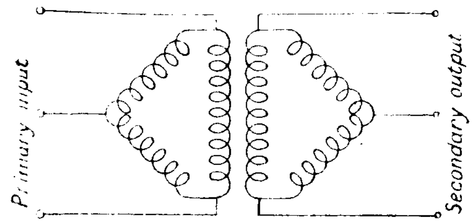
The action can be explained by considering it at any particular instant. Suppose at that instant the terminal A of the secondary coil of the transformer is negatively charged and the terminal B positively The natural direction for the current to flow is from B down to E_4, thence to E_2, and from there to E_3, and so on to A. But this is exactly what the highly ionized state of the vessel will not allow the current to do. The current cannot flow from E_2 to either E_3 or E_4, though it can flow the other way. The current from B therefore goes to E_2 and thence through the resistance R_1, and back to the tapping at C of the secondary. This tapping is taken from the exact centre of the coil.

Now, in the next half of the cycle A is positively charged and B negatively. The current flows from A to E_3, thence to E_2 and R_1 and so back to C. So whether A is positive or negative, and so with B, C remains constantly relatively negative. If C, R_1 is tapped, therefore, a direct current is delivered.

The two electrodes, E_3, E_4, are the two anodes of the circuit, and each is connected to one side of the A.C. supply. The electrode E_2 is called the starting or exciting electrode. As the current alternates, first one anode and then the other comes into play, and the flow of current is constantly towards the cathode. The circuit E_1, D, R_2, E_2 is sometimes known as the keep-alive circuit, and provides for the starting of the arc by rocking the tube until contact is made between the two lots of mercury and then broken as already explained.

MERCURY VAPOUR ARC. Type of arc used for high-frequency oscillations. Several types of mercury vapour arcs have been tried, but they have advanced very little beyond the experimental stage. In the mercury vapour arc, instead of the ordinary spark gap in air a mercury vapour lamp at the proper pressure is used. In 1903 Cooper Hewitt pointed out how the mercury vapour lamp could be used to generate oscillations, and many experimenters have followed, notably Simpson, Liebowitz and Vreeland.

MESH GROUPING. Transformers used on three-phase circuits are arranged with their primary windings either connected all in series, or with the three supply lines attached to the three corners. This is called a mesh connexion or delta connexion (*see* Fig. 1). They may be joined up so that one end of each primary winding is connected to each line whilst the three other ends are joined together, and may be connected to a fourth line which is



MESH CONNEXIONS OF THREE-PHASE TRANSFORMERS

Fig. 1. Mesh grouping is shown of a transformer primary and secondary windings

called the neutral. This fourth wire is not, however, used in all cases. This connexion is called star.

The two terms mesh grouping and delta grouping are synonymous, and are chiefly explained under the latter heading in this Encyclopedia.

There is, however, one arrangement of star mesh grouping which is employed in rectifier circuits, and which is of peculiar interest in wireless telephony, as it enables a very pure continuous wave to be obtained from commercial town supplies of 50 cycles without the necessity of employing any running machinery.

In Fig. 2, P_1, P_2, P_3 are the three primary windings of a three-phase transformer, connected in this case in mesh or delta to the town supply mains. There is, however, no necessity for the primaries to be connected delta, they may be connected star, or star with a neutral point connected or not to a fourth wire, depending on the regulations of the local electric supply authority.

The secondary windings of the transformer corresponding with the primary windings are shown as S_1, S_2, S_3. These, however, must be connected star as shown, for the neutral point of the three windings becomes the negative of the direct current supply.

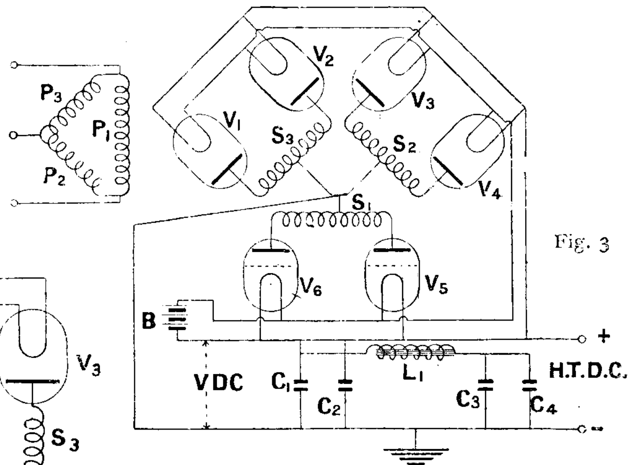


Fig. 3

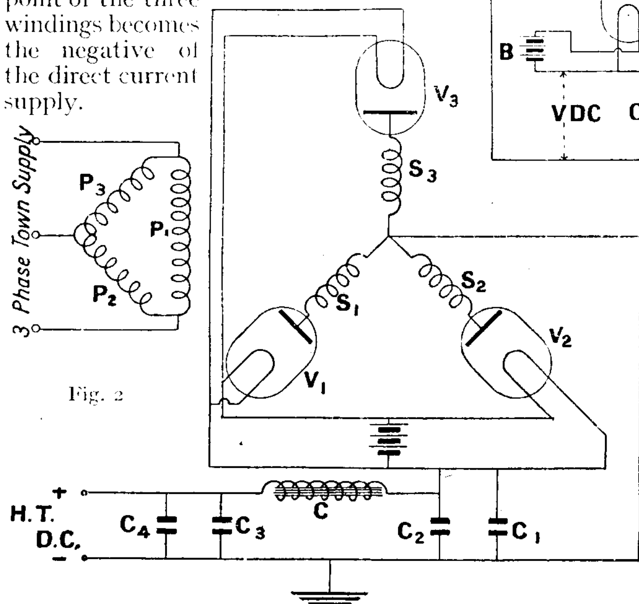


Fig. 2

MESH GROUPING OF THREE-PHASE TRANSFORMERS

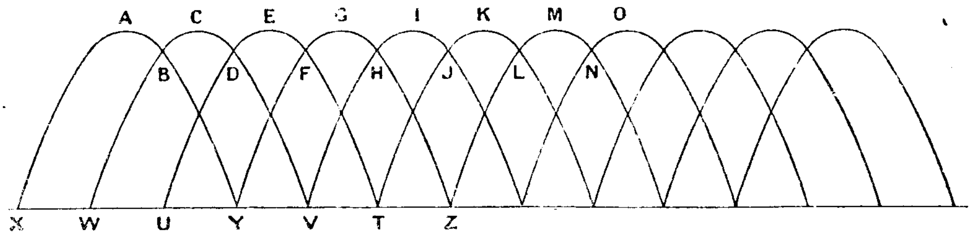
Fig. 2 (below). Three-phase alternating current is transformed and rectified to high-tension direct current for valve working. Fig. 3 (above). This is another arrangement in which mesh grouping is employed for the same purpose as in Fig. 2

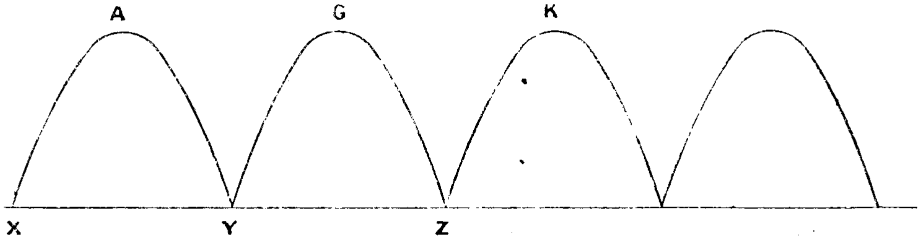
The three ends of the three secondary windings, S_1, S_2, S_3 are connected directly to the anodes of three rectifying valves, V_1, V_2, V_3, the filaments of which are lighted from a battery. It should be noted that as this battery is at the full transformer secondary potential above earth, it and the wiring from it to the valves must, therefore, be very carefully insulated for several thousand volts.

Connected between this battery and earth are two large smoothing condensers, C_1, C_2, in parallel. Between these condensers and the next bank of condensers there is a very large smoothing choke, C. The current then comes to a second bank of condensers, C_3 and C_4, which may conveniently be of the same capacity as the first group of condensers.

A still better circuit for the rectification of three-phase alternating current is shown in Fig. 3, which is a further development of Fig. 2, and is one of the most satisfactory ways of obtaining high-tension direct current for the commercial working of large valve transmitters, for speech and music, or wherever it is essential that the carrier wave shall be quite pure and free from hum.

It will be seen that a special three-phase transformer has to be used, or alternatively three separate transformers may be connected together in the manner shown. It is, however, essential that in either case there shall be a connexion to the central point of each secondary winding. These three points are connected together and become the negative terminal of the D.C. supply. Six rectifier valves are required in this system, one for each end of each secondary winding. The filaments of all six are wired in parallel and lighted from a well-insulated battery B, which becomes the positive D.C. terminal. The current at this point, VDC, is a three-phase current with double rectification. It is therefore a very nearly smooth direct current, as shown by the tops of the curve (Fig. 4) A B C D E F G H I J K L M N O, etc., where X A Y, W C V, U E T, are three half-cycles rectified and overlapping in their correct phase relationship.





HOW MESH GROUPING RECTIFICATION REDUCES RIPPLE

Fig. 4 (above). Reduction in ripple by using the three-phase double rectification method is seen by comparing these two diagrams. In Fig. 5 (below) only single-phase current with double rectification is used, while in Fig. 4 (above) three-phase double rectification is used

It will be realized how great is the reduction of ripple by using three-phase double rectification if the corresponding curve (Fig. 4) is studied in comparison with Fig. 5, which shows to the same scale the ripple which would be present at the same point, VDC (Fig. 3), if only single-phase current with double rectification was used.

The current from the point VDC passes through the smoothing system, C_1, C_2, L_1, C_3, C_4 (Fig. 3), and is then available as a perfectly pure high-tension direct current.

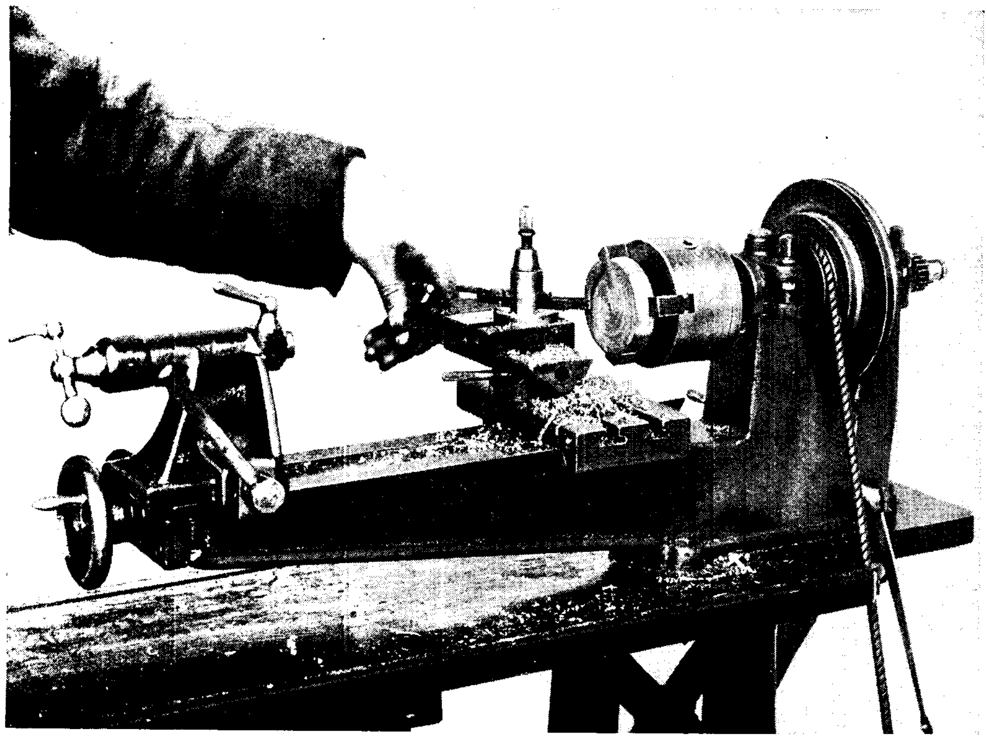
The same special precautions have to be taken to insulate the battery B and the valve filament lighting wires in this case as in the case of the simpler circuit shown in Fig. 2. In both cases the filaments of all valves may be lighted from an A.C. supply obtained through a specially insulated transformer, but this is not desirable if absolute freedom from all A.C. hum is required.—*R. H. White.*

See Delta Grouping.

METAL WORKING. General title covering most mechanical operations in the shaping of metals. The wireless experimenter who undertakes the home construction of wireless apparatus must needs know something of metal working and its processes. To those lacking technical training the principal subject for study is the operations associated with the shaping of metal into more or less circular form by means of a lathe. A typical turning operation is illustrated in Fig. 1, and the subject is dealt with in greater detail under the heading Lathe. Suffice it to say that even the least dexterous use of a small foot lathe enables the amateur to construct a large number of parts which would be beyond accomplishment by other means. The reader should always consult the large number of articles in this Encyclopedia describing how to make various sets and components where lathe work is involved, and also under the headings of metals such as Aluminium, and materials, as Ebonite.

Bending and shaping of sheet and rod metal form another considerable section of metal work. When the rods are of any substance, say more than $\frac{3}{8}$ in. in width and $\frac{1}{6}$ in. in thickness, they usually have to be made red hot before they can be properly bent, the process being then known as forging; it is dealt with in this Encyclopedia under that heading.

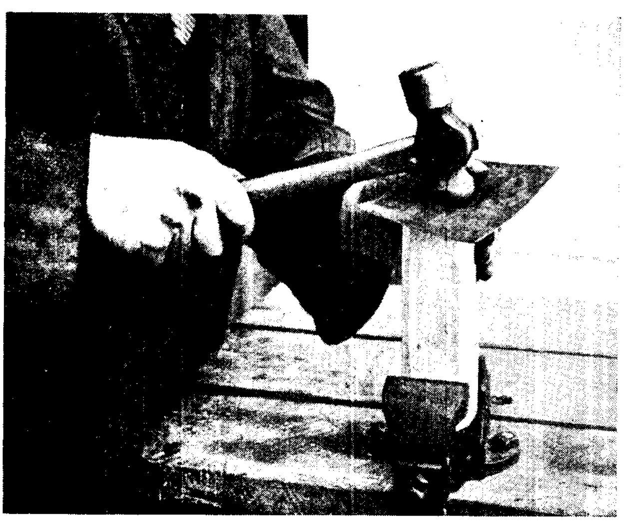
Sheet metal is worked in a variety of ways, but, so far as the amateur is concerned, chiefly by cutting the sheet material to the desired shape, usually with heavy tinman's snips or shears, when the thickness of the metal will permit of this operation, by the use of a hack-saw, or with a cold chisel and hammer. The edges are then generally cleaned up true, and the structure built up with a number of flat pieces united by brazing, riveting, or some other joining process. These processes too, are intimately



TURNING METAL IN A LATHE

Fig. 1. Constructional work for wireless frequently involves some form of metal working, and turning, as shown here, is one of a series of lathe operations that come under this heading

concerned with metal working, and the articles under their headings should be consulted, as well as the article Soldering.

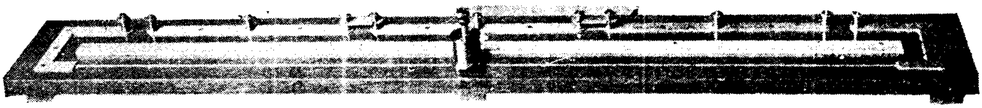


SHEET METAL SHAPING

Fig. 2. Sheet metal is shaped by hammering the material while it is resting upon a support. In the photograph a rest is held in a vice

When sheet metal is to be worked into curved shapes, those which are of purely geometrical form can often be developed by cutting a flat sheet of metal to a certain shape, and then bending it and bringing two of the edges of the sheet into contact with each other. For example a cone open at each end is formed by cutting a sheet of metal with two parallel but curved edges, thus forming a sector of a circle with a circular piece removed from the apex. The ends of this cut-away sector are cut to an angle corresponding with the angularity of the sides of the cone, seen in elevation.

When, however, the sheet is to be worked into a complicated shape, it is necessary to hammer out and stretch the metal, as in Fig. 2, by carefully hammering out those parts where its surface area is to be



METRE BRIDGE FOR ACCURATE RESISTANCE MEASURING

Fig. 1. This instrument includes a selected resistance wire exactly one metre long. The photograph shows a standard form of bridge, the circuit diagram being given in Fig. 2

Courtesy J. J. Griffin & Sons

increased. Other processes associated with metal working are those appertaining to finishing the surfaces. These include the production of a lustrous surface by polishing and the maintaining of that surface by lacquering. The latter process is dealt with in this Encyclopedia under its proper heading.

Other processes include the colouring of metal, grouped under the general title of oxidizing, and operations that are carried out by chemical and electrical processes, and are described under the heading of Oxidizing. *See* Aluminium; Brass; Forging; Lacquering; Lathe.

METRE. Standard unit of length in the metric system of measurement. The metre is approximately 39·37 inches. *See* Metric System.

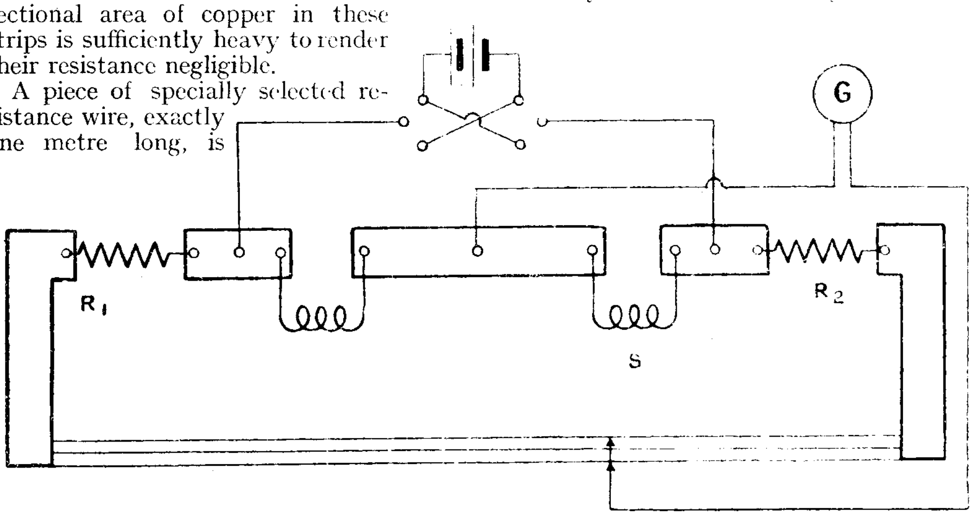
METRE BRIDGE. A standard form of metre bridge, by which really accurate resistance measurements may be taken, is illustrated in Fig. 1. Five copper strips, which are clearly shown, are mounted upon a mahogany baseboard. Terminals are provided at the ends of each strip, and at the centres of three of them. The sectional area of copper in these strips is sufficiently heavy to render their resistance negligible.

A piece of specially selected resistance wire, exactly one metre long, is stretched tightly between the tips of the bent strips at the ends of the base. An accurate scale, divided into the usual metric divisions, is fitted near to and parallel with the wire.

The little brass object shown near the centre of the wire is a sliding contact, which has a pointer projecting from its side nearest to the scale. Connexion from this slider is taken to the terminal in the centre of the middle copper bar, as in indicated in the diagram Fig. 2. A galvanometer is inserted in this lead, and between the two points just mentioned.

In the diagram, Fig. 2, P is the resistance to be measured, and S another resistance whose value should be approximately equal to P. Further resistances R_1 and R_2 have also to be used, these being of somewhat similar value to P and S. This bridge is similar to the Foster bridge, under which heading the method of employing it is fully described. *See* Bridge; Foster Bridge.

METRIC SYSTEM. System of weights and measures based on the metre. The metric system is a decimal system. For



HOW A RESISTANCE IS MEASURED BY THE METRE BRIDGE

Fig. 2. Connexions of the metre bridge are shown. P is the resistance being measured, and S another resistance whose value should be approximately equal to P. R_1 and R_2 are other resistances nearly equal to P and S

COSMOS SET

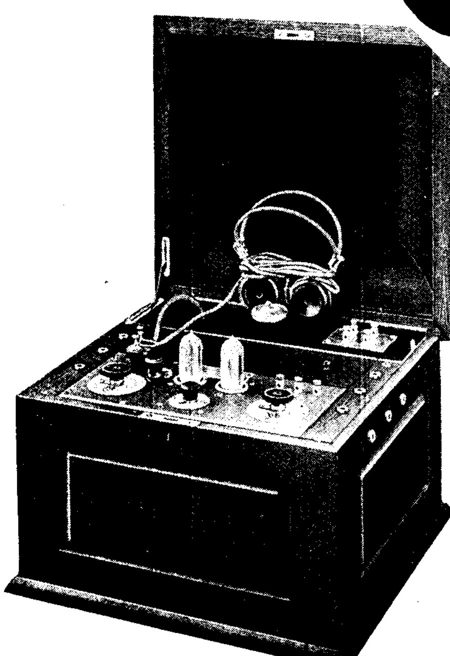
Fig. 1. Cosmos crystal set with telephones. This is variometer tuned

Courtesy Metropolitan-Vickers Electrical Co., Ltd.

measurements and weights above the unit Greek prefixes are used, as kilo for a thousand times, hecto for a hundred times, and so on. For measurements and weights which are submultiples of the units Latin prefixes are used, as milli for one-thousandth, etc. Thus a kilometre is a thousand metres, a millimetre a thousandth part of a metre. The unit of weight is the gram, and of length the metre. *See* C.G.S.; Units.

METROPOLITAN-VICKERS. Name of an important firm manufacturing wireless apparatus. Fig. 1 shows a small crystal receiving set. The whole is contained within a polished wood case with a hinged lid, and tuning is effected by means of a variometer. The crystal detector is mounted on the top of the ebonite panel and the variometer beneath it. Fine adjustment is provided on the crystal, to ensure getting maximum sensitivity and purity of reception. A baize-lined compartment is formed within the case, and this serves to receive the telephones when not in use.

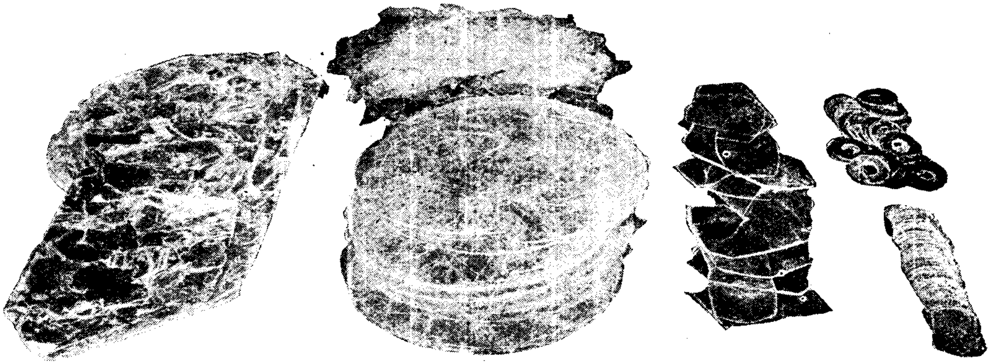
A similar crystal set, with the addition of a two-valve amplifier, is illustrated in Fig. 2, and is in substance a standard crystal set with a two-valve low-frequency amplifier which fits into the compartment otherwise occupied by the telephones. With such an arrangement, loud-speaker results are obtained from the set in any location where the plain crystal gives reasonably good signals, *i.e.* within 20 miles of a broadcasting station.



METROPOLITAN-VICKERS APPARATUS

Fig. 2 (top). Added to a Cosmos crystal set is a two-valve amplifier and loud speaker. Fig. 3 (left). This is a two-valve Cosmos set for use with telephones

Courtesy Metropolitan-Vickers Electrical Co., Ltd.



SPECIMENS OF MICA AS EMPLOYED FOR WIRELESS PURPOSES

Various specimens of mica are shown. Mica is a semi-transparent mineral which easily splits up into plates, and its high insulating value causes it to be largely used in electrical work, particularly in the construction of fixed condensers

Courtesy Micanite and Insulations Co., Ltd.

A two-valve set is shown in Fig. 3. The whole is built into a cabinet, and is typical of a large range of receiving sets manufactured by the company and marketed under the trade name of Cosmos.

MFD. This is the usual contraction for microfarad, a millionth part of a farad, and the usual unit of measurement of capacity of condensers, etc., such as are used in wireless. *See* Capacity; Electrostatic Units; Units.

Mg. Chemical symbol for the metallic chemical element magnesium (*q.v.*).

MHO. The unit of conductance. As conductance is the reciprocal of resistance, it is measured by the reciprocal ohm or mho, which is simply ohm spelt backwards. *See* Ohm.

Mhy. This is the standard abbreviation for microhenry, the millionth part of a henry, the unit of inductance. *See* Henry.

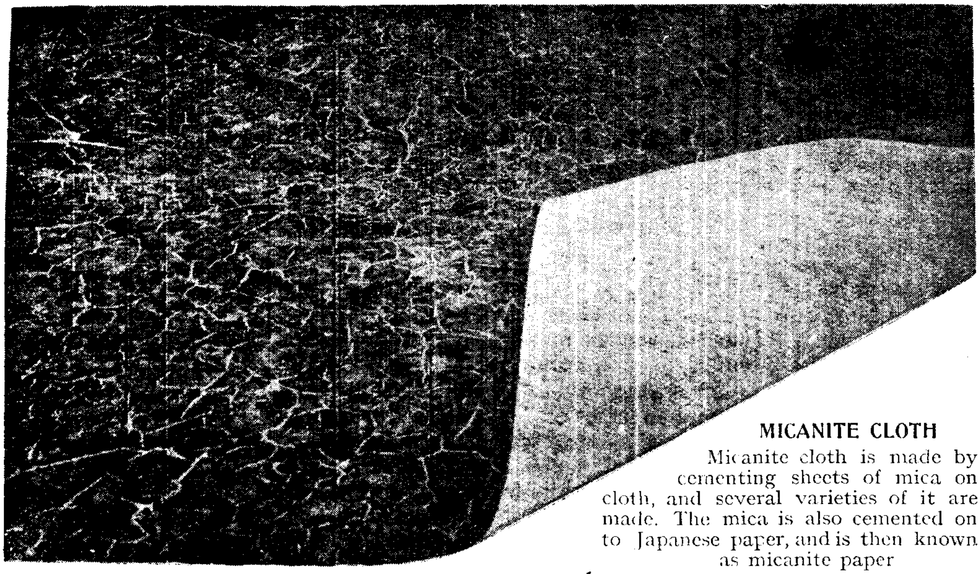
MICA. Insulating material largely used in electrical work. Mica is the general name given to a group of widely distributed rock-forming minerals which are remarkable for their easy cleavage into thin plates, their elasticity and toughness, and their high value as insulators. It is transparent, and owing to its resistance to fire and sudden changes of temperature is largely used for chimneys of lamps, windows for stoves, lanterns, etc. Moulded mica is used as a substitute for hard rubber. Mica softens at a temperature of 1136° F.

The dielectric strength of mica varies greatly according to its quality. The laminae of mica are generally separated and sorted into various grades of purity, and then cemented together to form plate or flexible reconstructed mica of any required thickness or purity. It is obtainable in flat sheets, circular sheets, washers, etc., and the photograph shows some of the various forms in which it is sold. The dielectric constant is, according to Kaye and Laby, 5·7 to 7, but other observers have obtained as high a value as 8 and as low a value as 4 with good mica. The dielectric strength varies from 17,500 to 28,000 volts per millimetre, but this is greatly reduced when the mica is coated with oil or immersed in it.

For the wireless amateur the most extensive use of mica is in the construction of fixed condensers. When buying it the purchaser should see that the mica is free from cracks and holes, and that it is of even thickness and of an even colour throughout. The presence of streaky patches of different colours indicates the presence of other minerals, which may be good conductors and ruin the mica as a dielectric. The mica, in any case, should be obtained from a reputable wireless firm, or from a firm which specializes in electrical supplies. *See* Condenser, page 486; Dielectric; Insulation.

MICANITE. This is a prepared form of mica which consists of picked sheets of mica cemented together with an insulating cement and by intense heat. It is of more even texture than single sheets of the unprepared mineral, and it has the advantage that with several sheets so moulded together faults do not come opposite one another, and the insulation is better. Micanite is prepared by the Micanite and Insulations Company, Ltd. *See* Dielectric.

MICANITE CLOTH. This is a prepared insulator made by cementing sheets of mica on to cloth. The photograph shows a piece of micanite cloth folded over at one corner, showing the different texture of the two sides. A similar cloth is known as micabond cloth, and is made of muslin, Indian mica, and paper, with a binding material consisting of gutta-percha tissue. Micanite paper and micabond is made of Japanese paper, mica, and rubber, and makes an excellent insulating material. *See* Insulation; Mica.



MICANITE CLOTH
Micanite cloth is made by cementing sheets of mica on cloth, and several varieties of it are made. The mica is also cemented on to Japanese paper, and is then known as micanite paper

MICARTA. A mica compound insulating material largely used in electrical work. It is a hard tan-coloured homogeneous material, which has a mechanical strength fifty per cent greater than that of hard fibre. It is for this reason extremely useful in the manufacture of commutator bushings, brush holder insulation, and for all purposes for which ebonite may be used.

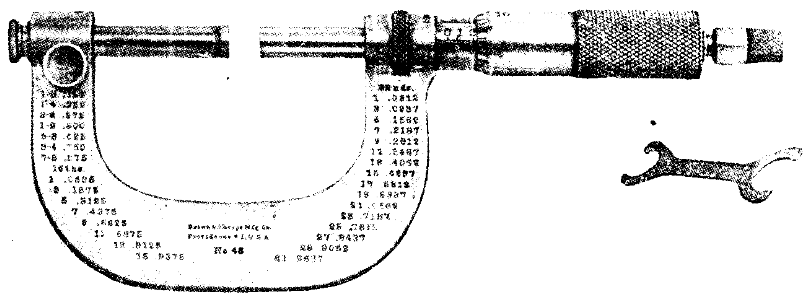
It can be used, for example, for insulating knobs and control handles of condensers, rheostats, etc. Like ebonite, it can be milled, turned, tapped, and threaded. It is not brittle, and does not warp under any normal conditions, and will take a high polish. It has the advantage of being insoluble in most of the ordinary solvents, as alcohol, oil, hot water, etc., and is impervious to moisture. *See* Bakelite; Ebonite.

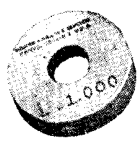
MICRO. Latin prefix which is used for one-millionth. Thus a microfarad is the one-millionth part of a farad, and is the practical unit of capacity. It is usually abbreviated to mfd. Similarly, a microhenry is the millionth part of a henry (*q.v.*); a microhm is the millionth part of an ohm, etc. The prefix occurs in such words as micrometer, which means a measuring instrument which is capable of measuring very accurately down to very small fractions of an inch; a microphone, which magnifies very small sounds, etc. *See* Electro-magnetic Units; Electrostatic Units; Farad; Units.

MICROMETER. Measuring instrument, by means of which objects in any reasonably hard material may be measured with great accuracy. A standard form of micrometer is illustrated in Fig. 1. This instrument will measure any object whose dimensions do not exceed 2 in., and with a limit of error of one-thousandth of an inch.

It consists essentially of a horseshoe-shaped frame of steel, which must be very rigid, and which has at one end a stop, known technically as the "anvil." The other limb of the frame carries a threaded nut, into which the spindle fits. The latter is threaded with the same pitched screw as the nut, and it is surrounded by a graduated scale known as the thimble. This is knurled at its end, in order that it may be conveniently gripped by the finger and thumb without much pressure being necessary.

The nut is usually split in order that any wear may be automatically taken up by the natural springiness of the material





STANDARD BROWN & SHARPE 2 IN. MICROMETER

Fig. 1. In the centre is the micrometer, on the left is a standard 1 in. disk for testing, and on the right is an adjusting key

Between the nut and the frame a long sleeve is placed, this being an integral part of the frame and graduated on the outside, first into tenths of an inch, and secondly each tenth into fortieths of an inch. The thread with which the nut and the spindle fitting in it are cut has a pitch of forty threads per inch.

Thus one revolution of the thimble will move the spindle through a distance of one-fortieth of an inch. The thimble, however, is itself divided into twenty-five equal divisions, so that 40 × 25 being equal to 1,000, it will be seen that the rotation of the thimble through one of its divisions will cause the spindle to travel one-thousandth of an inch. Thus by a combination of the readings on the spindle and thimble it is possible to measure any distance from ·001 in. to 1 in.

The particular micrometer illustrated is fitted with an extension piece which is adjustable, and which allows a maximum distance of 2 in. to be measured. It will be seen that the left-hand side of the frame is fitted with a locking screw (Fig. 1). By undoing this screw it is possible to move the anvil backwards or forwards as desired, to measure large or small objects.

To obtain really accurate results with the micrometer it is essential that a very light touch be used. The correct way to hold it is shown in Fig. 2. It will be seen that the frame is held in the palm of the right hand, the thimble being held between the thumb and first finger. The object to be measured is held in the left hand, and the thimble of the micrometer is rotated so that the object is gripped lightly between the anvil and the end of the spindle. Let us take, for example, the setting of the micrometer so that objects of 1 in. or less may be measured.

To do this it is necessary to use the circular gauge shown in Fig. 1. Loosen the locking screw on the left-hand end of the frame, so that the anvil spindle slides freely in its housing. Rotate the thimble so that the first division on the latter is exactly in line with the horizontal line on the sleeve. This will set the end of the screwed spindle at zero. The next step is

MICROMETER IN USE

Fig. 2. How the micrometer is used, and how to hold it while measuring a piece of work is clearly shown in this photograph

to hold the gauge against the end of the spindle so that the flat surface of the latter forms a tangent with the circumference of the gauge. This will bring the opposite side of the gauge in line with the anvil, and the latter should now be pushed hard up against the periphery of the gauge and the lock nut tightened. The accuracy of this setting may now be verified by loosening the thimble and screwing it up once more, when it should again read zero.

Assume now that a piece of wire is to be measured for the purpose of ascertaining its gauge. For this purpose all covering matter should be removed, since the gauge of a wire is necessarily given without its insulation, and the wire gripped lightly in the micrometer. On reading the scales it is found that the thimble has not uncovered any of the divisions on the horizontal scale, so that we know that the diameter of the wire is less than ·025 in., or one-fortieth of an inch.

Therefore the complete reading will be round the end of the thimble. This we will assume to be in such a position that the twenty-second division is in line with the horizontal line on the sleeve. From this we know that the end of the spindle is twenty-two thousandths of an inch from the anvil. This is the thickness of the wire, and would be written as ·022 in. Reference now to a table of the Standard Wire Gauge (S.W.G.) would show the gauge of the wire to be No. 24.

The measurement of a larger object, such as a brass bush for a condenser or filament resistance, would be carried out in a similar manner. Assuming that the thimble had uncovered four large and two small divisions on the sleeve, and that the third division on the thimble was coincident with the line on the sleeve, the measurement would be four-tenths plus two-fortieths plus three-thousandths, which equals ·453 in.

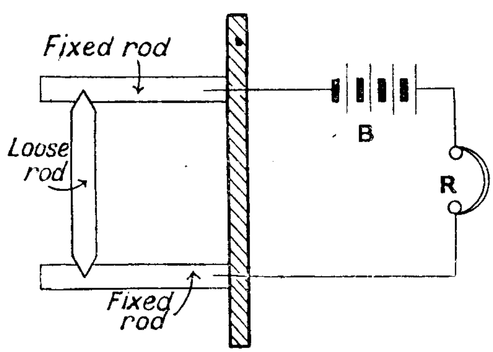
It is absolutely essential when taking any measurements with a micrometer that the surfaces of the object to be measured and the micrometer should be perfectly clean, for a particle of grit may easily measure ·001 in., and thus make an error in reading. The micrometer itself is readily cleaned by placing a piece of clean paper between the spindle-end and the anvil, screwing the former up just as though the paper had to be measured, and then pulling the paper backwards and forwards. Any dirt on the metal surfaces will be found to adhere to the comparatively rough surface of the paper. No abrasives of any kind should ever be used. Even the finest emery paper, however lightly applied, will wear down the contact points of the instrument, and so make it inaccurate in its readings. *See* Caliper; Gauge.

MICROMETER SPARK GAP. This is a small adjustable spark gap in the aerial circuit of a multiple tuner (*q.v.*). It is adjustable by means of a screw, the pitch of the thread of which is such that one turn of the screw lessens or increases the distance between the electrodes by one-hundredth of an inch. It allows heavy charges to spark across to earth.

MICROPHONE OR MICROPHONE TRANSMITTER. A microphone transmitter is an instrument used in an electrical current for transforming sound waves into an electrical current the amplitude of which varies in sympathy with the sound waves.

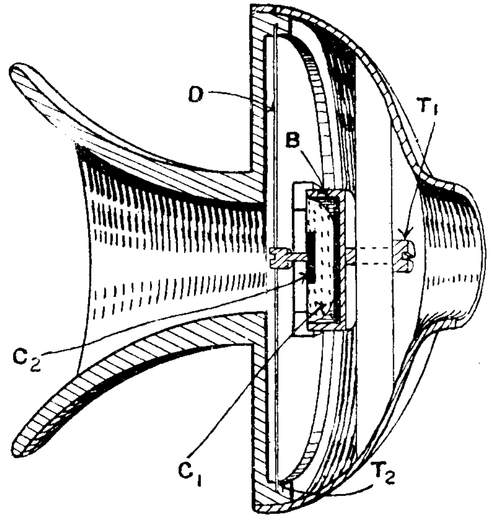
A steady electro-motive force applied to a circuit containing a variable resistance will produce a current in the circuit which will vary according to whether the resistance is increased or decreased. If the resistance can be varied by means of sound waves any sound affecting the resistance will cause the current in the circuit to vary, thus producing a similar sound in a receiving instrument connected in the circuit.

The simplest form of variable resistance microphone is that shown in Fig. 1. A loose-fitting carbon rod pointed at the ends rests in holes in top and bottom carbons attached to a sounding board. While the vertical rod is undisturbed a steady current will flow from the battery B and will not affect the telephone receiver R. When the sounding board vibrates, the



SIMPLE CARBON MICROPHONE

Fig. 1. Represented in this diagram is the simplest form of variable-resistance microphone



SOLID-BACK MICROPHONE

Fig. 2. Principles of working of a solid-back microphone are shown in this sectional view of the instrument

contact resistance of the rod will vary, causing a varying current in the circuit, which will actuate the diaphragm of the receiver in sympathy with these vibrations.

There are many types of variable resistance microphones in use, the most common being the solid-back type, used for commercial telephone services.

The main features of the solid-back type are shown in Fig. 2. The small metal box (B) is filled with fine carbon granules. In the back of the box is fixed a carbon electrode, C_1, while the front is closed with a thin mica disk, to which is fixed the carbon electrode C_2. The front disk is attached by means of a small screw to a thin diaphragm D, held rigidly round its edge. Electrical contact is made to the diaphragm D and to the metal box B.

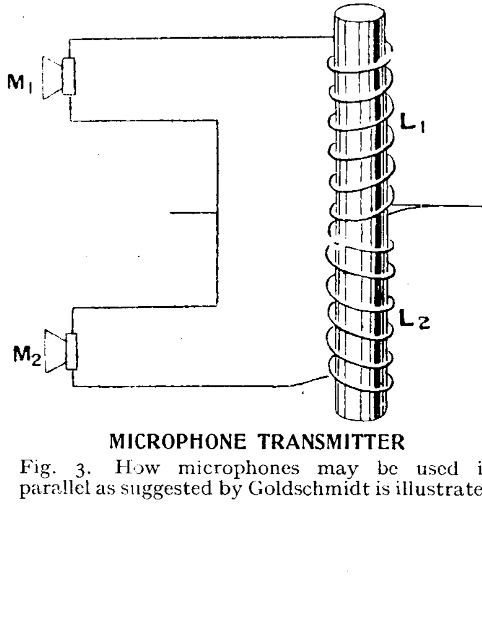
Thus any current in the circuit will pass via the diaphragm and front electrode C_2 through the carbon granules and the electrode C_1. Hence, when sound vibrations affect the diaphragm it will be caused to vibrate, and these vibrations, being imparted to the electrode C_2, will cause the resistance of the carbon granules between C_2 and C_1' to vary, since the resistance to the passage of the current will be greater when the granules are loosely packed than when they are tightly packed.

This type of microphone is only capable of carrying up to about an ampere without overheating, and is therefore useless for modulating directly a wireless telephone transmitter except for very small powers. In the case of transmitters with an input of more than a few watts it is usual to connect the microphone in a local valve circuit and to use the valve as an amplifier of the current variations produced by the sound waves. If necessary the amplified currents are passed through one or more valves until the variation of current is sufficiently great to control efficiently the wireless transmitter.

One of the most serious defects of this type of microphone is its tendency to "pack," especially if at all overloaded. Packing is generally caused by heating of the granules, thus causing them to adhere to one another, or by not holding the microphone in a vertical position. The defect is evidenced by bad speech distortion, and can usually be remedied by gently shaking the microphone.

When large currents have to be dealt with several microphones can be connected in parallel or in series-parallel, and so arranged that they are all equally affected by the sound waves. In practice, however, this is not easy to accomplish, as it presupposes that each microphone is acted upon to an equal extent by the sound vibrations and that no local currents circulate round the microphones owing to any differences between their electrical resistances.

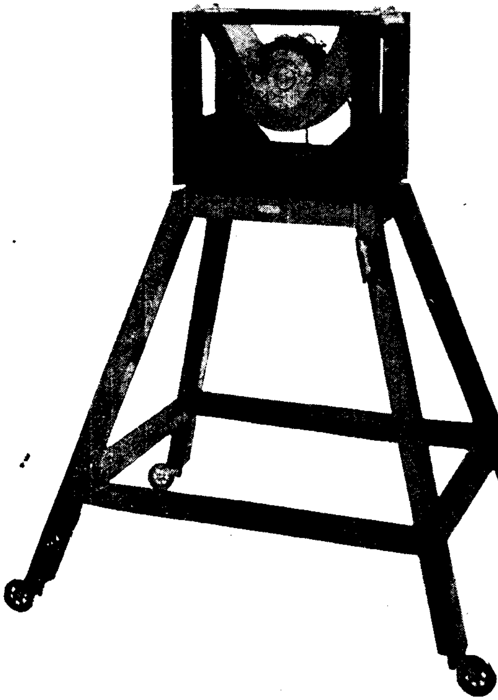
One of the simplest methods of using microphones in parallel was devised by R. Goldschmidt, the connexions of the arrangement being shown in Fig. 3. The microphones M_1 and M_2, each connected in series with a coil, are connected in parallel,



MICROPHONE TRANSMITTER

Fig. 3. How microphones may be used in parallel as suggested by Goldschmidt is illustrated

but the two coils are wound in opposition on an iron core. If the currents through the two microphones are equal, the current through the coils L_1 and L_2 are equal, and no magnetic flux is set up in the core. If, however, the currents of the two microphones are not equal the out-of-balance current will cause the core



MARCONI BROADCASTING MICROPHONE

Fig. 4. Stations of the British Broadcasting Company use this form of microphone. It is remarkable for its extraordinarily faithful reproduction of music and the human voice

Courtesy Marconi's Wireless Telegraph Co., Ltd.

to become magnetized and will be choked down by inductance of the core.

Besides the variable-resistance carbon-granule type of microphone there have been designed several forms of liquid microphone. In this type a stream of liquid is made to impinge on a plate. The contact resistance of the liquid with the plate is then modulated by the voice. An advantage of the liquid microphone is that the medium forming the variable contact, *i.e.* the liquid, is continually being replaced, and therefore overheating is prevented. This type, however, should be used to modulate an alternating and not a direct current, on account of electrolysis effects when used with the latter.

The microphone illustrated in Fig. 4 is known as the Marconi "L" type microphone, and it is the instrument which came into universal use by the B.B.C. for all purposes during the year 1923. This instrument is of the electro-dynamic type; that is to say that there is a field magnet, energized from some local source of supply, and a second coil carrying the current modulated by the sounds to be recorded.

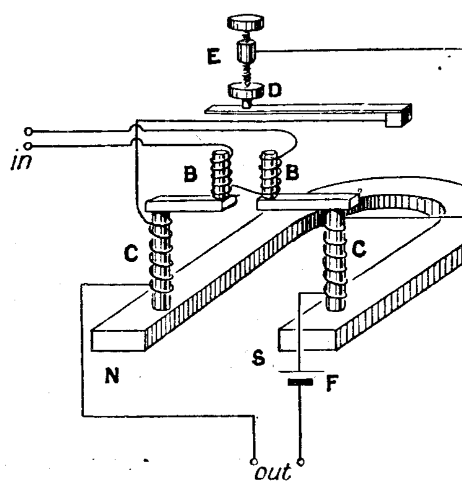
The microphone rests upon a thick band of Sorbo rubber, which effectively prevents noise intrusion through vibration of the building in which it is placed. A stout wooden framework supports the rubber band. The whole apparatus is, again, supported upon a wooden structure fitted with wheels to enable it to be conveniently moved about the studio. The switch controlling the microphone may be seen mounted upon the right-hand leg of the framework.

This instrument was chosen not because of its great sensitivity, but more on account of its extraordinarily faithful reproduction of music and the human voice.—*R. H. White.*

See Broadcasting; Jervis-Smith Microphone; Majorana's Microphone; Manometric Flame; Sound; Telephone.

MICROPHONIC AMPLIFIER. The microphonic amplifier invented by S. G. Brown is illustrated in Fig. 1.

It consists of a permanent horseshoe magnet N, S, which has mounted on its



MICROPHONIC AMPLIFIER PRINCIPLE

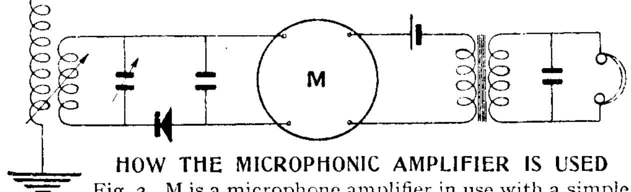
Fig. 1. From this diagram may be gathered the principle of the action of the microphonic amplifier

two poles the coils C, C, having soft iron cores. These cores are attached to the horseshoe magnet at one end, and at the other carry extension pieces made of soft iron. Each of the extensions has wound on it a coil B. There are two of these coils B, and they are connected in series. The incoming signals pass through them.

Mounted above these pole tips is an armature or reed made of Invar, a form of nickel steel. This reed is set so that it is quite near to the pole tips. The reed carries on its upper surface a button of hard carbon D, whilst a contact screw E, having an iridium tip, makes microphonic contact with the carbon. This contact closes a circuit consisting of the telephones, loud speaker, or other apparatus in which the magnified signal current is required.

The current from a local battery F flows through the coils C, C, the contact D, E, and the external apparatus.

It will be seen that as the reed is in a magnetic field, any variable direct current passing through the coils B, B will cause the reed to move. This movement will disturb the microphone contact, which will cause a larger current to flow through the external apparatus, as well as through the coils C, C.



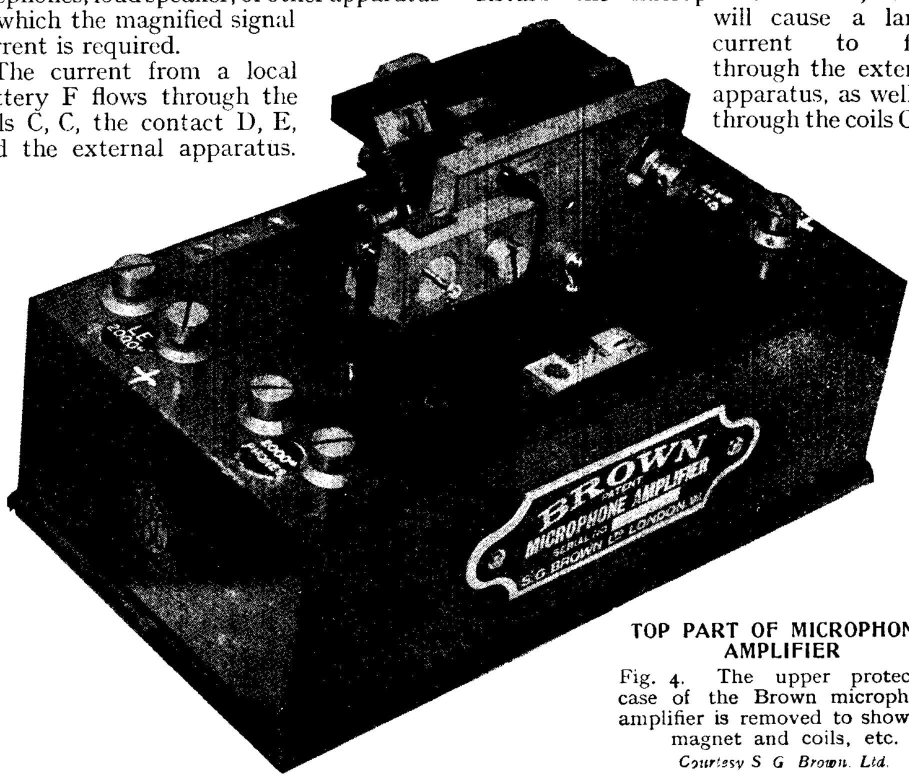
HOW THE MICROPHONIC AMPLIFIER IS USED

Fig. 2. M is a microphone amplifier in use with a simple crystal set

BROWN MICROPHONIC AMPLIFIER

Fig. 3. By using this amplifier an increase in volume is claimed equal to two stages of ordinary L.F. amplification

Courtesy S. G. Brown Ltd.



TOP PART OF MICROPHONIC AMPLIFIER

Fig. 4. The upper protecting case of the Brown microphonic amplifier is removed to show the magnet and coils, etc.

Courtesy S G Brown. Ltd.

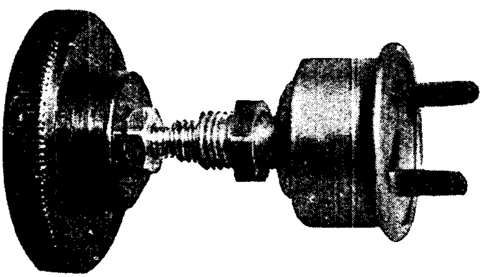
Two or more microphonic amplifiers may be coupled in cascade in a similar manner to that now so generally adopted with thermionic valves. The amplifier only requires a single dry cell for ordinary telegraphic purposes.

The principle illustrated has been employed with modifications by S. G. Brown in many of his sound amplifiers.

A simple receiver circuit employing the Brown amplifier is illustrated in Fig. 2.

Figs. 3 and 4 show the Brown microphone amplifier with and without the upper case. *See* Amplifier; Loud Speaker; Relay.

MICROSTAT. Trade name applied to a patented form of filament rheostat, an illustration of which appears in the figure. The container at the bottom is a brass



MICROSTAT FILAMENT RESISTANCE

The instrument shown depends upon the varying resistance of carbon granules under pressure

Courtesy Waites Bros.

pressing which holds carbon granules. One of the tabs projecting through the base of the instrument is insulated from the main stamping and forms one connexion. The second is attached to the brass case itself.

The top of the container is fitted with a screwed gland in which a spindle having a piston-like end is fitted. The rotation of the knob to the right causes the piston to be screwed down, which action compresses the granules and lowers the resistance. The reverse action follows when the knob is rotated counter-clockwise.

It is essential that the knob be locked extremely tightly upon the spindle, otherwise it will tend to become unscrewed, since the movement of the spindle is relatively left-handed. The action of the instrument is stated to be very progressive, and it is said to allow of very minute changes of resistance from a low minimum to a high maximum. There is no off position for the microstat. *See* Filament Resistance.

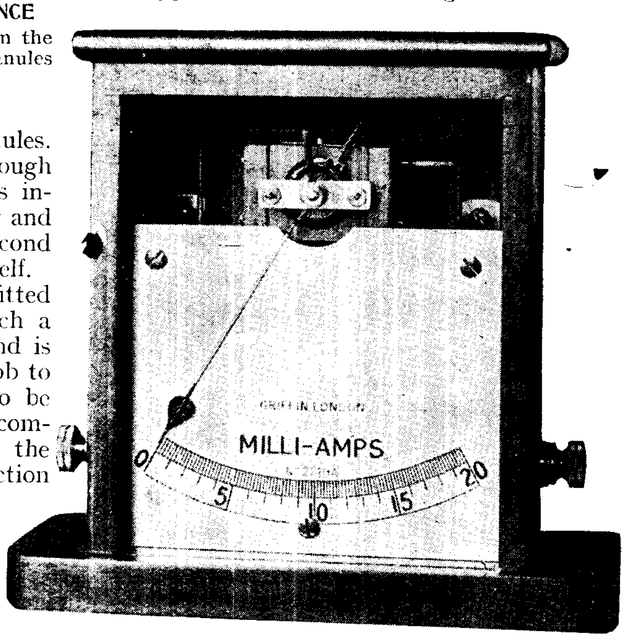
MIL. One-thousandth part of an inch. This is a measurement used in the foot-pound-second system of units. In the Birmingham wire gauge the sizes of the wires are given as so many mils. Thus the diameter of No. 17 gauge wire is 58 mils, or $\frac{58}{1000}$ in., and that of 22 gauge is 28 mils, or $\frac{28}{1000}$ in. The standard wire gauge sizes, the only legal standard wire gauge in England, are also stated in mils.

MIL-FOOT. This expression is sometimes used of a wire which is 1 ft. in length and which has a diameter of 1 mil.

MILKY ACID. This term is generally used for accumulator acid which has become so full of gas bubbles as to appear milky. *See* Accumulator.

MILLI. Prefix which is used to indicate the thousandth part. Thus a milliampere, or milliamp., is the thousandth part of an ampere; a milliammeter is an ammeter which measures a current by the one-thousandth of an ampere.

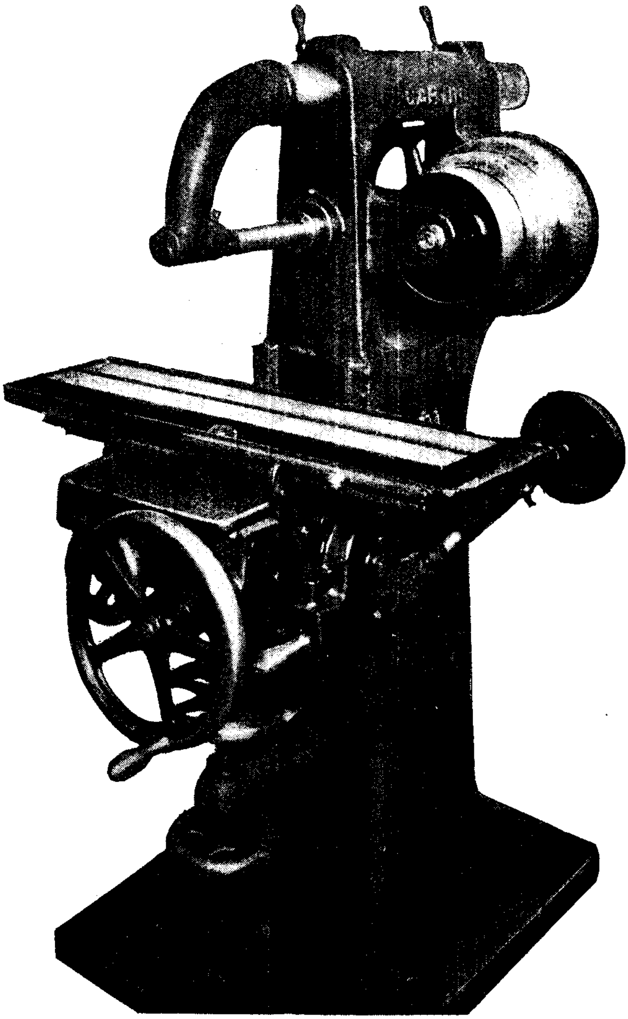
MILLIAMMETER. The milliammeter shown in the figure is of the moving-coil type, and is in a mounting which renders

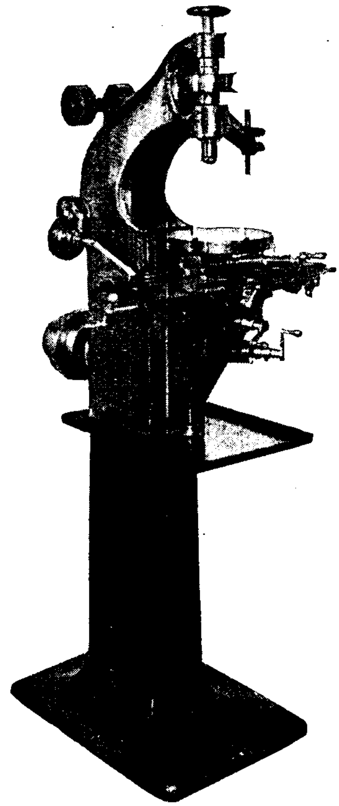


INSTRUMENT FOR MEASURING MILLIAMPERES

Milliamperes from 0 to 20 are measured by this instrument, which works on the moving coil system

Courtesy J. J. Griffin & Sons





MILLING MACHINES

Fig. 1 (left). Wireless parts are frequently milled on a plain machine of this pattern. Fig. 2 (above). This is a vertical milling or profiling machine with an additional geared table capable of cutting intricate shapes

Courtesy Burton Griffiths & Co., Ltd.

it suitable for laboratory use. The movement in the case is inverted, and the magnet, together with its pole-pieces, and also the moving system, may be clearly seen in the top of the picture.

The instrument is scaled to read from 0 to 20 milliamperes, although this range may be increased by the connexion of a suitable shunt. A glass panel in front of the instrument excludes all possible entry of dirt, and protects the movement from moisture from the atmosphere. The terminals are carried in bushes mounted upon the sides of the polished wooden cabinet. *See* Ammeter.

MILLIMICRO. This is a combination of milli, meaning one-thousandth, and micro, meaning one-millionth, so it is equivalent to a thousand-millionth, that is one-billionth part. The term billi is often used in its place, as in such expressions as billi condenser (*q.v.*), which is a condenser capable of fine adjustment and having a very small capacity. *See* C.G.S.; Units.

MILLING. General term used in metal working to describe all those processes in which a rotating cutter removes metal by passing the latter across the face of the cutter. Milling is a comparatively modern development, and with the aid of suitable tools, accurate and expedient shaping of metal or fibre is accomplished. The home worker intending to carry out much experimental work, and having power available for driving small machine tools, can well utilize a plain milling machine, such as the Garbin, illustrated in Fig. 1.

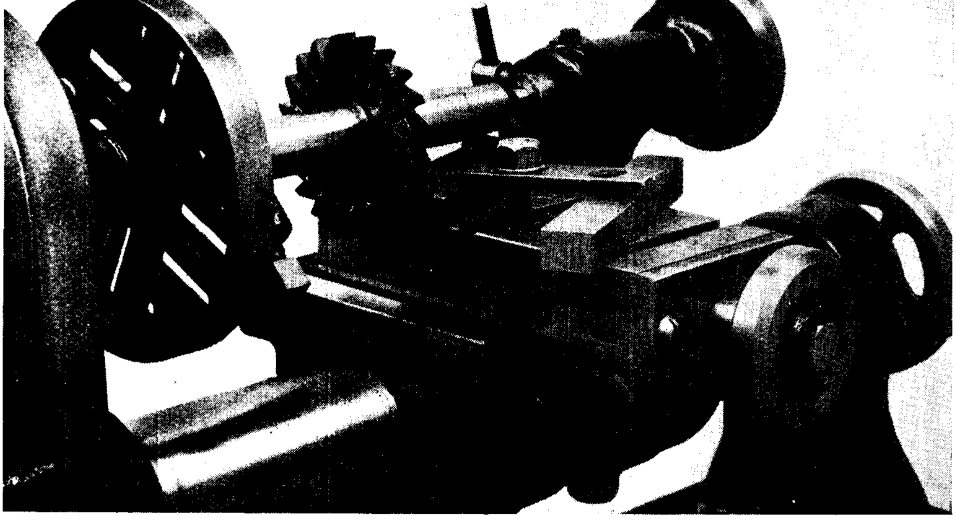


Fig. 3. In this round-bed Drummond lathe is a milling cutter ready to operate upon the work in place on the saddle. The milling cutter is on the mandrel, driven between centres by means of the usual lathe carrier rotated by a driving pin attached to the lathe face plate

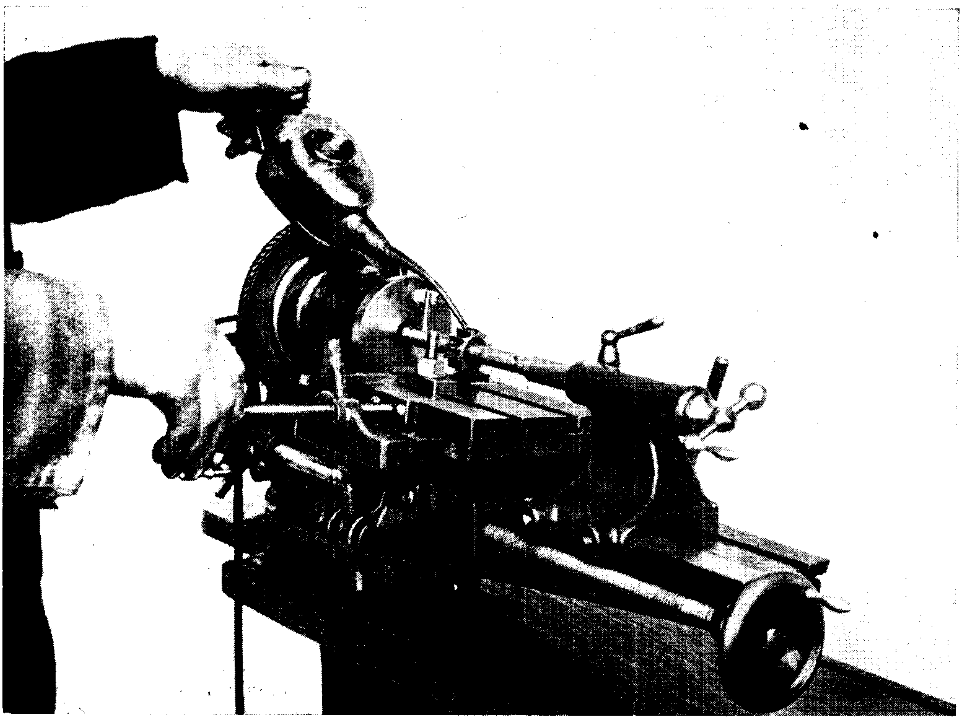


Fig. 4. On this small lathe, as used by many amateurs, the J.R. milling attachment is seen in use. The work is mounted on the milling table, which can be raised or lowered and traversed across or along the bed at will

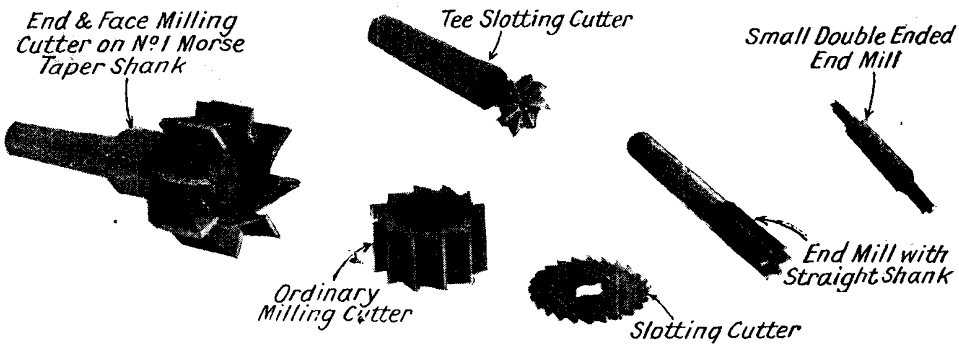
This general class of machine is available from quite small sizes suitable for use on the work bench. In essence it comprises a horizontal table whereon to mount the work to be milled. By means of hand wheels this table can be moved in two directions at right angles to each other, and also raised or lowered. The belt pulley seen on the right of the machine drives the mandrel or cutter spindle through reducing gearing.

The spindle proper has a tapered end, and fits into a tapered hole in the mandrel, the outer end of the cutter spindle being supported by a bearing in an overhanging arm.

Another type of machine is illustrated in Fig. 2, and is known as a vertical milling machine. In this case the cutter spindle is vertical, and in addition to the plain table already described a second circular table is mounted above it, and by means of worm gearing can be revolved upon a central bearing. Consequently, this type of milling machine is able to produce all manner of intricate shapes, either with curved or plane surfaces, and for this reason is sometimes known as a profiling machine.

When power is not available, milling operations must be restricted to some extent, and the best way to tackle them is by the use of some form of milling attachment in conjunction with a well-built metal-turning lathe. Some lathes, such as the round-bed Drummond, can be used for many milling operations by the use of milling attachments used on the mandrel and milling cutter, which are normally mounted between centres while the work is operated, or the top slide, which has T-slots machined in it for reception of the holding-down bolts. A typical operation of this character is illustrated in Fig. 3.

On most ordinary screw-cutting lathes suitable for amateur work milling in any practical form can only be carried out with a milling attachment, and one such device, as applied to the J.R. lathe, is shown in operation in Fig. 4, which also shows the ordinary milling cutter mounted on the mandrel between centres, and driven in the usual way with a driver peg through the driver plate. It should be noticed that in milling operations of this character the lathe should be run at its slowest speed.

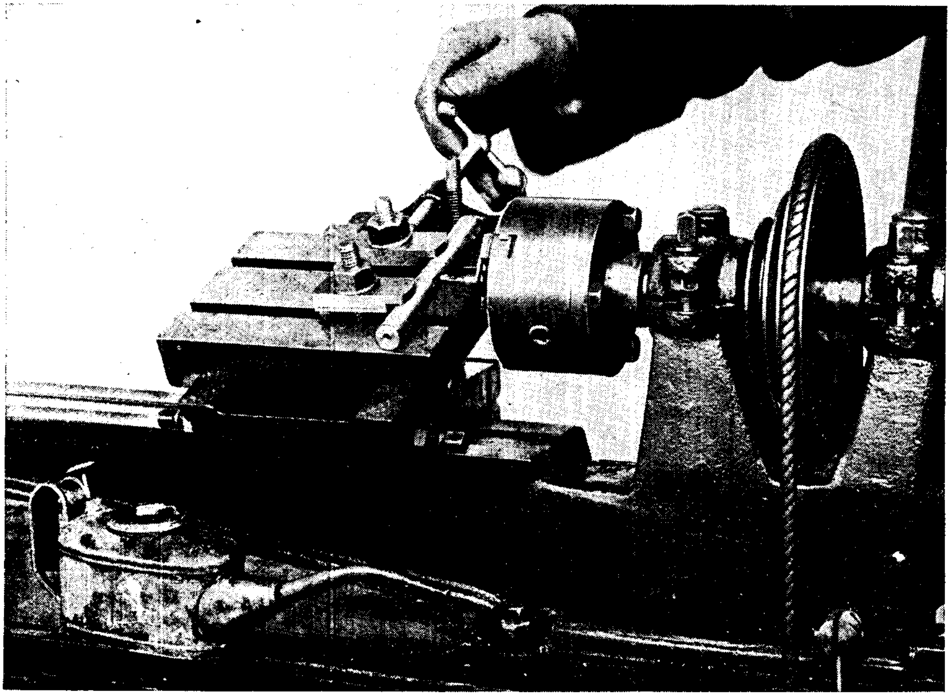


MILLING CUTTERS FOR SHAPING WIRELESS COMPONENTS

Fig. 5. A selection of cutting instruments particularly useful for milling purposes, a necessary process in the making of various wireless components, is shown in this photograph. Their names are placed alongside as a means of reference for the amateur who possesses a lathe, with which these tools are used

In the example illustrated the work is held down to the slotted table, which is arranged to slide on a pivoted plate which is itself capable of being raised or lowered by means of a right- and left-hand screw thread at the front part of the apparatus. Consequently a fine regulation of the depth of cut is possible.

The saddle of the milling attachment is traversed along the bed by means of the lead screw, and is fed across the bed by a separate screw rotated by a detachable handle. With such an arrangement a wide variety of operations can be performed with small cutters. The appliance provides all the requisite movements for amateur milling operations, and has the merits of rigidity, strength, and steadiness of action under heavy cuts. A useful selection of milling cutters is illustrated in Fig. 5. This class of milling cutter is usually made either to affix to a plain mandrel, or as an



HOW A ROUND BAR IS END-MILLED

Fig. 6. Here a small shaft or round bar of metal is being end-milled to form a key-way. The method of setting up the metal worked should be noted

integral shank. That on the left is a No. 1 Morse taper shank, and simply fits into the correspondingly shaped hole in the mandrel nose. Similar cutter circular shanks can be screwed into a collet chuck or an accurate three-jaw self-centring chuck.

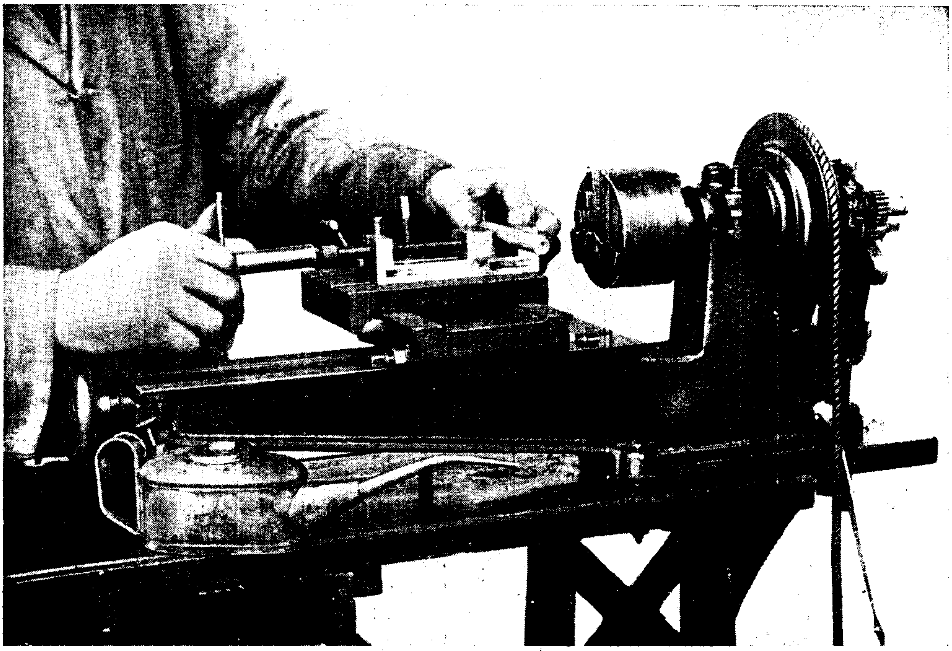
For milling flat surfaces, the end and face mill, which is one that cuts on the outer periphery and also on its outer face, is very useful. An alternative is a plain milling cutter with teeth on its outer periphery. Slots are usually cut with a thin cutter, very much like a small circular saw. Other slots are cut with end mills, which are simply small cutters with four or six cutting faces, the appearance of which is clearly visible in Fig. 6. T-slots are usually machined with a special cutter made for the purpose, an example of which is illustrated at the upper part of Fig. 5, and comprises a small diameter cutter having a narrow neck and a No. 1 Morse taper shank.

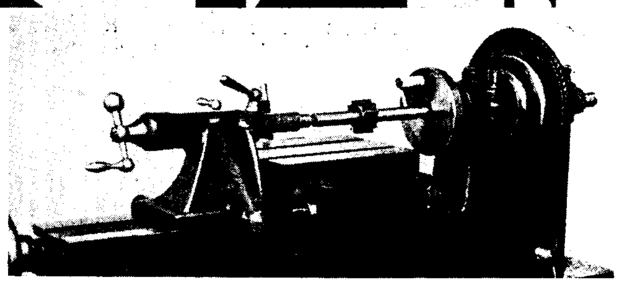
The size and proportion of milling cutters should be selected according to the nature of the material and the size of the work to be machined. As an average for wireless work, the smallest commercial cutters up to 2 in. in diameter will be satisfactory when used with the average 3 to $3\frac{1}{2}$ in. centre lathe such as that illustrated.

The work to be milled is usually secured to the saddle or milling table by means of clamps, which are simply flat plates of metal held down by bolts, which pass through holes drilled in them, the heads of the bolts resting within the T-slots. The clamps should normally be horizontal, packing blocks being used, as needful, to elevate the end opposite the work.

This method of clamping the shaft to the milling table, for the operation of end-milling or cutting a key-way, is clearly illustrated in Fig. 6. Alternatively, the shaft or other piece of work can be held in a small machine vice clamped to the saddle as illustrated in Fig. 7. Such a fitting is well worth the extra cost, as it enables a multitude of small objects to be grasped and held firmly in almost inaccessible positions and saves much time.

Whenever possible the milling cutter should be mounted on the mandrel, and rotated between centres in the manner clearly illustrated in Fig. 8, which shows





MILLING METHODS

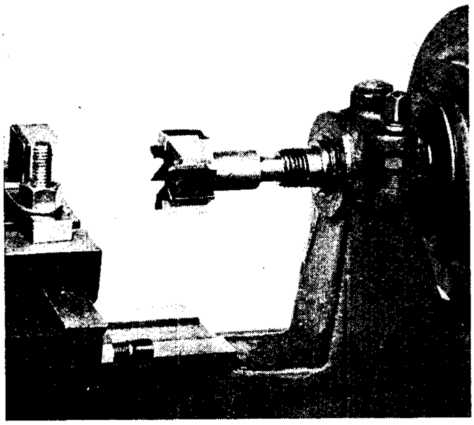
Fig. 7 (above). In place of clamp plates and bolts a machine vice clamped to the saddle may be used for holding small work. Fig. 8 (right). This photograph shows the method of mounting a milling cutter on a mandrel between centres

a $1\frac{1}{2}$ in. diameter by $\frac{3}{4}$ in. face-plate milling cutter mounted in position. When work of a key-way character is to be machined, and it can only be reached with a very fine mill, the pattern which fits directly in the end of the mandrel nose, as illustrated in Fig 9, is to be preferred, as this allows much greater scope for placing the work to be operated upon, and there is then no difficulty in arranging matters so that the work can clear the mandrel.

While the milling operations are in progress the milling cutter should be kept well lubricated, either with saponaceous solution made up of soft soap and water or with one of the ready-prepared compositions which can be purchased in gallon tins ready for use, or, if only a few jobs are to be carried out, by the use of ordinary light machine oil applied from time to time from an oilcan. The purpose of the lubrication is to assist in keeping the cutter cool, expedite the passage of chips, and reduce the friction between these and the backs of the milling cutter teeth.

The wireless experimenter should not find any difficulty as regards the shape of the milling cutter teeth, as the commercial parts are thoroughly well designed. Most important points are to run the cutters at the proper speeds. For ordinary work it is hardly possible to run the cutters too slow: the chief fault is that they are run too fast. A mandrel speed of from 40 to 60 revolutions per minute is generally about right for most operations connected with milling small wireless parts.

When feeding work up to a milling cutter, the work should always be traversed between the cutting edge, or against the direction of revolution of the cutting part of the cutter, and never in the direction in which it is revolving. The feed should be as rapid as possible, and can be regulated



END AND FACE MILL MOUNTED

Fig. 9. Mounted directly on the lathe mandrel is an end and face mill. The mill has a Morse taper shank

by noting how the cutter is progressing. When the chips come away quickly and freely, the speed is about right. If the cutter revolves without removing the proper proportion of the metal it is supposed to be cutting through, the rate of feed is either too slow or the cutter is blunt. If the cutter shows a tendency to stick and revolve unevenly, or with a jerky motion, the rate of feed is too high, or the cutter may be out of truth, or the teeth be unequally ground.

The teeth of milling cutters should preferably be sharpened by grinding on the front face, and on that part of the cutting edge which forms the diameter of the cutter, as without a proper cutter-grinding machine they are bound to be unequally ground and rendered practically useless.

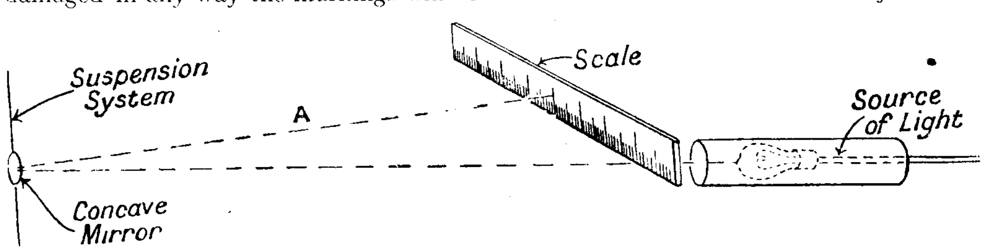
When not in use cutters should be kept in a drawer, preferably placed on pegs so that they do not move about, the object being to prevent the cutting edges coming in contact, as if they are chipped or damaged in any way the markings will be transferred to the work and a fine finish made impossible. The finish from a milling cutter should be quite high class, provided a rough cut be taken first, and then a fine finishing cut, slightly increasing the speed of the cutter and reducing the rate of feed for the latter operation.—*E. W. Hobbs.*

MINIUM. This is another name for red lead, the scarlet crystalline powder obtained by roasting lead monoxide. *See* Litharge; Red Lead.

MIRROR GALVANOMETER. General term applied to any galvanometer in which a beam of light is used as an indicator instead of the more usual pointer. It will be appreciated that a pointer, however well balanced, possesses weight, and therefore inertia. From this it is naturally follows that an appreciable force is required to cause it to move over the scale. As a beam of light possesses no weight and no air friction, its use as a pointer must mean an enormous increase in the electrical and mechanical efficiency of the instrument employing it, for no effort is required to move it.

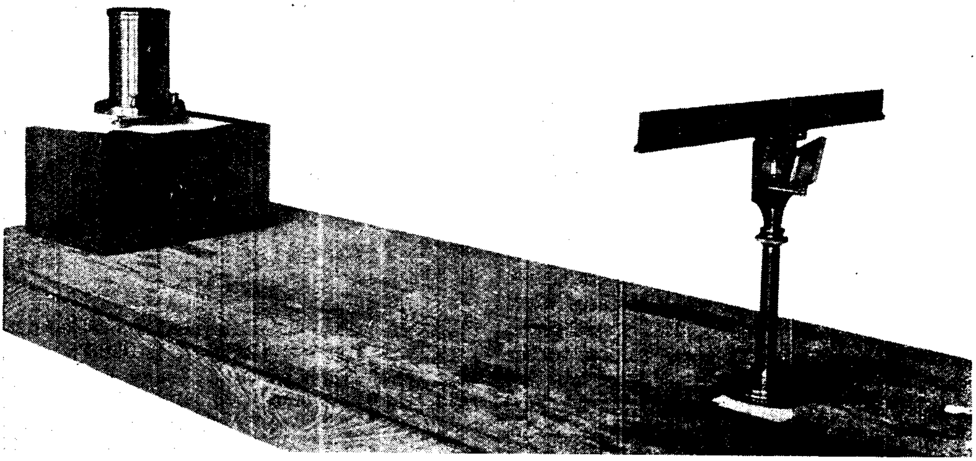
The diagram Fig. 1 will explain the method generally adopted for utilizing the light beam for indicating purposes. The moving system of the galvanometer is fitted with a small but extremely light circular concave mirror. Light is played on to this mirror from any convenient source, either by means of an electric or other lamp suitably projected, as in Fig. 1, or reflected light, as in Fig. 2. The mirror reflects this light back horizontally, as at A, Fig. 1, and the mirror is ground so that the reflected light takes the form of a narrow, parallel beam. The latter plays on a suitably divided scale.

The distance between the mirror and the scale may be anything from 3 to 10 ft., or even more, so that the additional advantage of the multiplying effect of the distance is used. Thus a very minute



METHOD OF USING LIGHT BEAM IN MIRROR GALVANOMETER

Fig. 1. How the beam of light is reflected on to a scale by a mirror in a galvanometer is indicated. The principle upon which this works is that a movement of the mirror alters the position on the scale of the reflected beam. The mirror can be moved by extremely small currents



SCALE AND MIRROR GALVANOMETER READY FOR USE

Fig. 2. In this form of mirror galvanometer the light is reflected on to the scale. Mirror galvanometers are more efficient than those employing pointers

Courtesy J. J. Griffin & Sons

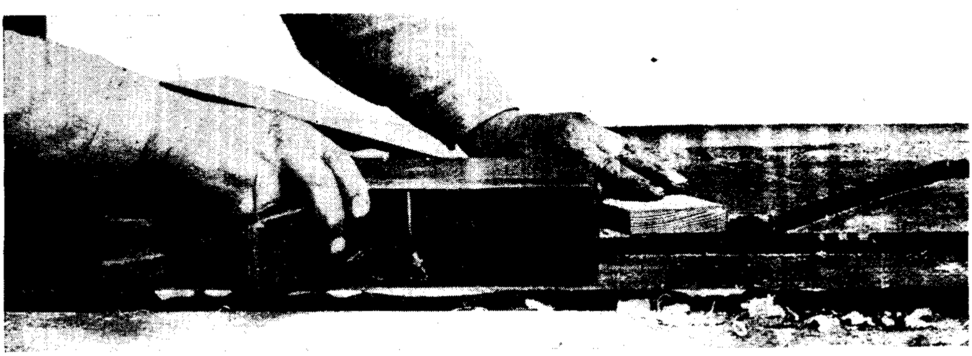
movement of the mirror causes quite a considerable deflection at the end of the beam. Such galvanometers may be made to indicate currents of less than ·00008 of a millionth of an ampere.

A typical example of a mirror galvanometer is given in Fig. 2. Here the instrument itself is shown mounted upon its cabinet, the height of which is suitable for the light being projected on to the scale. The galvanometer is fitted with adjustable legs in order that its correct height and dead uprightness may be assured.

The scale is shown on the rear end of the bench. It is mounted upon a stand, also provided with adjustments. Immediately beneath the scale a circular hole is provided, behind which a square mirror is placed. The latter is adjustable so that any convenient light may be diverted and used for reflecting purposes. Sometimes the image of the scale on the mirror is looked at through a telescope and the divisions thus read by bright daylight.

It is of the utmost importance that the distance from the mirror to the scale be measured accurately each time the instrument is set up. Further, inaccuracies will occur if the scale is not perfectly square to the galvanometer. *See* Galvanometer.

MITRE BOARD. An implement used by woodworkers in the construction of mitred joints. In a form that is suitable



HOW TO USE THE MITRE BOARD FOR CABINET JOINTS

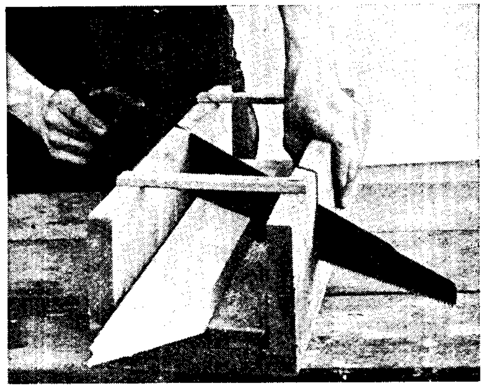
In the construction of mitred joints the mitre board is invaluable. Amateurs who make their own cabinets and other components in woodwork will find it of considerable assistance in accurate work for amateur purposes the mitre board may consist, as shown in the illustration, of a board about 4 ft. in length, 9 in. in width, and 1 in. in thickness, the underside of which, at the right-hand end, is provided with a cross batten about 2 in. in breadth and 1 in. in thickness. A second length of timber, about ½ in. in width and 1 in. or so in thickness, is glued and screwed to the top of the first board, with their edges flush.

At about the centre of the length of this second board are attached three pieces of timber, triangular in shape and about 1 in. in thickness. The two angular faces have to be accurately planed, and so adjusted that the angle each of them makes to the inner edge of the second piece of wood is exactly 45°. In use, a piece of work that has been sawn to a mitre, that is, to an angle of 45°, is pressed by the left hand against one face of the triangular pieces or stops. A suitable plane, such as a jack plane or a metal plane with machined sides to the body, is then rested on its side on the baseboard with the cutting iron vertical. It is then pressed backwards and forwards with the right hand across the angular face of the end of the piece of work, which it thus planes truly to an angle of 45°, and at the same time the face of the joint is kept square with the working face of the timber.

The angle for the stop may, in some cases, be varied, as for instance, when preparing hexagonal frames, such as those sometimes used for frame aerials. In this case the angle, instead of being 45°, will be 60°, otherwise the implement is used in the same way. A hole should be drilled at one end of the baseboard, and when not in use the board should be hung up on the wall in a dry and equable place.

MITRE BOX. Device employed by woodworkers to facilitate the more accurate cutting of timber to known angles, customarily 45°. There are a variety of different patterns of commercial mitre box available, but the experimenter can readily construct one from three pieces of floor board about 6 in. in width and 1 in. in thickness, and a couple of feet in length. These are screwed together to form a trough. The upper edges of the two boards forming the sides are connected together by cross battens at the ends, and carefully adjusting the sides in relation to the bottom so that the angles are exactly 90°.

In the middle of the length of the device a line is accurately marked with the aid



HOW A MITRE BOX IS USED

This photograph shows a simply made mitre box, and how it is used for cutting wood at fixed angles

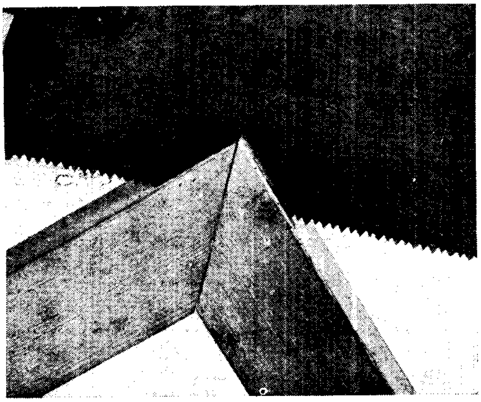
of a set square and projected across each of the vertical side pieces. A saw cut is then made across these lines right to the bottom. A batten is connected across the top near to each side of the saw cut, to keep the structure rigid.

At a little distance each side of the centre line a similar saw cut is made at an angle of 45°. In use, the piece of material to be sawn to a mitre is placed within the trough and held there with the left hand while a hand saw is operated with the right hand through one or the other of the saw cuts. This serves to guide the saw and keep it perfectly upright, and at the correct angle.

Work cut in this way is remarkably true, and requires but very little subsequent attention by planing on a mitre board. The implement is indispensable for such purposes as the cutting of mouldings to fit around the base of a cabinet for a wireless receiving set. The same principle can be employed for the construction of a smaller size of mitre box, which can be used in exactly the same way.

MITRED JOINT. Term used to describe all kinds of butt joints wherein the two parts forming the joint meet at the ends at an angle to each other, usually at eight angles, the joint faces then being cut uniformly at an angle of 45°. The same expression is used when the angle of the joint faces is other than 45°, as, for instance, in an hexagonal wooden frame for a frame aerial when the angle between any two members is 60° while the faces of the joint are at 30°.

Mitred joints are chiefly found on framing and on the beading and moulding on cabinets of wireless receiving sets. In preparing mitred joints the timber is first sawn to shape in a mitre box (*q.v.*), planed up true on a mitre board (*q.v.*), and the joints finished with glue, screws, nails, or dowel pins. A better and stronger joint is made by making a saw cut or saw cuts parallel to each other and parallel with the widest face of the work, as shown in Fig. 1. A slip of wood is then cut and inserted in the saw cut, as shown in Fig. 2, glued, and when the glue has set the surface cleaned off smooth and true with a plane.



CUTTING SLOTS FOR FEATHER

Fig. 1. Mitred joints are considerably strengthened by cutting slots in this way and fitting a feather

For heavier work the keyed mitred joint, as shown in Fig. 3, is often used. This has the advantage that the X-shaped hardwood key is simply fitted into a V-shaped recess cut on one of the faces of the work, and is clearly visible in Fig. 3. To obtain a good fit it must be accurately carried out, and when completed the key and the joint faces are well glued, and the whole secured with dowel pins, screws, and the like.

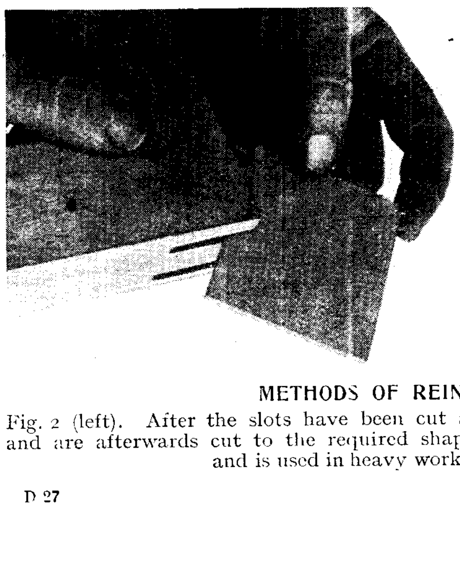
M.M.F. This is the standard abbreviation for magneto-motive force, the force tending to produce magnetic flux. *See* Magneto-motive Force ; Magnetism.

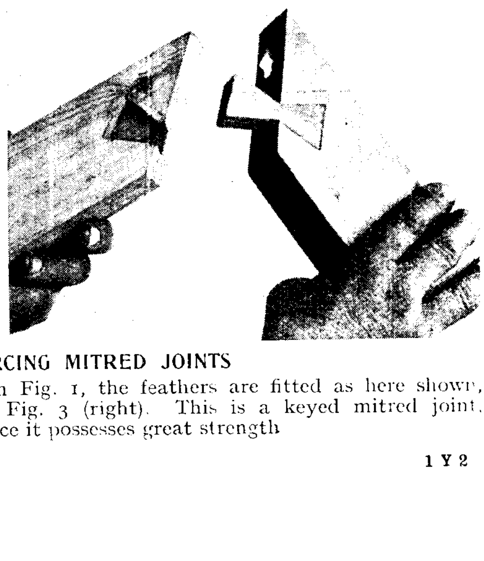
Mn. This is the chemical symbol for the metallic element manganese (*q.v.*). *See* also Manganin.

MODULATION. The varying of a continuous oscillation in accordance with the varying frequency and amplitude of audible sounds. An unmodulated continuous wave is the product of an oscillating valve or other high-frequency oscillator, and this wave, stopped at the time intervals determined by the international Morse code, forms the basis for continuous wave telegraphic transmission.

In order to transmit speech or telephony from this continuous wave, the tapping key used for interrupting the wave is replaced by an apparatus for moulding it to interpret audible sounds. Fig. 1 illustrates a continuous or carrier wave, and this wave modulated is shown in Fig. 2.

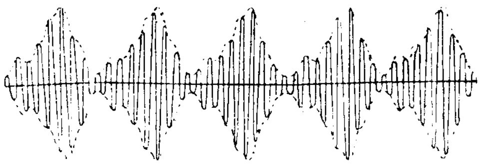
There are many methods by which modulation can be effected, which methods vary with the power used at the transmitting station, among other factors which have a deciding influence. The three most common ways of effecting modulation are by varying the amplitude of the aerial oscillations, by wave-length changes, or by a combination of both

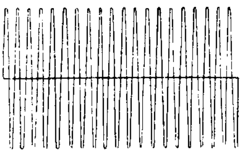




METHODS OF REINFORCING MITRED JOINTS

Fig. 2 (left). After the slots have been cut as in Fig. 1, the feathers are fitted as here shown, and are afterwards cut to the required shape. Fig. 3 (right). This is a keyed mitred joint, and is used in heavy work, since it possesses great strength





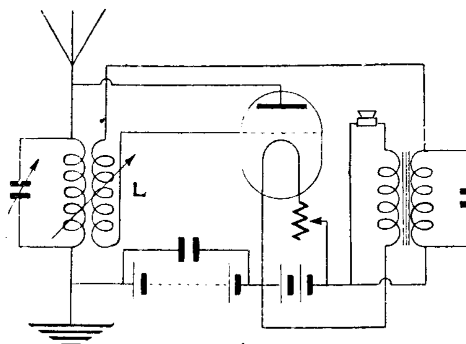
MODULATION

Fig. 1 (left). Continuous cı carrier wave before modulation, and Fig. 2 (above), Carrier wave as it is modulated is shown

these factors. In all cases modulation is effected at radio-frequency, as low-frequency currents are practically non-radiating. Modulation is obtained by either direct or indirect methods, the former being more suited to transmitters of low power.

Modulation by grid control of the oscillating valve is an example of the first of these three methods. Fig. 3 illustrates a valve transmitter modulated by grid control. An inductance is arranged in the anode circuit of the valve, and forms part of the aerial circuit. The secondary coil of a step-up transformer is included in the grid circuit, to the primary of which a suitable battery and microphone is attached. In this illustration the filament battery is used for the purpose. The effect of speech and music on the microphone is to vary the strength of current flowing through the primary coil of the transmitter. This current is amplified in the secondary coil of the transformer, and regulates the operation of the valve by varying its grid potential. In this way the amplitude of the valve's oscillations, and consequently the aerial oscillations, are modulated according to the strength of the audible sounds.

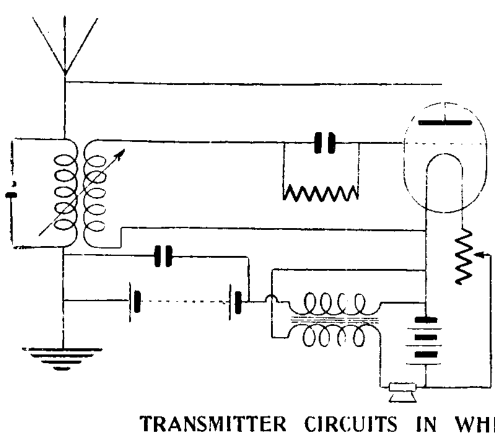
A somewhat similar effect may be obtained by coupling the microphone circuit to the anode circuit, thus causing the current modulations to affect the operation of the valve in the anode circuit. Such a circuit is shown in Fig. 4.

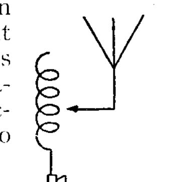


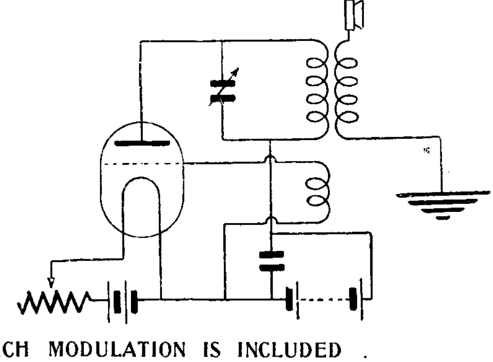
MODULATION EFFECTED BY GRID CONTROL

Fig. 3. By means of grid control through the transformer, modulation is effected. The diagram shows the necessary connexions

Another method, also employing varying amplitude to obtain modulation, dispenses with the high-tension battery, this supplying the anode potential alone. In this arrangement the valve only oscillates when speaking, and is known as the dumb or quiescent aerial. Poor speech results from this type of modulation, and in general practice it is found better to







TRANSMITTER CIRCUITS IN WHICH MODULATION IS INCLUDED

Fig. 4 (left). Modulation is carried out by coupling the microphone circuit to the anode circuit. Fig. 5 (right). Direct modulation is included in the aerial circuit. This is also known as resistance modulation have the oscillator constantly working. Modulation by wave-length changes is brought about in one method by a specially constructed condenser placed in the oscillating aerial circuit. The condenser consists of two or more metallic plates, set close to each other. One plate is rigidly housed and free from movement or vibration. The other plate may consist of a microphone diaphragm, or a plate attached to a microphone diaphragm, and operated from it by a lever motion to secure a maximum movement of the former. The effect of speech on the moving plate and diaphragm causes it to vibrate, and the resulting varying capacity modulates the aerial oscillations by the variation in wave-length. The extreme smallness of the variation in capacity renders this type of modulation somewhat inefficient, but further experiments on this type will possibly result in greater practicability.

The foregoing methods of modulation embrace indirect modulation. Fig. 5 shows an example of direct modulation in an aerial circuit. This is known as resistance modulation. The microphone in the aerial circuit has its resistance varied by the variation of pressure between the carbon granules. The varying resistance resulting gives a corresponding variation in the amplitude of the oscillator, and in this way modulation is effected. *See* Broadcasting; Microphone Transmitter; Transmission.

MODULATOR TRANSFORMER. A transformer used in transmitting circuits for the purpose of controlling, or assisting to control, the operation of the oscillator valve. It is in circuit with the microphone, and is supplied with direct current from the filament battery.

The following method of constructing a modulator transformer is recommended. The bobbin should be about 4 in. long by 2 in. in diameter, with a $\frac{1}{2}$ in. diameter hole through it. The latter should be filled with soft iron wires. The primary winding should consist of about 400 turns of No. 22 D.C.C. wire (about 6 oz.). A strip of oiled silk or paraffined paper should be wrapped around the primary, and the secondary commenced. This should consist of about 16,000 turns of No. 40 D.C.C. wire. Half a pound will be required for this winding.

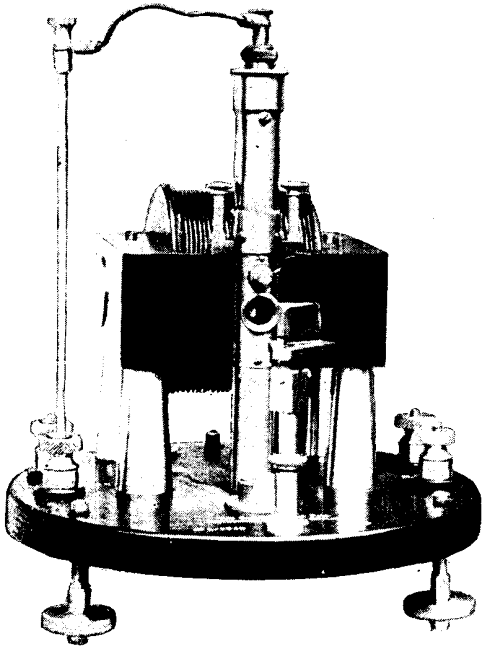
The lines of construction of spark coils should be followed. A $\frac{1}{2}$ in. spark coil may be used as a modulator transformer, but as there are not enough turns on the primary, it is not very efficient. The modulator transformer is usually employed in conjunction with a modulator valve (*q.v.*), but it can also be used in direct connexion with the oscillator valve, in which case the action is as follows. The variations of current produced by speech induce electro-motive forces in the transformer secondary. These electro-motive forces modify the continuous wave oscillations in the grid circuit of the oscillator valve, and are thus transmitted by means of the subsequent additional variations of grid potential to the plate circuit, and thence to the aerial.

MODULATOR TUBE. This is an American term for the modulator valve.

MODULATOR VALVE. One used in a transmitting circuit to modulate or control, and at the same time to amplify, the oscillations generated by the oscillator valve. It is used in conjunction with a transformer in circuit with the microphone. The voltage of the grid of the modulator valve is varied by the secondary coil of the microphone or modulator transformer, and in this way the modulator valve acts as a variable resistance, while simultaneously amplifying the variations impressed on the oscillations set up by the oscillator valve. *See* Modulator Transformer; Transmission; Valve.

MOLECULE. The smallest quantity of an element or a compound which can have a stable independent existence. There are as many different kinds of molecules as there are different kinds of matter. Molecules are made up of atoms, and atoms, in their turn, of positive and negative particles of electricity. *See* Atom; Electron.

MOLL GALVANOMETER. Type of moving coil galvanometer invented by Dr. Moll, of Utrecht University. Its principal advantage lies in the fact that it has a very short period, which approximates 1·3 seconds. It is frequently used with thermopiles, these obtaining equilibrium of temperature in rather less than 2 seconds. For this reason it is particularly suitable for making rapid observations or taking readings on electromagnetic forces which fluctuate frequently. The Moll galvanometer is also of great use in conjunction with potentiometers and bridges for making measurements by the "null" method.



MOLL GALVANOMETER

Fluctuating electro-magnetic forces are read rapidly by this type of moving coil galvanometer, which has a very short period of swing

Courtesy Cambridge and Paul Instrument Co.

The figure is an illustration of the Moll galvanometer as manufactured by the Cambridge and Paul Instrument Co. The mirror is 6 mm. in diameter, and is carried upon a light former-less coil. Two phosphor-bronze strips are used in order to ensure that the mirror remains in the most effective position in the magnetic field. One strip forms the connexion from one end of the coil to a terminal, and the other connects the lower end of the coil to a projection of the suspension tube. The moving system is kept at a normal tension by means of a spring, which forms no part of the electrical system. This arrangement is said to improve the stability of the zero position, and to ensure a short period.

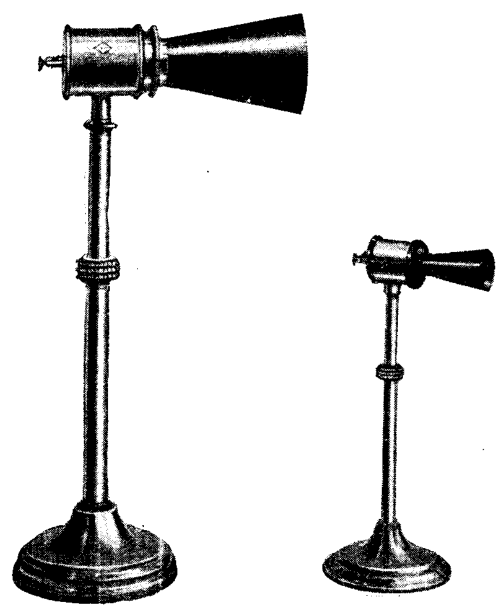
The magnetic field is intensified in the vicinity of the coil by means of soft iron cheeks built into the base of the suspension tube. The pole-pieces of the electro-magnet serve as a support to the suspension tube, while the magnet itself is supported upon a base fitted with levelling screws. Four terminals are fitted, these being for the field connexions and galvanometer respectively. The effects of external magnetic fields are considerably reduced by the presence of the electro-magnet.

A 2,000 ohm resistance is fitted in the base of the instrument, which is permanently shunted across the galvanometer terminals and serves to damp the instrument slightly.

Apart from the mirror carried by the moving coil, there is a lens fitted into the suspension tube. There is also a prism stand on the base of the instrument, into which horizontal and vertical prisms may be fitted if required.

Some idea of the sensitivity of this instrument may be gathered from the fact that a deflection of one millimetre at a distance of one metre is produced by a current of 0·00008 micro-amperes. *See* Galvanometer.

MOLL THERMOPILE. Type of thermopile due to Dr. Moll, which was specially designed to be used with the galvanometer bearing his name. It consists essentially of a brass case mounted upon a vertical stand. This case contains the elements of which the thermopile is composed. One of them has a funnel-shaped opening, which serves as a kind of directional tube through which heat may be collected. The other instrument has merely a slit, and is used for spectral investigations.



MOLL THERMOPILE

Used in conjunction with the Moll galvanometer, this instrument indicates slight and quick changes of temperature electrically

Courtesy Cambridge and Paul Instrument Co.

The principal use of a thermopile of this nature is in the determination of very slight and quick changes of temperature. As the thermopile sets up a potential difference when heated, it follows that if it is connected to an extremely sensitive galvanometer, such as the Moll galvanometer *(q.v.)*, these differences of temperature will be electrically recorded. Their use, for wireless purposes, is, of course, confined to the laboratory.

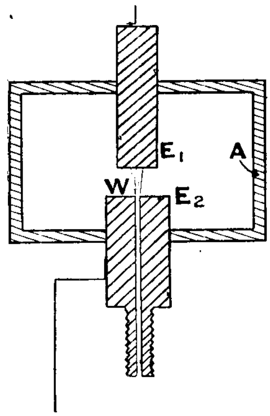
MOLYBDENITE. Sulphide of molybdenum, MoS_2. The name is also given to the mineral which consists chiefly of molybdenum disulphide. It resembles a lead ore in appearance, and is very soft, with a bright metallic lead-grey to bluish or reddish tinge.

Molybdenite is used as a crystal rectifier with copper usually, but it makes a good rectifier with a number of other substances, as chalcopyrites, bornite, iron pyrites, and tellurium. It is best used with a small dry battery. In the Telefunken molybdenite detector contact is made by a silver spring, and gives very good results for short-range work.

Molybdenite is also one of the substances which form one of the electrodes of the T.Y.K. arc.

MOMENTUM. The product of the mass of a moving body and its linear velocity. The angular momentum of a body is a term used in connexion with rotating bodies, and is the product of the moment of inertia of the body about the axis of rotation and its angular velocity. Such a quantity is important to calculate in all pieces of apparatus where there is a high speed of rotation, as, for example, in the Goldschmidt alternator.

MORETTI ARC. Form of arc oscillation generator in which the atmosphere round the arc between the copper and carbon or two copper electrodes is provided by the vaporization of water. The diagram shows the principle of the arc, and it is claimed that this type of arc is one of the most powerful generators yet discovered. The two electrodes are shown at E_1 and E_2. Through E_2 is cut a longitudinal hole through which a stream of acidulated water, W, passes. The electrode E_1 is the negative electrode, and E_2 the positive, and the stream of water impinges on E_1, the velocity of the stream being regulated by a suitable valve in the feed pipe. The electrodes are shown surrounded by an air-tight insulating casing, A, but in actual practice the arc functions as well in air without the casing.



MORETTI ARC

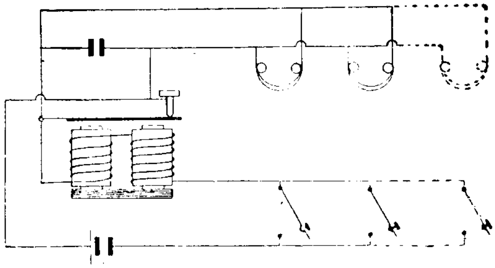
Water is driven through the electrode E_2, to impinge on E_1. The intense heat of the arc splits the water into oxygen and hydrogen, which recombine and continue the cycle of operations

The action is explained by Professor Vanni as follows: At the moment of the formation of the arc the water vaporizes rapidly, passing into a spheroidal state, and thus breaks the circuit very rapidly. The water, by the intense heat of the arc, is partly split up into its components, hydrogen and oxygen, and the mixture, being explosive, combines again, and the whole cycle of operations is repeated. The spark frequency of the Moretti arc is several hundred thousand per second.

A number of improvements have been carried out in the actual construction of the arc by Bethenod, and as generally used the arc is placed in series with resistance and inductance across the terminals of a 600-volt direct current generator. *See* Arc Transmitter; Colin-Jeance Arc; Poulsen Arc.

MORSE CODE. System of signals for the telegraphic transmission of alphabetic letters, numerals, punctuation marks, and conventional phrases. It was invented by S. F. B. Morse for use with his self-recording telegraph. The code was revised in 1851 by an international committee, and this code, now known as the International or Continental code, is the one used everywhere except on American land telegraph lines and certain countries where the language calls for modified codes. The code used in the United States is now usually known as the American Morse code, and when the term Morse only is used it is taken as meaning the International code, which is given on page 1199.

How to practise Morse. For those who wish to have an experimenter's licence it is necessary that they should be able to send or receive at least twelve words per minute in the International



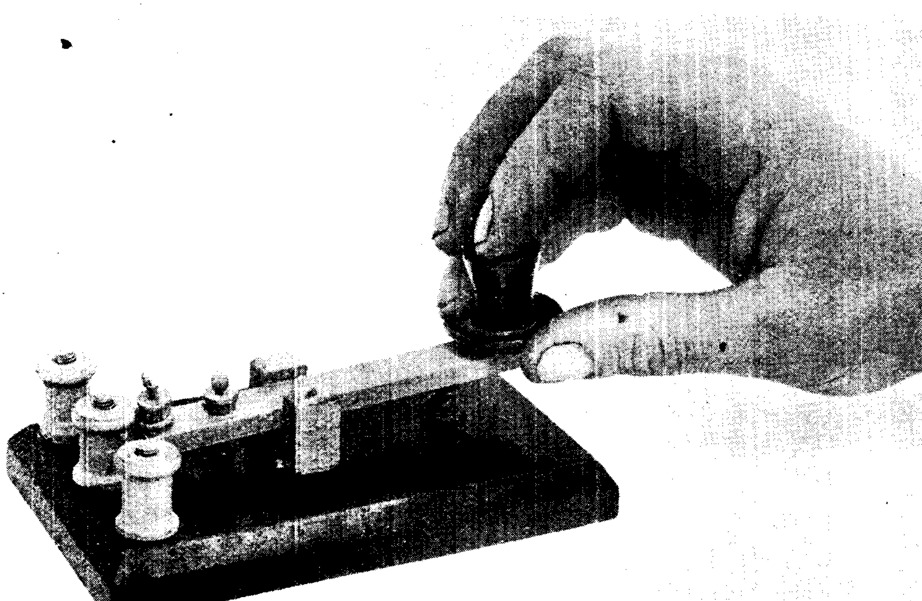
BUZZER PRACTICE BOARD

Fig. 1. Several learners can practise the Morse code simultaneously by means of one buzzer in a circuit of this kind

Morse code. Under the heading Omnigraph in this Encyclopedia is given a means by which the wireless amateur may practise the Morse code by himself. It is better, wherever possible, to practise with a fellow-amateur, and afterwards either to make oneself perfect under the tuition of a skilled operator, or alternatively to practise reading with another amateur, as a check on accuracy, the Morse signals continually being sent out by ships, etc.

The most important thing to remember in sending Morse is to get absolutely sharp and clear signals properly timed. A slight variation of time is sufficient to alter the entire meaning of a message. For example, the signal for *c* is —·—· and if the operator hesitates after the second dash the signal becomes —·— · which reads *ke.* Or, as another example, suppose the operator is sending the words Dine today, the Morse code for which is —·· ·· —· · — ——— —·· ·— —·—— If the signals are carelessly spaced the receiver might get the following code signals —··· ·—·· ——— — —· · ·— — · —— which reads Blot neatem, an unintelligible message. The importance, therefore, of proper timing cannot be insisted upon too strongly.

The time intervals are as follows: The time occupied by a dash should equal that occupied by three dots. The time occupied by the interval between two elements of one letter or other symbol should be equal to the time occupied by one dot. The interval between two letters in a word should be equal to the time occupied by three dots. And finally the interval between two words should be equal to the time occupied by five dots. Thus, if one second, say, is spent on sending a dot, three seconds are required for sending a dash, and a letter like *g* ——· would require nine seconds, that is three seconds for each dash, one second for the dot, and one second each for the two time intervals



HOW TO USE A MORSE KEY

Fig. 2. Wireless signals transmitted in Morse code by the hand method are sent from a key, which is held as illustrated. When the key is depressed the electrical circuit is closed

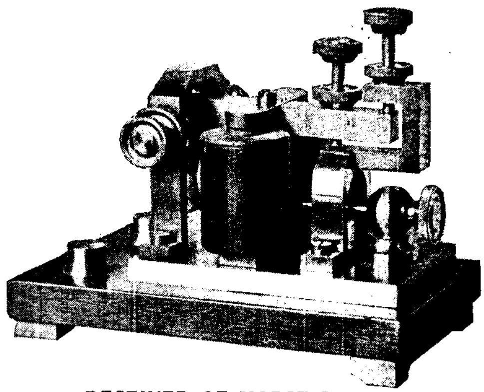
between the first two dashes and the second dash and dot. The time is purposely exaggerated to show the principle.

The photograph, Fig. 2, shows how the Morse key should be held. The first and second fingers should be placed on the top of the key button, and the thumb below it to control both the upward and the downward movement. The arm should be allowed to rest on the table to allow the wrist perfect freedom of movement. The key button should not be held too tightly, or the hand will soon become tired, resulting in telegrapher's cramp.

Fig. 1 shows a circuit diagram for two amateurs who wish to practise together. The circuit shows how two pairs of headphones are connected up through a condenser, battery and buzzer to keys. The addition of more headphones and keys is a simple matter, the wiring following on for a third pair as indicated by the dotted lines. *See* International Code; Omnigraph.

MORSE SOUNDER. A Morse signal-receiving instrument, which gives audible clicks when reception is in progress. It is in universal use throughout the whole of the manually operated Post Office telegraph system. A standard G.P.O. pattern sounder is illustrated in the figure. It will be seen that a heavy brass plate is mounted upon a wooden base, which also carries the terminals. The brass plate supports an electro-magnet of the horseshoe type, having its poles pointing vertically. To the left of the magnet is an inverted U-shaped bracket which supports a horizontal spindle. The latter carries a square-sectioned brass bar, to which an iron armature, situated directly over the magnet poles, is attached. This armature is at right angles to the bar, as can be seen from the photograph.

The other, or free end of the bar, is placed between a pair of adjustable stops, which may be fixed so that the movement of the bar may be restricted either upwards or downwards as required. A spring is fitted to the bar, so that normally it rests underneath and in physical contact with the upper stop. Current from the line or relay is conveyed to the magnet via the terminals shown. Thus, when a signal is being received, the magnet is energized and the armature, and therefore the bar, is pulled downwards against the tension of the spring.



RECEIVER OF MORSE SIGNALS

Morse signals are received on this instrument, which is known as a Morse sounder. A series of double clicks represent the dots and dashes of the code

Courtesy J. J. Griffin & Sons

Immediately the bar reaches the under stop a metallic click is heard.

When the current ceases the magnets become de-energized, with the result that the spring returns the bar rapidly to its upper or normal position. A second click is then heard when the movement is completed. It will be apparent, then, that for each dash or dot a double click is made by the instrument, and that the difference between the dots and dashes may be discerned by the operator by noting the interval between the first and second clicks.

The design of the instrument is such that a different note is made between the downward and upward clicks, thus allowing the operator to discern the difference easily.

MORTISE AND TENON. Name given to extremely useful and practical joints in woodwork. The mortise and tenon forms one of the principal joints in all forms of woodwork, particularly cabinet-making. In essence a mortise is a rectangular, relatively long, narrow slot cut into a piece of timber, the tenon being a tongue-like projection formed on the end of the piece of timber to be fitted into the mortise. If these two portions are accurately fitted together and the joints secured with glue, dowel pins, or the like, it is practically as strong as if the wood were grown together solidly.

There are numerous varieties of the mortise and tenon joint, but most of them are simply detailed developments of the straightforward joint which is shown in Fig. 1. It is the usual practice when proportioning such joints to make the width of the mortise one-third the width of the timber at the point where the mortise is to be cut. The tenon is necessarily exactly the same size as the mortise.

The first step in preparing such a joint is to mark out the timber accurately. The length of the mortise is defined by two lines pencilled across the face of the timber with the aid of a set square. These two lines are projected around the sides of the timber and at the back of it. With the aid of a mortise gauge (*q.v.*) the width of the mortise is marked on both sides of the timber. Holes are then bored through it and the slot cut out with the aid of a mortise chisel (*q.v.*) and trued up with ordinary firmer chisels, as shown in Fig. 2.

The tenon is marked out in a similar manner to the mortise, and at the preliminary stages the bulk of the wood can be removed by carefully sawing it away with a tenon saw in the manner illustrated in Fig. 3, which shows the first of the two cuts, and in Fig. 4, which shows the last cross-cut. The first two are taken in the longitudinal direction of the grain, and the others across it. In sawing them it is very necessary to keep them perfectly square, otherwise the shoulders will not abut the face of the timber in which the mortise is cut.

Final fitting is accomplished by chiselling across the faces of the tenon and, if necessary, truing up the shoulders, during both of which operations it is absolutely imperative to keep all the working faces absolutely square, otherwise the resulting joint will be untrue. To secure a mortise and tenon joint of this character calls for the use of glue, screws, nails, or wooden dowel pins, any of which should be driven through the timber at right angles to the mortise.

In cases where a mortise is to be made at the end of a piece of timber, as, for example, at the top of a leg for a wireless cabinet, it would be insecure if the tenon were left at the full width of the timber. The joint can be secured in the manner illustrated in Fig. 5, this joint being known as the haunched mortise and tenon. It is prepared in the same way as the previous example, and after that a portion of the tenon is cut away, as is clearly visible in Fig. 5. It is customary to leave a small portion of the tenon at the shoulder the full width of the wood and cut a slot in the other part where it enters the mortise. The final fitting is given by careful chiselling, as shown in the same illustration.

The advantage of the haunched mortise joint is that it leaves the timber solid at the top; while the small portion of the tenon which is left of full width checks any tendency for the rail to twist or distort.

In cases where the rail is to be mortised into another piece of timber so that it shall not readily be withdrawn, a form of dovetail is adopted, as illustrated in Fig. 6. In this case the work is prepared in a similar manner to the first example, but one of the ends of the mortise is cut away to an angle, and the tenon is similarly cut back on the shoulder end. The tenon is then inserted into the mortise in the manner indicated in Fig. 6, and pressed upwards until the angular end of the mortise is in contact with the corresponding angle of the tenon.

A wedge is then driven into the mortise on the opposite side of the tenon, and this makes it impossible to withdraw the rail from the post. This type of joint is particularly useful in many forms of construction, such as the legs of a wireless experimenter's table and some of the tie-bars of a wooden lattice mast.—*E. W. Hobbs.*

MORTISE CHISEL. Distinctive term for a particularly strong form of chisel used by woodworkers. It is of two forms, one used in conjunction with a mortising machine, the other, that is of interest to the experimenter, is a hand tool provided with a hardwood handle, and used by grasping the chisel in the left hand and driving it with a mallet in the right hand. A hammer should not be used, as this will ultimately split or splay out the top of the chisel and ruin it for ordinary use. If a mallet is not available a small piece of wood interposed between the hammer and the chisel handle will protect the latter.

As its name suggests, the tool is particularly adapted for cutting mortises, that is, relatively deep, narrow holes in wood. Consequently the chisel is more or less square in cross section, the lower end being ground over to a bevel, the extreme edge of which forms the cutting edge. Two of the sides of the shank are parallel. The back is flat, and the front part of the chisel is tapered. The upper end is either

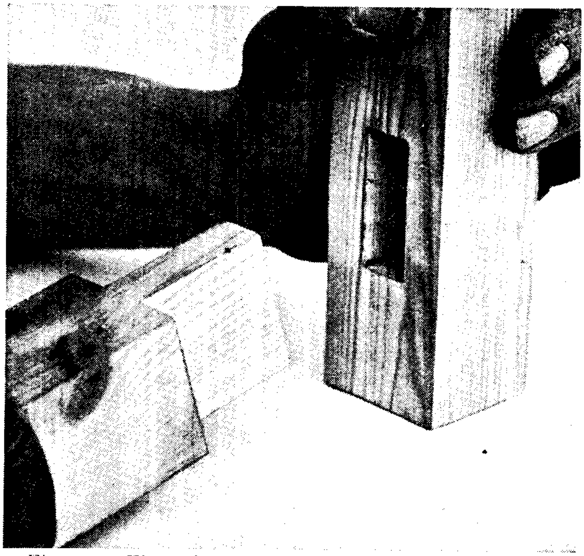


Fig. 1. Fitted into a slot known as the mortise is a simple tenon

Fig. 2. Chisel and mallet are used for cutting the mortise

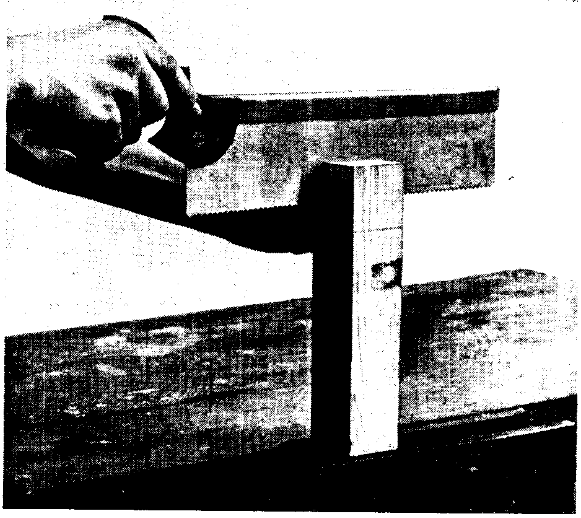


Fig. 3. Longitudinal cuts are made with a tenon saw for the tenon

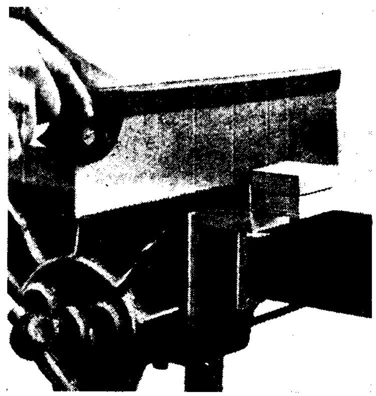


Fig. 4. Cross-cuts made by a tenon saw form the tenon shoulders

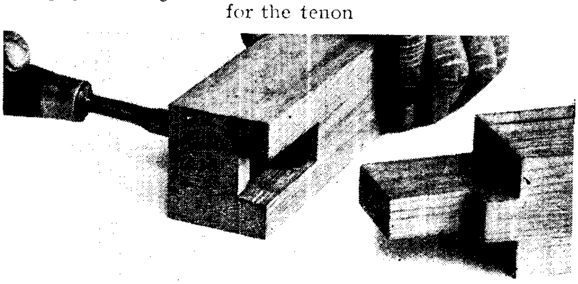


Fig. 5. In this case the tenon is haunched, and the mortise is cut accordingly

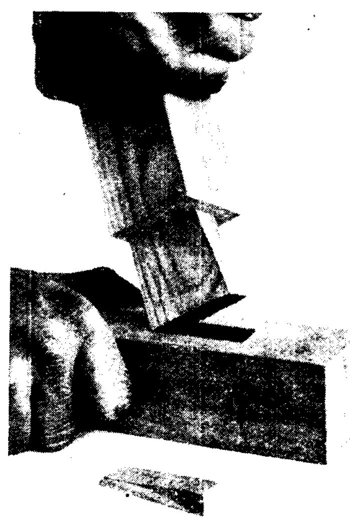
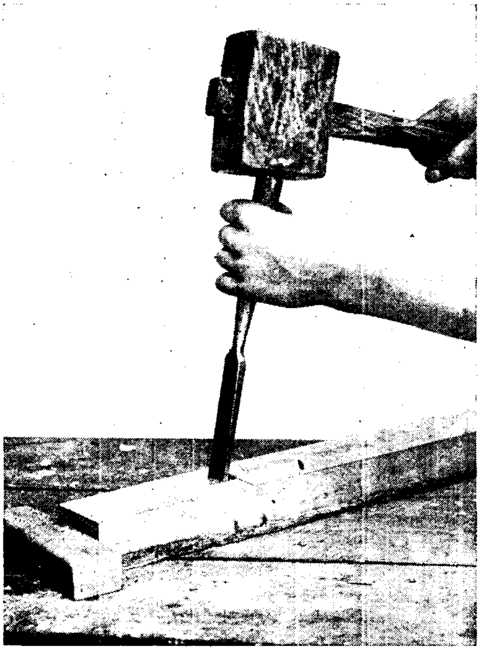


Fig. 6. This is a locked or dovetailed mortise joint. The wedge locks the joint

HOW TO MAKE MORTISE AND TENON JOINTS



HOW A MORTISE CHISEL IS USED

Mortise chisels are largely used with the mallet, and are particularly strong. In the photograph a mortise is being cut

forged up to form a socket, into which the handle is inserted, or a tang is worked and driven into the handle in the ordinary way. In any case, the handle should be provided with a strong ferrule to prevent it splitting under the blows of the hammer.

In use, in making a mortise in a piece of wood, some of the material is removed by drilling; but the bulk of the shaping is accomplished by holding the mortise chisel vertically in the left hand and driving it firmly into the wood as far downwards as possible, as in the illustration, then taking a slanting cut towards the first, thus removing a V-shaped piece of wood in the form of chips. The process is repeated at both ends of the intended slot, and continued to the requisite depth.

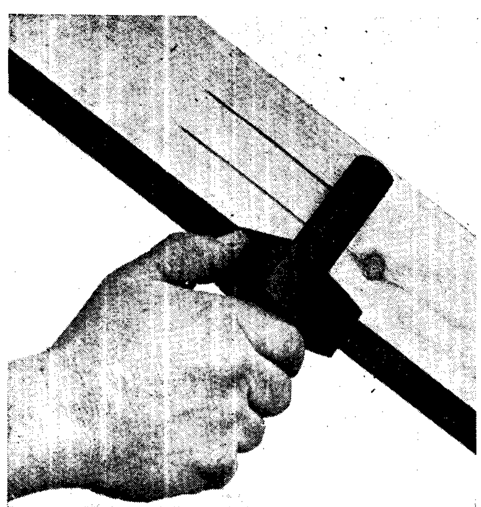
Usually, when the bulk of the slot has been thus shaped, the final fitting is accomplished with firmer chisels. The mortise chisel requires the same attention as any other woodworking chisel, which is generally a matter of storing it in a dry, equable temperature, keeping the metal parts slightly greased if the tool is not in constant use, and always maintaining a very keen cutting edge. The latter is rather more blunt than the firmer chisel, as the strain at the end of the tool is very considerable.

There are a number of hand-power mortising machines serviceable for the home constructor. Most of the mortise chisels for this class of instrument are ground with two projecting portions on the end of the cutting part, these being used to pierce the fibres and assist the free cutting of the implement. *See* Chisel.

MORTISE GAUGE. Marking tool used by woodworkers, and chiefly intended for drawing pairs of parallel lines. The tool comprises a head or stock, more or less rectangular in shape, and a movable bar or blade. This is approximately square in cross-section, and free to move in the head, but can be clamped there by means of a thumb-screw, wedge, or similar fastening device.

Near the extreme end of the blade is a small steel point or cutter securely fixed to the blade. On the face of the blade, from which the point of the cutter protrudes, a groove is cut, extending the whole length of the blade. In this groove is a metal strip or bar capable of movement in the groove. The end of the bar which abuts the cutter is provided with a steel cutting point, and means are also provided for locking the metal bar to the blade or to the head.

In use, the head is moved along the blade until the distance from the working face of the cutter on the blade is the desired distance from one side of the mortise,



USING A MORTISE GAUGE

Marks are being made on a piece of wood at a set distance from the edge. The instrument used for this process is a mortise gauge and is the distance from the working face of the material. The width of the mortise is determined, and this distance measured from the first cutter to the cutter on the movable strip, and the latter then locked in its position.

The tool is now ready for use, and is grasped, as shown in the illustration, in the left hand and held with the face of the head against the working face of the timber. It is then drawn along over the surface of the wood towards the worker, and the whole inclined slightly so that the two cutting points form two parallel incisions in the surface of the wood, thus accurately indicating the position for the mortise. The length of the mortise is measured and marked with the aid of a set-square in the usual way. If the mortise is to go right through the timber, the mortise gauge is used on both sides of the work, thus giving the whereabouts of the mortise on each face of the timber through which it is to be cut. The tool should be kept in a dry place, and clean and in good condition by wiping it over with a rag steeped in linseed oil.

MOSCICKI CONDENSER. Type of condenser suitable for extremely high pressures and used extensively in circuits conveying currents at very high tension. Peak pressures up to 35,000 volts may be withstood by these condensers, and even higher pressures by connecting a pair or more in series.

The dielectric used in the Moscicki condenser is glass, which is made in the form of a tube, having a thickened wall at its open end, for it is at that point that the static stress is greatest. By this construction the walls can be left comparatively thin with perfect safety and a high capacity is assured. The inner and outer surfaces of the condenser are covered with chemically deposited silver, which is given a coating of copper. The latter is electroplated in the usual manner.

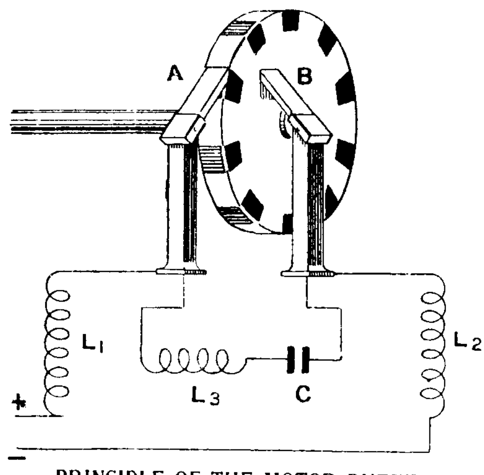
A china or bakelite insulator is inserted in the neck of the condenser, which is sealed with an insulating compound of high dielectric strength. This compound completely surrounds the coatings on the tube, the latter being embedded in it. Surface leakage is eliminated by this means.

It is general practice for condensers of this type to be enclosed in an iron tube, somewhat bigger internally than the condenser is externally. The space between the two is filled with a liquid composed of water and glycerine. This mixture serves to distribute any heat which may be set up at any point in the condenser, and this minimizes the risk of dielectric fracture through that cause. Furthermore, the liquid will not freeze at any normal atmospheric temperature.

Moscicki condensers are usually made very long and narrow, and are intended to be fixed vertically upon the floor. An advantage of this arrangement is that they may be banked together without taking much floor space, and at the same time inter-condenser connexions are kept very short. *See* Main Condenser.

MOTOR. A machine in which electrical energy is converted into mechanical energy by the reaction between the current in a coil of wire and a magnetic field. *See* Dynamo; Generator.

MOTOR BUZZER. Buzzer which is motor driven. It is used for energizing an oscillatory circuit, and is more efficient



PRINCIPLE OF THE MOTOR BUZZER

Motor buzzers are used for energizing oscillatory circuits. This diagram shows the working principle

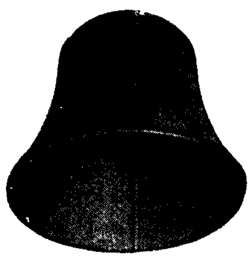
than the ordinary armature type, which is sometimes used for the same purpose.

The figure shows the principle of the motor buzzer. A wheel, which has set in its edge a number of insulating segments, usually of mica, is driven round at high speed by a motor. A and B are two brushes, one in contact on the edge of the wheel, and the other on the side, and these are connected to two inductance coils L_1 and L_2, which, in turn, are connected to a source of direct current. Shunted across the two coils is a third coil, L_3, and a condenser, C, forming an oscillatory circuit connected to the two brushes.

When the brush A is on a conducting segment of the wheel a current flows through L_1 and back through L_2. When the brush A is on an insulating segment, the circuit is broken and the counter-electro-motive forces in L_1 and L_2 charge the condenser. The condenser discharges with high-frequency oscillation as the gap between A and the next conducting segment on the wheel becomes small enough. The action is then repeated. *See* Buzzer ; Spark Gap.

MOTOR GENERATOR. Dynamo driven by a motor. Its function is to generate a voltage differing from that of the supply mains. *See* Dynamo ; Generator.

MOUTHPIECE. Name given to a bell-shaped attachment forming part of a transmitting microphone or telephone. A typical example is illustrated and is constructed of ebonite. The smaller outer end is screwed, and fits into an aperture similarly screwed which acts as a cover to the transmitter. The large end of the mouthpiece is bell-shaped and rounded. The smaller end is closed by a membrane pierced with a number of holes. This checks the entrance of dust into the interior of the transmitter.



BELL MOUTHPIECE

Bell-shaped attachments are used on telephones and microphones to convey sound to the diaphragm, whose movement actuates the electric current

A variety of devices are used in conjunction with mouthpieces to improve their hygienic properties. For example, duplicate covers of paper or other material are employed, and these when soiled can be thrown away and replaced by new. A small pad of porous material impregnated with an antiseptic is sometimes employed in the inside of the mouthpiece. Other patterns are made of glass, and different materials, so that they can easily be washed or otherwise cleaned. *See* Telephone.

MOVING-COIL INSTRUMENT. General term applied to a type of direct current measuring instrument, in which the moving system consists of a coil free to rotate within a strong magnetic field. This system may be considered to be a development of the method employed in the D'Arsonval galvanometer (*q.v.*).

Briefly, the main features of a moving-coil instrument are a strong permanent magnet of the horseshoe type, which is fitted with cast-iron pole-pieces. The latter are connected by two brass strips which carry the jewelled bearings for the movement. Most of the cylindrical space between the pole-pieces is taken up by a solid, circular, cast-iron core, which is held also by the brass pieces.

A coil of fine wire, having many turns in the case of a voltmeter and few in the case of an ammeter, is mounted upon an extremely light rectangular aluminium frame. The latter is pivoted about its longer axis by a spindle at either end, the latter running in jewelled bearings. This coil rotates within the annular gap between the core and the pole-pieces.

Connexions to both ends of the coil are made by means of hair springs, which also serve as the instrument control. The pointer, which is accurately balanced, is mounted on the coil spindle and moves with it.

The coil normally rests at an angle of 45° with a line cut through the poles, and when a current passes the lines of force due to the current tend to set themselves in line with those due to the magnet. A deflection of the coil is the result, and the extent of this is directly proportional to the current and inversely proportional to the strength of the control springs.

These instruments are ideal for direct current working, but will not operate on alternating current. They possess many advantages over other types for direct current work, and among those advantages the following are the chief :—

The intensity of the magnetic field results in few ampere-turns being required on the coil, which means a light moving system, high sensitivity and small power losses.

They are automatically damped by the permanent magnet, and are remarkably dead beat.

They are free from errors due to temperature and hysteresis.

The deflection being proportional to the current or voltage, an evenly divided scale, which is ideal, results. *See* Ammeter ; Astatic Galvanometer ; Galvanometer ; Voltmeter.

S. R. MULLARD

During the late war this noted scientist became head of the wireless research laboratory of the Imperial College of Science. He has won a high reputation for his researches on thermionic valves

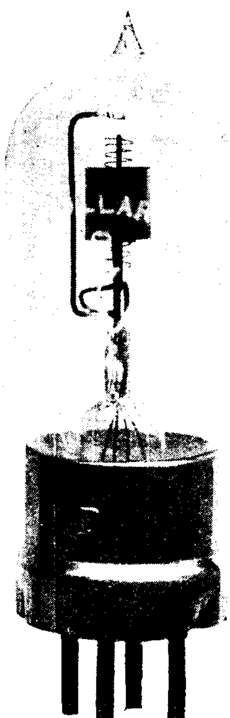
MOVING COIL RELAY. A specially sensitive form of relay by means of which messages can be printed on the tape of a Morse inker. Several relays have been devised for this purpose on the model of the moving coil galvanometer, an extremely sensitive pattern being that invented by S. G. Brown. In this a moving coil, suspended in a strong magnetic field, is deflected by the oscillations when rectified by any form of contact or ionized gas rectifier.

The moving coil carries a long stylus ending in an iridium point, the end of which rests upon a metal cylinder. This cylinder or drum is divided into two parts by a mica or other insulating sheet, and is slowly revolved by a motor in order that any sticking of the contact point may be prevented. The local circuit through the Morse inker is closed when the moving coil deflects, and so causes the point resting on the drum also to deflect and make contact with the metal on one side of the revolving cylinder.

Another well-known type of moving coil relay is the Weston, which is provided with a platinum circuit closer in place of a pointer. The contact screws are adjustable, and so arranged that the circuit closer can be set to move through an arc ranging from $\frac{3}{8}$ in. to less than $\frac{1}{100}$ in. This instrument can be used as an ordinary or polarized relay where a great degree of responsiveness is required. *See* Inker.

MULLARD, S. R. British wireless authority. Born in 1884, he was educated as an electrical engineer, and was ultimately appointed head of the research laboratory to Edison & Swan, Ltd., where he developed the Pointolite arc lamp, the characteristic curve of which is very steep for small currents and high voltages. During the Great War he served in the Royal Air Force, and became head of the wireless section research laboratory at the Imperial College of Science for the Air Ministry. He carried out a series of researches on valves, and in 1920 founded the Mullard Radio Valve Company.

MULLARD VALVES. Series of transmitting and receiving valves manufactured by the Mullard Radio Valve Company. The Mullard O.R.A. type valve is illustrated. The two types of L.F. O.R.A. take 1·4 to 1·8 filament volts and a filament current of ·3 or ·4 ampere, according to the type, and 20 to 50 volts on the anode. The O.R.A. Type A and B are excellent amplifiers, and type B, which is of special construction, is particularly efficient when used for high-frequency amplifiers on wave-lengths below 300 metres. Both valves take 3·6 to 4 volts on the filament, and 20 to 90 volts on the anode, working best on 3·8 volts and 30 volts respectively. The R.A. valve is of more robust construction, and can be used as a detector or amplifier, taking from 50 to 100 volts on the anode and 3·6 to 4 volts on the filament. The Mullard type S3 is designed to

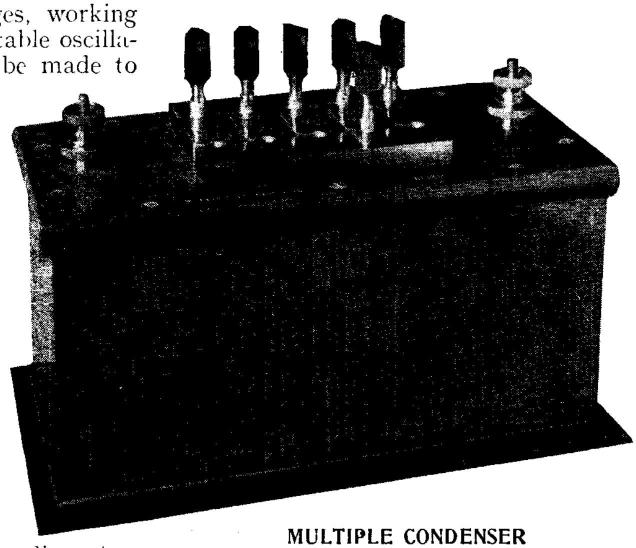


MULLARD O.R.A. VALVE

One of the valves made by the Mullard Valve Co., Ltd.

operate on low anode voltages, working on 15 to 50 volts. With a suitable oscillatory circuit the S3 valve can be made to oscillate on a 6 volt filament battery with little or no high-tension voltage, and so is very suitable for heterodyne wave-meter work.

The one-volt Ora is another type of valve manufactured by the company. The filament only requires 1 volt and ·25 ampere maximum current, so the filament can be supplied from a single dry cell. The anode voltage is 30–75. *See* Power Valve; Silica Valve; Valve.



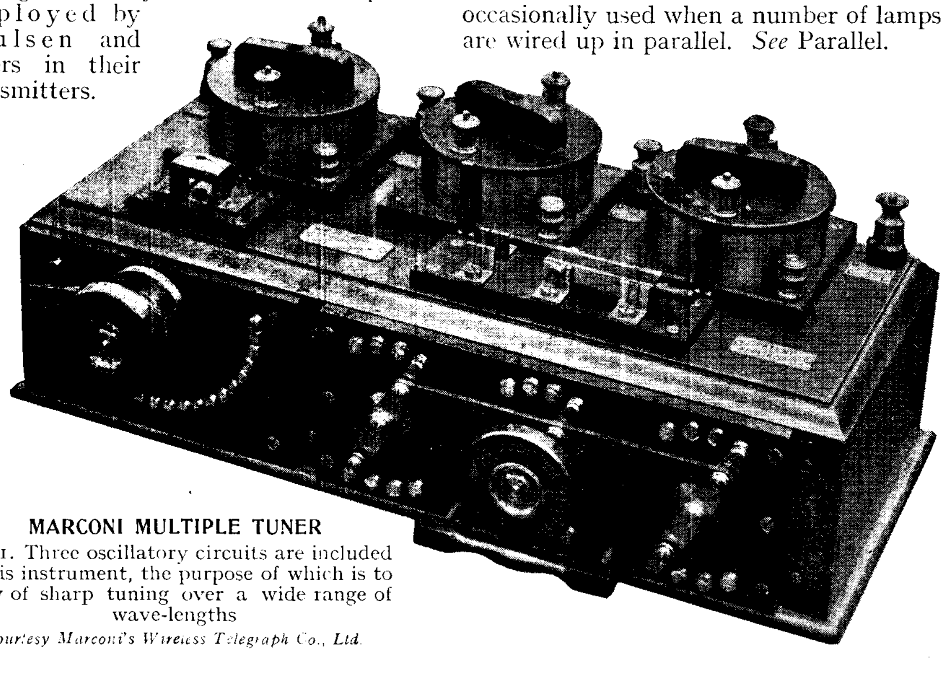
MULTIPLE CONDENSER

Capacity may be varied by plug-in contacts in this condenser. The insertion of a plug lessens the capacity, the plug short-circuiting one condenser

MULTIPLE ARC. Arc transmission is dealt with in this Encyclopedia under the headings Arc Lamp, Arc Transmitter and Continuous Waves, and in the first-mentioned article (page 122) there is a diagram illustrating a multiple-arc set. Under all three headings allusion is made to the method of placing the arc in a strong magnetic field and enclosing it in an atmosphere of hydrogen or hydrocarbon. The multiple-arc system, *i.e.* one in which a number of arcs are coupled in series, is sometimes used in order to dispense with the hydrogen or hydro-carbon atmosphere employed by Poulsen and others in their transmitters.

If a number of electric arcs are joined in series, and a condenser circuit possessing inductance is shunted over the whole number, oscillations will be created in this circuit, and fair results are obtainable in this way, even though the arcs are burning in air, or at any rate in an atmosphere deprived of hydrogen.

MULTIPLE CIRCUIT. This is a name occasionally used when a number of lamps are wired up in parallel. *See* Parallel.



MARCONI MULTIPLE TUNER

Fig. 1. Three oscillatory circuits are included in this instrument, the purpose of which is to allow of sharp tuning over a wide range of wave-lengths

Courtesy Marconi's Wireless Telegraph Co., Ltd.

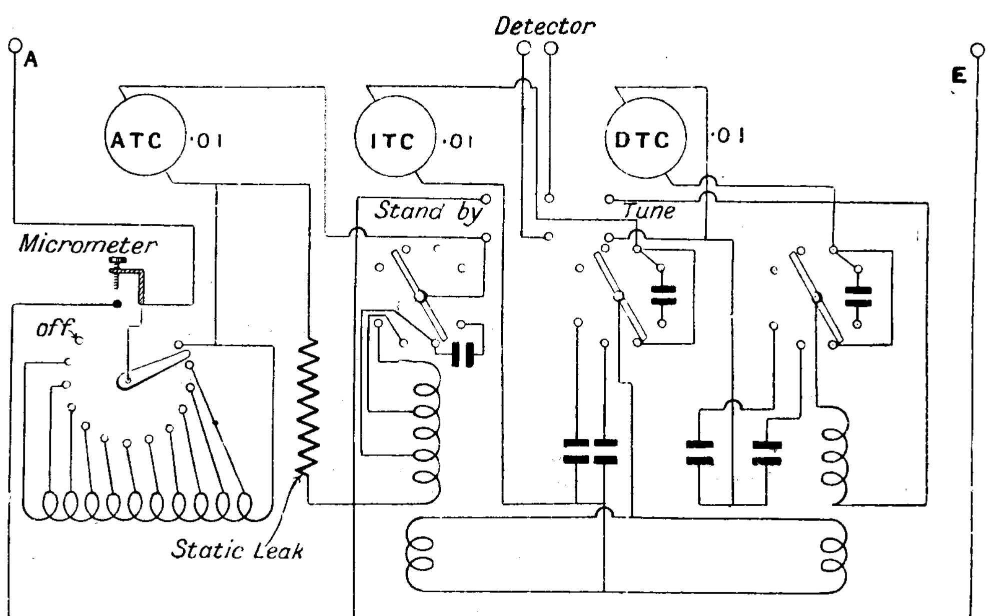
MULTIPLE CONDENSER. Name given to any form of a bank or number of condensers which can be plugged or switched into a circuit to increase or decrease its capacity as required. Such a form of condenser bank is useful to the wireless experimenter, and it is a simple matter to connect up a number of fixed condensers so that any or all can be switched in, in parallel or series, as required. On page 359 the way condensers are joined in series and parallel is explained, and also the effect on the total capacity of the system. The article on Electrostatic Capacity by Sir Oliver Lodge should also be consulted. An example of a high-class laboratory type multiple condenser is seen in the photograph. The method of adjusting the capacity is similar to that of the Wheatstone bridge. The condensers are arranged within the teak cabinet, which is fitted with an ebonite top. The latter supports the heavy brass blocks, connexion between which is made by the insertion of ground-in brass taper plugs.

It should be noted that capacity is placed in circuit by taking the plugs out. This is accomplished by arranging the connexions so that the insertion of a plug short circuits a condenser. The terminals fitted have a second knurled locking nut, which allows of the convenient clamping of two wires simultaneously. *See* Calibrated Resistance ; Parallel ; Series ; Swiss Commutator.

MULTIPLE MICROPHONE. Name given to a number of microphones wired up in parallel and operated by means of a common mouthpiece. *See* Microphone.

MULTIPLE TUNER. An instrument consisting of three adjustable oscillatory circuits. These three oscillatory circuits allow sharp tuning over a wide range of wave-lengths. The tuner is shown in Fig. 1, and the connexions in Fig. 2. The aerial circuit contains a tapped inductance and a variable aerial tuning condenser (A.T.C.) of ·01 mfd. maximum capacity. The tapped inductance control knob and stud contacts are seen on the left of the front of the tuner, Fig. 1, and the condenser is the top left-hand condenser.

On the right hand of the front of the case of the tuner is a control handle, which is connected to three sets of stud contacts and switch arms by ebonite bars. Rotation of this knob enables all three circuits to be adjusted proportionately together. This master switch is known as the tuning switch, and it is calibrated



WIRING DIAGRAM OF MARCONI MULTIPLE TUNER

Fig. 2. Small charges on the aerial leak through the static leak, shown in this diagram, to earth, while heavy charges spark across the micrometer gap. Wave-lengths of signals received on the multiple tuner range from 80 to 2,000 metres

to show the wave-length which can be received for each position of the contact arms.

The central condenser is the intermediate circuit tuning condenser (I.T.C.), and the right-hand one is the detector circuit tuning condenser (D.T.C.). The intermediate circuit consists primarily of two inductance coils and the variable condenser, and the detector circuit of a fixed inductance, a variable condenser and the primary windings of the magnetic detector connected to the detector terminals. There are a number of fixed block condensers which can be placed in series in the circuits.

On the top of the tuner in front of the centre and right-hand condensers is a change-over switch. This is used to change over from a stand-by position to a tune position. In front of the aerial tuning condenser is the micrometer spark gap. This prevents the accumulation of heavy static charges on the aerial. It is adjusted by a screw so that one complete turn adjusts the gap through $\frac{1}{100}$ in. In the circuit diagram is shown a static leak. Small charges on the aerial leak through this to earth, while heavy charges spark across the micrometer gap. The multiple tuner has a range of from 80 to 2,600 metres.

The multiple tuner is part of the receiving apparatus used on board ship to receive from Marconi disk discharger sets. The complete receiving apparatus consists of a magnetic detector, multiple tuner, telephones, and telephone condenser. The aerial and earth terminals are joined to the aerial and earth respectively through an earth arrester (*q.v.*). *See* Disk Condenser; Intermediate Circuit; Magnetic Detector; Micrometer Spark Gap.

MULTIPLIER. This term is very often used for the coil of wire in which the needle of a galvanometer is pivoted. *See* Galvanometer.

MULTIPOLAR. Term used of motors whose field magnets have more than two poles. A two-pole dynamo is said to be bipolar. Nearly all modern machines are multipolar. *See* Dynamo; Generator.

MUSCOVITE. This is another name for mica, which is also occasionally known as Muscovy glass, from the fact that it once came from Russia.

MUSH. Term used for the irregular intermediate frequencies set up by an arc transmitter which interfere with the fundamental wave-lengths. A mushy note is one which is not absolutely definite or clear cut, and so hard to read. It is a note received by the heterodyne method when damped waves or modulated continuous waves are being received. *See* Beat Reception; Heterodyne.

MUSHROOM VALVE. Alternative name given to the Cossor R.M.R. and other Cossor valves on account of the shape of the grid and anode, which are fashioned somewhat like a mushroom. *See* Cossor Valve.

MUSICAL ARC. Name given to an arc giving a regular, distinct musical note. The phenomenon of the musical arc was first observed by Lecher, and investigated by Duddell and Peuckert. It is also known as the singing arc. *See* Duddell's Musical Arc; Tone Wheel.

MUSICAL INDUCTANCE. An inductance used between the grid and the filament. This musical inductance takes the place of the ordinary grid leak. Such an inductance is of the order of henries and contains an iron core.

MUTE AERIAL. This is an alternative name for dumb aerial (*q.v.*).

MUTUAL INDUCTANCE. Mutual inductance may be defined as the amount of mutual induction which occurs between two coils when the current in one is varied at unit rate. The unit of mutual inductance is the same as for inductance, viz. the henry, and the mutual inductance of two coils is said to be one henry when one E.M.F. of one volt is induced in the one by a variation in current of one ampere per second in the other. The value of mutual inductance may be calculated from the formula

$$M = \frac{L_1 - L_2}{4}$$

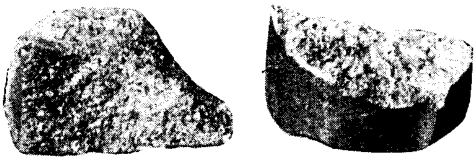
where M = mutual inductance, L_1 the inductance of the coils joined in series so that their magnetic fields are in the same direction, L_2 their inductance when connected in series so that their fields are in opposition. *See* Coil; Inductance; Inductance Coil.

N

N. This is the chemical symbol for the gaseous element nitrogen, a constituent of the atmosphere. *See* Nitrogen.

Na. Chemical symbol for sodium. It is the first two letters of the Latin name for sodium, natrium. *See* Sodium.

NAGYAGITE. This is one of the more important minerals which contain gold. It contains lead, gold, antimony, sulphur, and tellurium; and is so called from its discovery near Nagyag in Transylvania.



NAGYAGITE CRYSTAL
Nagyagite is an important mineral containing gold, and is used as a crystal rectifier

The mineral is often known under the alternative names of black or leaf tellurium. It is used as a crystal rectifier, usually in conjunction with zincite. *See* Tellurium.

NALLY, EDWARD JULIAN. American wireless pioneer. Born April 11th, 1859, in Philadelphia, he joined the Western Union Telegraph Company in St. Louis and worked his way up in the telegraph service until, in 1913, he was appointed vice-president and general manager of the Marconi Wireless Telegraph Company of America.

Nally was one of the first to see the possibilities of wireless, and under his control the first commercial wireless communication was established between the United States and Japan, in 1914, and in 1920 he founded the first commercial wireless service between the United States and Great Britain, and afterwards to other countries. He was appointed the first president of the Radio Corporation of America, and is a member of many scientific and other societies.

NATURAL FREQUENCY. The frequency at which free oscillations would be propagated in any circuit. All circuits possess a natural or fundamental frequency, the value of which depends upon the ratio of inductance and capacity in that circuit. This property may be understood from the analogy of the tuning-fork. The pitch of the note when struck (which is the equivalent of the frequency of vibration of that fork) is determined entirely by the area of cross-section and length of the prongs of the fork. It is entirely independent of the force with which the fork is struck, all the difference that that makes being a change of amplitude of wave, or loudness of note.

In the same way with any electrical circuit, if any closed circuit possessing capacity and inductance is impressed with one charge of electricity, then that charge will oscillate to and fro in the circuit, always at the same frequency, but gradually getting weaker in strength (amplitude) until it is finally dissipated in the form of heat, due to resistance.

When an oscillating or alternating current of a frequency of n is applied to a circuit whose natural frequency is also n, then that circuit is said to be in resonance, that is to say, it will respond in the same way as one tuning fork to another, and similar, fork if the latter is struck. *See* Free Oscillations; Resonance.

NATURAL MAGNET. This is the name given to the lodestone, or iron ore, magnetite, which has the natural properties of a magnet. When suspended, it points north and south, and was the first form of magnet used by the early navigators. *See* Lodestone.

NATURAL RECTIFIER. Alternative name given to rectifying crystal detectors, which possess the property of passing an electric current in one direction only. *See* Crystal.

NATURAL WAVE-LENGTH. The natural wave-length of an aerial is the length of wave which an aerial has, due to its own inductance and capacity. In considering the correct size and type of aerial to adopt, it is essential that consideration be given to the wave-lengths which are most likely to be used in transmission and reception on that aerial. Every aerial possesses certain amounts of inductance and capacity, depending on its type, length, proximity to earthed bodies, etc., and upon these factors depend its inherent quantities of inductance and capacity.

In the first place, the natural wave-length is chiefly dependent upon the length of the aerial. If its length is increased, then its wave-length is also increased. On the other hand, if parallel wires are added to an aerial, the capacity of that aerial is increased, because capacities in parallel result in increased capacity. The inductance, however, is decreased, for inductances in parallel result in decreased inductance. The net result of the addition of a parallel wire, therefore, may be to keep the natural wave-length approximately unchanged.

In the case of single or parallel wire aerials of the vertical or inverted "L" types, it is generally found that the natural wave-length is approximately four and one-quarter times its own length. In the case of a "T" aerial, however, the natural wave-length will be found to be more in the nature of five times the length of the aerial.

It is important to note that the length of an aerial for purposes of these calculations is taken as being, (*a*) in the case of inverted "L" aerials, the total length of the horizontal portion plus the length of the lead-in; and (*b*) in the case of a "T" aerial, one-half the total length of the horizontal portion plus the length of the lead-in.

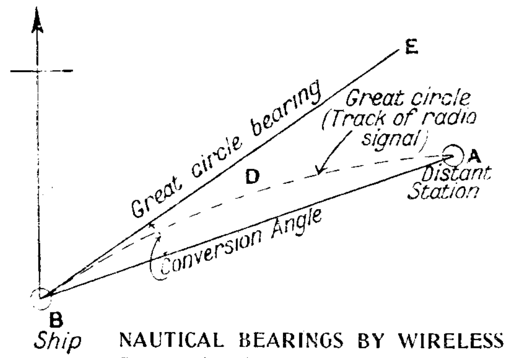
From the above it will be seen that if an aerial which is to receive broadcasting is made more than 80 ft. long, in the case of an inverted "L" aerial capacity will have to be connected in series with it, in order to reduce its wave-length so that the shorter wave stations may be received. This will result in reduced efficiency in receiving signals. From an efficiency standpoint it is always better to have an aerial of such a length that its natural wave-length is approximately the same as the wave-length of the signals that will be most frequently received or transmitted. If either inductance or capacity in series has to be added, then it is more efficient to add inductance, and for this reason an aerial should always err on the short side rather than the long. *See* Aerial; Capacity; Electrostatic Capacity; Inductance; Wave-length.

NAVIGATION BY WIRELESS. One of the principal uses of the wireless direction finder (*q.v.*) lies in its application to marine navigation. There are two methods by which this may be accomplished. One is to carry the direction-finding apparatus upon the ship itself and take bearings off fixed points on shore or other ships; the other system is to have the apparatus on shore, take the direction of the ship's signals, and inform the ship of her bearings.

The former method is by far the one in more general use. By this method the ship is able to find her bearings without delay and without having to transmit; and bearings may be taken from any high-powered wireless station when the ship is out of range of the ordinary coastal station. The ability to ascertain the relative positions of other ships is a great asset in fog or in congested waters.

The apparatus described under the headings Direction Finder and Robinson Direction Finder are both suitable for the purpose of marine navigation, but their methods of application are necessarily rather different.

The first operation to be performed before navigation can be proceeded with is the obtaining of the location of the ship by taking a wireless bearing. The actual manipulation of the set to obtain this is described under the headings mentioned above. For accurate results, however, it is essential that various corrections be made in order that the curvature of the earth may be allowed for. This correction is rendered necessary on account of the large distances over which wireless bearings are taken compared with the ordinary methods, where bearings are taken on visible objects. If corrections were not made to take into account the curvature of the earth serious errors would arise and ships would find themselves many miles out of their proper course.



NAUTICAL BEARINGS BY WIRELESS

Fig. 1. How the bearings of a ship are obtained by means of wireless is shown in this diagram

The diagram, Fig. 1, will indicate more clearly why these corrections become necessary.

In this diagram B represents the position of a ship which is taking a bearing on a land station, A. The dotted line, ADB, is known as the great circle, and represents the track of the radio signals. It will be seen that as the wireless bearing is taken from a circle, the result would be inaccurate. This inaccuracy is shown by the line BE, which represents the bearing which would be taken were a correction not applied. The correction, then, is the angle EBA, which is known as the conversion angle.

Fig. 2 is a table of conversion-angle scales, and the method of finding the conversion angle from these scales is as follows :—

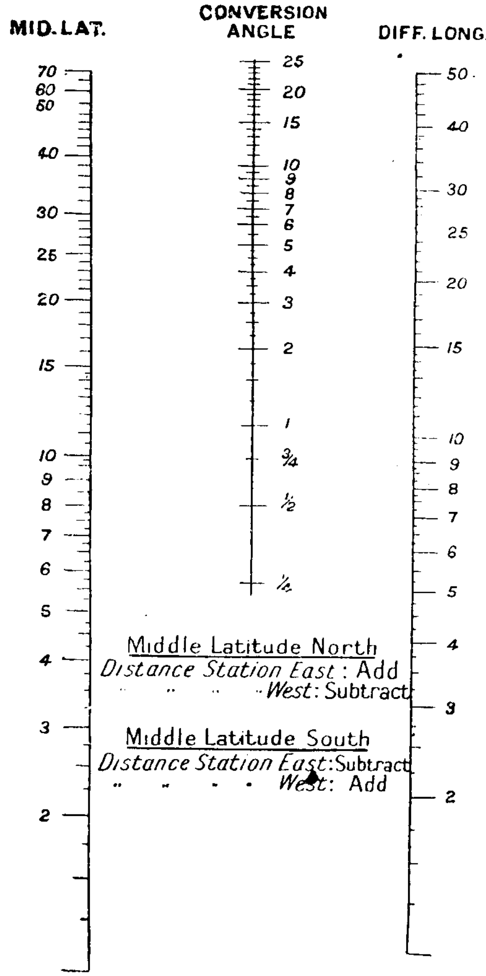
The first step is to find the mid-latitude of the ship and the distant station. This done, it is next necessary to find the difference in longitude between them. These values are then plotted on the scales, by placing a transparent rule across them. This rule has a line engraved upon it, and the point on the centre line of the scale table where the line crosses is the correct conversion angle for the particular bearings. From this it will be seen that the finding of a correct relative position of a ship by wireless becomes a matter of simplicity, and, furthermore, a reasonable degree of accuracy is assured. The figures in Fig. 2, for instance, are accurate for any distance up to one thousand miles.

It is important that in the fixing and calibrating of the direction finder (and this particularly applies to the Robinson system) allowances should be made for quadrantal errors due to the metal parts of the ship affecting the readings on the receiver. These errors, once found, may be tabulated on a chart as a permanent record, for they remain constant so long as the direction-finding apparatus is kept in one part of the vessel.

Another thing which may cause errors is coastal refraction. These errors are due to the fact that it occasionally happens that the line on the chart coincides with the coast lines near the wireless station on which the bearing is being found. Fortunately these errors will be found fairly constant for certain stations when a ship is traversing certain routes, and the navigator will learn from experience which stations are likely to be in error from this cause, and so avoid them.

One of the most useful factors in wireless navigation is the determining of the position of other vessels in fog. In this instance the bearing of a ship would be found, and after a short interval, again taken. Should very little deviation between the two bearings be found, then it is obvious that the two ships are steering head on towards each other. From this information the navigator can give orders to change the course of his vessel and so avoid collision.

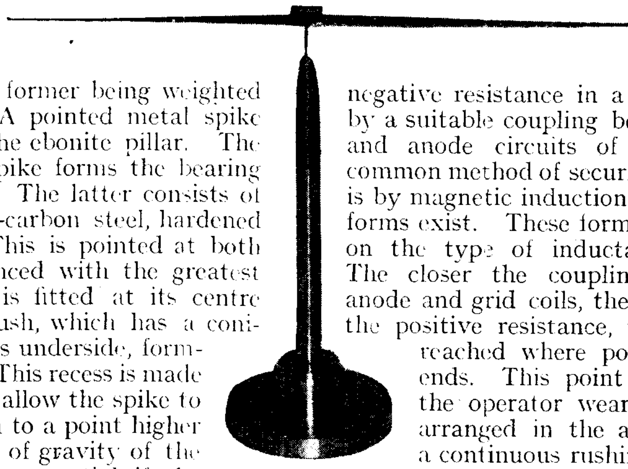
Where a ship is moving in congested waters and the weather is foggy, it is an easy matter to gauge the rate of approach of another ship by requesting that ship, by wireless, to make simultaneous sound and wireless signals. The operator of the ship which made the request then times the interval between the receipt of the two signals. As sound travels at about 1,100 ft. per second, it will be seen that an interval of 5 seconds would indicate that the other ship was approximately one mile away. The taking of a further reading at a short-time interval would render the speed of approach of the two vessels an easy matter to calculate.



CONVERSION ANGLES OF SHIP'S BEARING

Fig. 2. Conversion angles, shown in an alinement chart, as the example above, enable the bearing of a ship to be obtained by wireless

NEEDLE, MAGNETIC. The photograph is an illustration of a type of magnetic needle in general use for laboratory purposes. The base and standard are of ebonite, the former being weighted for stability. A pointed metal spike projects from the ebonite pillar. The point of this spike forms the bearing for the needle. The latter consists of a strip of high-carbon steel, hardened and ground. This is pointed at both ends, and balanced with the greatest accuracy. It is fitted at its centre with a metal bush, which has a conical recess on its underside, forming a bearing. This recess is made deep enough to allow the spike to project through to a point higher than the centre of gravity of the needle. This is essential if the needle is to balance laterally.



MAGNETIC NEEDLE

Balanced on a point is a standard magnetic needle, which is extremely sensitive in its action

Courtesy J. J. Griffin & Sons

Such a needle is extremely sensitive to magnetic influence of a mean order, and would, of course, normally lie in a direct magnetic north-south line.

NEGATIVE CHARGE. A body is said to be negatively charged when it has an excess of electrons, or negative particles of electricity. *See* Electricity; Electron.

NEGATIVE PLATE. Name given to one of the plates of an accumulator. There is always one more negative plate than there is positive, so that both sides of every positive plate may be acted upon. *See* Accumulator; Accumulator Plates.

NEGATIVE POLE. In a cell, this is the name given to the terminal towards which the electric current in a circuit connected to the cell flows. It is the pole from which the current flows inside the cell. In the simple voltaic cell consisting of two elements, zinc and copper, the terminal connected to the zinc element is the negative pole. In high-tension dry batteries and in most forms of accumulators the negative pole is generally coloured black, the positive pole being coloured red. In addition, or alternatively, they may be marked — and +. *See* Accumulator; Battery; Cell; Dry Cell.

NEGATIVE RESISTANCE. The effect observed in an oscillatory circuit which tends to keep the circuit in a state of self-oscillation. In order to appreciate negative resistance in an oscillatory circuit, a knowledge is required of the principles of the three-electrode valve.

One method of producing a state of negative resistance in a valve circuit is by a suitable coupling between the grid and anode circuits of the valve. A common method of securing this coupling is by magnetic induction, of which many forms exist. These forms are dependent on the type of inductance employed. The closer the coupling between the anode and grid coils, the lower becomes the positive resistance, until a point is reached where positive resistance ends. This point is indicated to the operator wearing headphones arranged in the anode circuit by a continuous rushing sound, which develops on still closer coupling the grid and anode coils into a shrill whistle. A state of negative resistance is now reached when the valve is found to self-oscillate strongly.

The circuit in this state is beyond the adjustment for successful reception, the incoming signals, if heard at all, being extremely distorted, although considerably amplified.

The Armstrong super-regenerative receiver takes advantage of the negative resistance of a valve circuit in this state of self-oscillation. A tuned oscillating circuit is arranged to give a positive grid potential on the original valve, which checks the negative resistance, and consequently the self-oscillation of the valve during each half-cycle of the incoming oscillations. Thus the undamped half-cycle of the incoming aerial oscillation is built up to an enormous extent when the circuit is in a state of negative resistance. The other half of the aerial oscillation is suppressed by the positive potential of the oscillator. It will be seen that the frequency of the oscillator must be the same as the frequency of the aerial circuit during the reception of a signal.

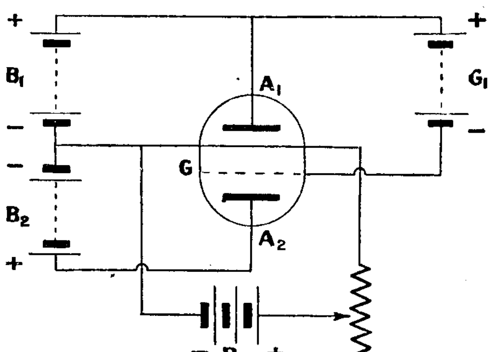
Special valves arranged to operate with a negative resistance are the negatron, the pliotron, and the plio-dynatron, all described separately in this Encyclopedia. *See* Oscillation.

NEGATRON. A negatron is a four-electrode thermionic valve devised by J. Scott-Taggart in 1919 for obtaining a negative resistance characteristic.

The valve contains two flat anodes, A_1 and A_2, Fig. 1, fixed one on each side of the filament. The anode A_1 is termed the main anode, and A_2 is termed the diversion anode. Between the anode A_2 and the filament is mounted a grid termed a control electrode.

If the valve is connected as shown in Fig. 1, then by a correct adjustment of the anode potentials and the emission current the total current in the anode circuits can be made equal to the emission current. When these currents are equalized, any increase of positive potential on the grid with respect to the filament will cause an increase of current in the diversion anode circuit at the expense of the current in the main anode circuit, which therefore decreases.

The filament is lighted from the battery B_1. The anode A_1 is connected to the filament through a battery B_1. The anode A_2 is connected to the filament through a battery B_2. A battery G_1 is connected between the anode A_1 and the grid, in order to make the potential of

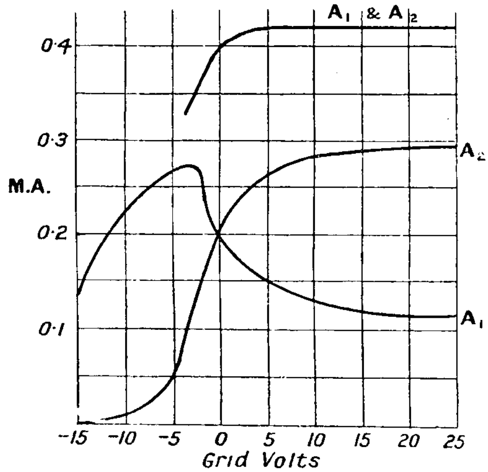


NEGATRON CIRCUIT

Fig. 1. Circuit diagram for the negatron, John Scott-Taggart's four-electrode valve

the grid negative with respect to the filament. The batteries B_1 and B_2 should be of the order of 60 volts, but these values are not critical provided the filament brilliancy can be adjusted.

When the potential of A_1 is increased the current in the anode circuit A_1 is increased. This causes the positive potential of the grid to increase, with a consequent increase of the current in the anode circuit A_2. The current in the anode circuit A_2 can, however, only be increased by some of the electrons going to the anode A_2 instead of to the anode A_1. Hence if the valve is used at the saturation point an increase of current in the anode circuit A_2 is accompanied by a decrease of current in the



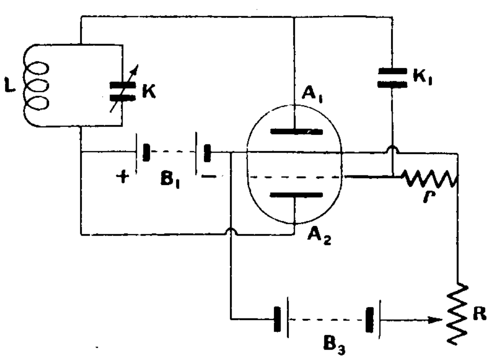
CHARACTERISTIC CURVE OF NEGATRON

Fig. 2. This is a characteristic curve of a negatron or four-electrode valve

anode circuit A_1, and an increase of current in the anode circuit A_1 is accompanied by a decrease of current in the anode circuit A_2.

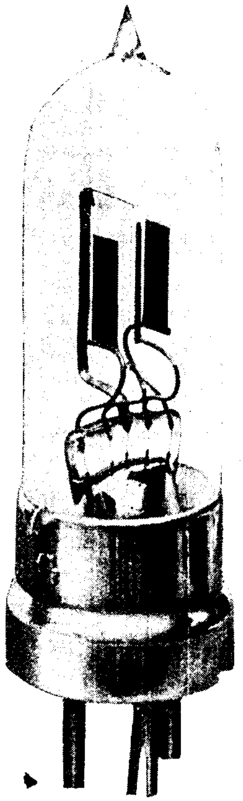
When the filament brilliancy is adjusted to give the correct electron emission the increase of potential of the anode A_1 tends to increase the current in the anode circuit A_1, but owing to the robbing action of the anode A_2 this tendency is overcome and actually a decrease of current in the anode circuit A_1 occurs.

Fig. 2 shows the characteristic curves of a negatron. A_1 represents the current in the main anode circuit A_1, A_2 represents the current in the anode circuit A_2, and the top curve the total of both anode currents. It will clearly be seen that as the current in the anode circuit A_1 decreases with an increase of positive grid potential the current in the anode circuit A_2 increases, and



CONNEXIONS OF A NEGATRON

Fig. 3. In this diagram are given the connexions for using the negatron for the production of beats for continuous-wave reception



NEGATRON VALVE

Fig. 4. Two anodes are included in the negatron four-electrode valve, one of which is the diversion anode

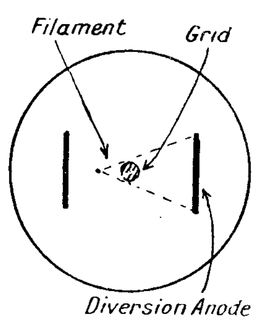
Courtesy Radio Communication Co., Ltd.

that over a considerable range of grid positive voltages the totals of the currents in the anode circuits are fairly constant.

Further, the current in the main anode circuit decreases to the left of the peak value because the valve is not saturated, since an increase of the grid negative voltage produces an increase in the space charge between the filament and the anode A_1, thereby decreasing the current in the main anode circuit.

The negatron, besides being applicable to receiving circuits, can also be used as a generator of local oscillations for the production of beats for continuous wave reception.

A diagram of connexions for using the valve for this purpose is shown in Fig. 3. The filament is lighted from a battery B_3 in series with an adjustable resistance R. The oscillatory circuit consists of the inductance L and the adjustable tuning condenser K. The battery B_1 provides the necessary positive voltage for the main anode A_1. A condenser K_1 is connected between the anode A_1 and the grid, and a high resistance *r* between the grid and filament. The condenser K_1 and the resistance *r* form a grid leak and prevent a high positive potential on the grid.



NEGATRON ELECTRODES

Fig. 5. Disposition of the anodes, filament, and grid of a negatron as seen from above

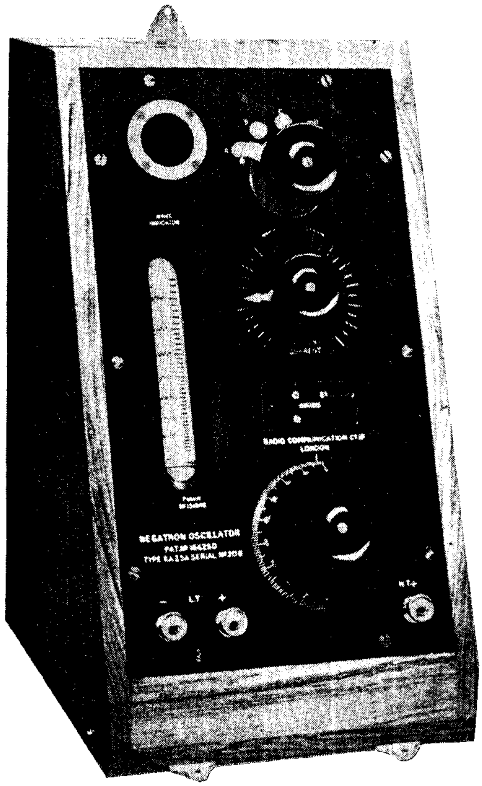
By the correct adjustments of the filament brilliancy and the potential of the main anode A_1 by the battery B_1 oscillations can be set up and maintained in the oscillatory circuit L K, and by the proper selection of the electrical constants of this circuit a wave-range of 600 metres to 20,000 metres can be covered.

Fig. 4 is a photograph of the most recent type of negatron valve, as made by the Radio Communication Co., Ltd. It will be seen that the bulb, which is tubular in shape, contains four electrodes. These are, respectively, the main anode, filament, the grid (in this case a metal rod), and diversion anode.

The disposition of the grid with respect to the filament is such that the former completely screens the anode from the electronic flow. The diagram, Fig. 5, will explain this. Here the negatron is shown cut in a horizontal section with the viewpoint from above. The dotted lines indicate how the grid screens the anode. The methods of supporting the electrodes in the valve are peculiar, but they follow standard valve practice in that all the electrode supports are held together in the one "pinch" of glass. The cap or base of the valve is also of the orthodox pattern. *See* Four-electrode Valve.

NEGATRON OSCILLATOR. The negatron finds its greatest application in the instrument illustrated in the photograph. This is known as the negatron oscillator. It is an instrument which is largely used in marine telegraphy, in conjunction with an ordinary valve receiver, for the reception of C.W. The principle upon which separate oscillators of this type work is explained under the headings Heterodyne and Optimum Heterodyne.

The principal feature of this oscillator is the manner in which the wave-length is automatically indicated upon the scale on the left-hand side of the instrument. Coarse tuning is effected by moving the arm over the studs in the switch at the top of the panel. This knob is geared to a vertical spindle upon which the scale is mounted. Upon this latter spindle is a cylinder carrying five independent scales, each one coming into line in the slot as the switch arm makes contact on the stud. Thus each stud has a definite wave-length range, the first one (which is the one in



NEGATRON OSCILLATOR

This instrument is largely used in marine telegraphy, the heterodyne principle of reception being employed

Courtesy Radio Communication Co., Ltd.

use when the photograph was taken) ranging from 600 to 1,200 metres.

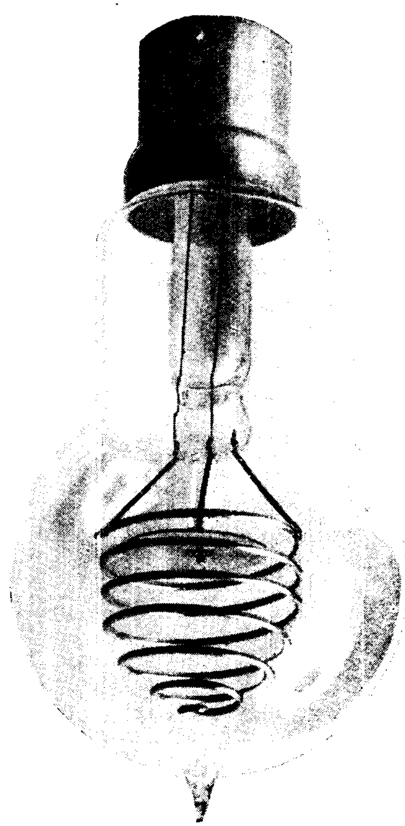
Fine tuning is accomplished by the condenser shown at the bottom of the panel. By a further system of gearing, a pointer is made to slide up or down the scale at the side of the slot, thus indicating at what point on the range the condenser is set, with a great degree of accuracy.

Filament control is provided by means of the centre knob, which is surrounded by a scale engraved upon the panel itself.

Electrically, the negatron oscillator consists of a closed circuit, containing the valve, and variable inductances and capacity. Coupling with the main receiver is effected by placing the oscillator in close proximity to the left-hand side of the tuner with which it is designed to work. The use of this very loose coupling absolutely prohibits self-oscillation.

NEON LAMP. An electric lamp filled with neon gas, which may be applied to a variety of indoor purposes. Neon gas-filled tubes were used at an early stage of wireless history by Professor Fleming as detectors in his original cymometer, or wave-meter. They have since been popularized, more particularly in connexion with luminous advertisements, under the name of "Osglims," and an ordinary pattern outwardly resembles the everyday incandescent electric lamp.

The bulb contains neon gas at a low pressure, and instead of a filament there are two electrodes, one commonly a spiral of wire, the other a plate, as shown in the photograph. In the commercial models a resistance wound on a tiny fibre former and mounted in the base of the lamp is connected in series with the latter in order to steady the current. The "Osglim," as ordinarily sold, can be used with from 200 to 250 volts A.C. or D.C., and consumes



NEON LAMP

Neon gas is used at low pressure to fill this electric lamp, which has two electrodes. Ionization of the gas causes the lamp to glow, and it then becomes a rectifier of electric currents, passing more current in one direction than in the other only about 10 milliamperes. Normally, only about 140 volts are required to set up a glow, and when once the current has begun to pass, the internal resistance of the lamp diminishes and decreases in proportion to the amount of the current. The actual luminosity of the lamp is due to the ionization of the gas by the electrical discharge which passes through it.

The neon lamp possesses several interesting properties, among which two may be mentioned as having special wireless applications. Firstly, it passes much more current in one direction than in another, owing to the difference in the areas of the two electrodes. Secondly, there is a marked difference between the voltage at which the lamp begins to glow and that at which it goes out. These properties were discussed and demonstrated by P. R. Coursey in a lecture to the Radio Society of Great Britain on July 25th, 1923, some of the points of which are here abstracted.

The fact that the neon lamp passes more current in one direction than in the other, an average ratio being about 4 to 1, enables it to be used under certain conditions as a rectifier.

Producing High-tension Current for a Transmitter

Where neither D.C. or A.C. mains are available, the production of H.T. for operating a transmitter becomes a troublesome problem, one of the approved methods, the use, namely, of a tuned vibratory transformer to step up the voltage from an accumulator, such as is used for filament lighting, being subject to several drawbacks in practice. These, as has been shown by F. L. Hogg, are removed by the use of neon lamp rectifiers. In this case the resistances inside the cup of the lamp as sold must be extracted.

The property which the neon lamp possesses of beginning to glow at a different voltage from that at which it goes out can be utilized to make it produce interrupted currents, and it is stated that neon lamps have been made to produce several watts of energy for a C.W. transmitter.

Coursey's demonstration of this method took the form of a circuit consisting of a neon lamp connected through a resistance, about ½ megohm, on to a D.C. main supply (200 volts) and with a variable condenser of ·001 mfd. across the lamp. When the supply voltage was first switched on, nothing happened, until the condenser was charged up to a voltage across the terminals of about 140, when the glow started. The discharge through the gas drew the charge out of the condenser, and discharged it until the voltage dropped to about 120, when the glow in reality (though, apparently, owing to the high frequency of the interruptions, a steady flow was maintained) stopped, and the condenser was then free to charge up again until the voltage once more reached 140, when the process was repeated. The smaller the capacity of the condenser the less time it took to charge up.

By making it small, extremely high frequencies can be obtained. The pitch of the resultant note heard in a telephone receiver can be varied by altering the adjustment of the condenser, but such changes of pitch are not an ordinary tuning phenomenon, because the alteration in this case is an alteration of the time-constant of the circuit.

Using the Neon Lamp as an Amplifier

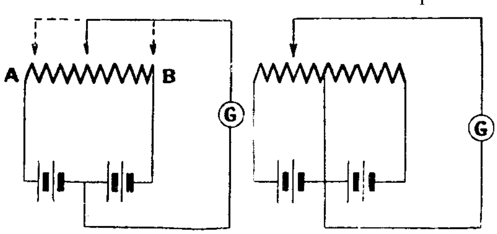
The neon lamp in its standard form has been used experimentally as an amplifier, but greater efficiency has been secured by a three-electrode pattern developed in Holland, and the subject of the British Patent No. 17528 (N. V. Philips). In this the glow is confined to the surface of the cathode, which consists of a thin rod of magnesium or similar alkaline metal. "Surrounding the cathode are two spirals of iron wire one serving as the anode and maintained at a positive potential of about 120 volts with respect to the cathode, while the other serves as an auxiliary control electrode, and is maintained at a steady positive potential with respect to the cathode of about 20 volts less than the main anode. There is thus little or no current flow to this electrode, but by its position it is well adapted to control the flow of current through the gas from the main anode. The lamp is thus enabled to act as an efficient amplifier."

Other suggested uses of the neon lamp for wireless purposes are: (1) in connexion with relays; (2) as a simple indicator of high-frequency voltages; (3) as a resonance indicator for simple forms of wavemeter; and (4) for the rapid measurement of high resistances. The last-named application was elaborated by A. D. Cowper, who gives two methods. One of these, while rapid and direct, gives approximate results, and is only suitable for comparisons of grid leaks and so forth. By the other, absolute values can be calculated if the precise capacity of a large fixed condenser is known. In both cases the "overlap" of about 20 volts in the glow voltage, as compared with the die-away voltage, is the basis of measurement. —*O. Wheeler.*

NEON TUBE. This is the American term for the Neon lamp (*q.v.*)

NEUTRAL POINT POTENTIOMETER. A type of potentiometer in which a positive or negative bias or a neutral position is obtained by the movement of the potentiometer slider. The neutral point effect is obtainable in two ways, which are shown in Figs. 1 and 2.

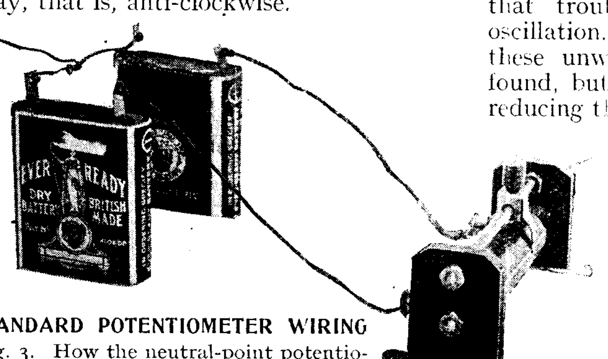
In Fig. 1 a potentiometer of the ordinary three-terminal type is used. The neutral-point effect is obtained by tapping the battery at a central point and the circuit is completed to the slider. It will be seen that when the slider is towards the point



NEUTRAL POINT AND POTENTIOMETER TAPPING

Fig. 1 (left). In this arrangement the battery is tapped centrally. Fig. 2 (right). The potentiometer is tapped centrally in this case as well as the battery

A, at the left of the resistance in Fig. 1, the current in the galvanometer circuit will flow in a clockwise direction. On moving the slider to a point B, towards the other end of the resistance, the current will flow in the galvanometer circuit in the opposite way, that is, anti-clockwise.



STANDARD POTENTIOMETER WIRING

Fig. 3. How the neutral-point potentiometer is wired up

Between these positions a point will be found where the potential from one battery neutralizes the potential of the other, and no current will flow in the galvanometer circuit. This circuit arrangement is shown in Fig. 3, where potential is obtained from two dry cells.

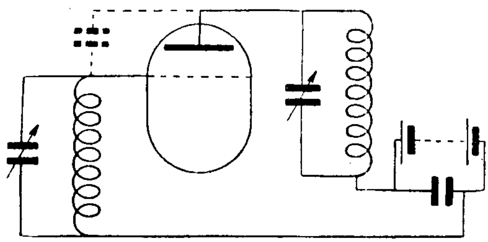
Fig. 2 shows a theoretical wiring of a neutral point potentiometer in which a central tapping on the resistance is made. This tapping connects respectively to the midway tapping point of a battery and one side of the galvanometer circuit. The other end of the latter is connected to the slider of the potentiometer. This circuit actually consists of two battery circuits, to either of which the slider may connect, according to its position. At the point where the slider meets the midway battery tapping no potential occurs in the galvanometer circuit, as at this point it is not included in either battery circuit.

NEUTRAL WIRE. This is the name generally given to the middle wire of a three-wire system. *See* Delta Grouping; Mesh Grouping.

NEUTRODYNE. A circuit arrangement applied to a receiving set where H.F. amplification is used for neutralizing the effects of capacity of the valve and its holder. Fig. 1 represents a part of a valve receiving circuit in which the valve capacities are represented by a condenser shown in dotted lines. It will be seen that a complete oscillatory circuit exists, formed by the inductances and capacities in the anode and grid circuits.

Thus a difference of potential occurs at the anode side of the coil in the anode circuit. Instead of being handed on to the next valve for further amplification, a part of this potential leaks through the capacity of the valve and its valve holder and affects the grid to such an extent that trouble is experienced with self-oscillation. Various methods of damping these unwanted oscillations have been found, but all of them have the effect of reducing the efficiency of the set.

The device invented by Professor Hazeltine, and called the neutrodyne receiver when applied to a receiving set, employs another tunable oscillatory circuit which is inductively coupled to the anode coil. One end of the neutrodyne device is connected, in



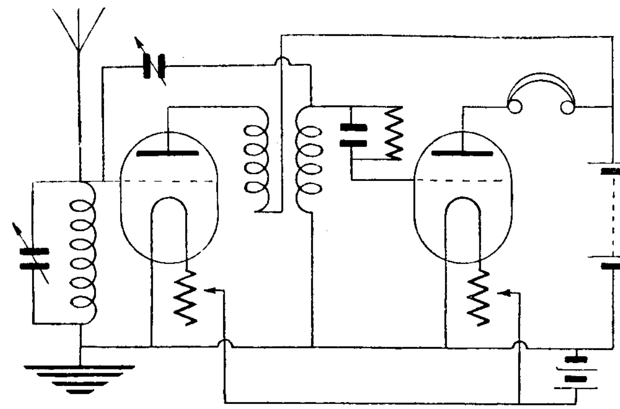
THEORETICAL BASIS OF NEUTRODYNE CIRCUIT

Fig. 1. Valve capacity between anode and grid circuits is shown by the dotted part of this diagram of an ordinary closed circuit

the case of transformer coupling, between the grid side of the secondary of the high-frequency inter-valve transformer and the grid of the preceding valve. In the case of high-frequency transformer coupling the inductance necessary for the oscillatory circuit constituting the neutrodyne feature is found in the secondary coil itself, and only a small variable condenser is necessary, which is wired in series with it. Fig. 2 shows a neutrodyne receiver of one-stage high-frequency transformer coupling.

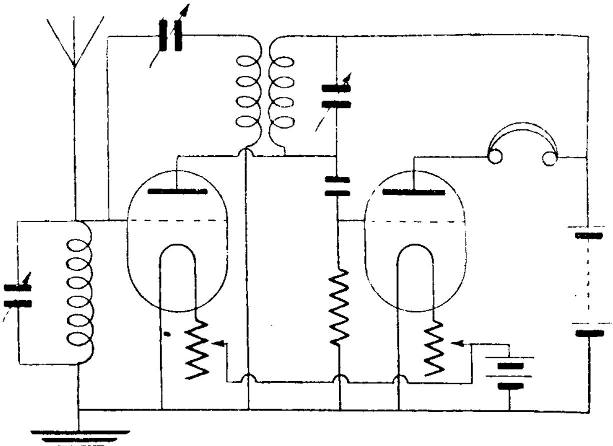
This condenser enables the circuit to be tuned to the same frequency as the anode coil. The windings of the transformer are arranged so that the impulse transmitted to the grid through the valve capacity is neutralized by the impulse imparted through the neutrodyne condenser.

The application of the neutrodyne to systems of tuned-anode coupling is rather more elaborate. As there is no secondary coil to utilize for the neutrodyne, it is necessary to couple inductively an inductance to the tuned-anode inductance. This inductance is of such a size as to match the tuned anode in frequency. The neutrodyne condenser, as in the case of the transformer-coupled set, is wired in series with the inductance, the other end of which connects to the common earth of the set. The wiring of a set using the neutrodyne in a tuned-anode high-frequency circuit is seen in Fig. 3.



APPLICATION OF NEUTRODYNE CIRCUIT

Fig. 2. Added to a single stage of high-frequency amplification is a neutrodyne circuit. This diagram shows how the neutrodyne principle of a small stabilizing condenser is applied



NEUTRODYNE IN TUNED ANODE CIRCUIT

Fig. 3. Arranged in a tuned anode high-frequency circuit is a neutrodyne condenser, seen at the top of the diagram

The most convenient method of coupling the tuned anode and the neutrodyne coils is by using duo-lateral coils for this purpose mounted in a standard two-coil holder. For the purpose of the neutrodyne receiver, a small condenser only is required, and such a condenser is described under the headings Condenser and Neutrodyne Receiver (pages 502 and 1468). The condensers used are special tubular condensers, practically billi condensers; they are easily and cheaply made for any particular set.

NEUTRODYNE RECEIVER & HOW TO BUILD IT

A Stable Unit with Two H.F. Stages on Prof. Hazeltine's Principle

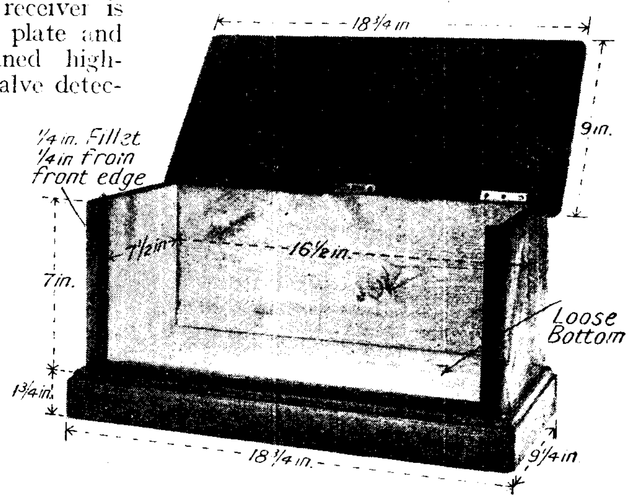
When more than one stage of high-frequency amplification is required this type of receiver will be found both stable and efficient. Its construction is fully described and illustrated with a special photogravure plate. The article on Hazeltine Receiver should be consulted ; also Condenser ; High-frequency Amplification ; Neutrodyne

A neutrodyne receiver is a form of receiver employing tuned high-frequency amplification embodying condensers of small capacity wired to neutralize the internal capacity of the valves and the valve holders. The advantage of these condensers, which constitute the special feature of the neutrodyne receiver, lies in their suppressive action on the regenerative effect caused by inter-valve capacitive coupling. This effect is particularly evident in multi-stage high-frequency amplification and limits the number of valves that may be used.

A three-valve neutrodyne receiver is shown in Fig. 10 on the special plate and consists of two stages of tuned high-frequency amplification with valve detector. Battery terminals are placed to the right side of the set and permit the addition of low-frequency amplification, which may be made up in a cabinet to suit the receiver illustrated. A switch is placed centrally on the panel which in the "off" position disconnects high- and low-tension batteries and automatically shorts the aerial and earth terminals, which considerably minimizes the possibility of damage to the apparatus through static discharges.

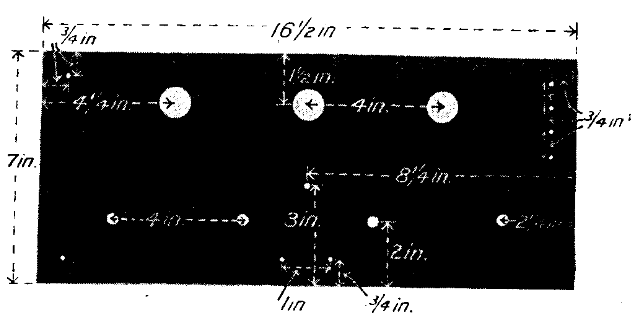
The cabinet, shown and dimensioned in Fig. 1, is made up to the instructions to be found under the heading Cabinet, in this Encyclopedia. A loose bottom of $\frac{3}{8}$ in. wood is cut to fit the cabinet, and is subsequently screwed at its front edge to the inside of the lower side of the panel, as shown in the later photographs. The cabinet is made with a hinged top, as shown, and measures $18\frac{3}{4}$ in. by 9 in. over all.

The dimensioned panel, of $\frac{1}{4}$ in. best quality ebonite, is shown in Fig. 2. The 1 in. holes shown form valve peep-holes, and are covered with fine mesh copper gauze fitted with highly polished rings of brass, which are shown in Fig. 2. Three valve holders are fitted as may be seen in subsequent illustrations, and are made up as shown by the completed valve holder in Fig. 3. The underside of the valve legs must be well countersunk to avoid contact with the base. Three filament resistances are attached to a platform of ebonite, and are illustrated



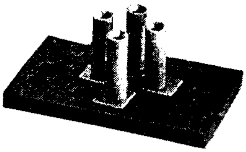
DIMENSIONS OF NEUTRODYNE RECEIVER CABINET

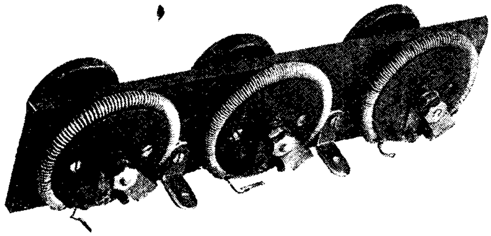
Fig. 1. For containing the neutrodyne receiver a cabinet is made to the dimensions and design given in this diagram



NEUTRODYNE RECEIVER PANEL

Fig. 2. Dimensions are given here for cutting the ebonite panel and drilling to accommodate the neutrodyne receiver components





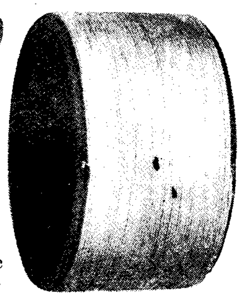
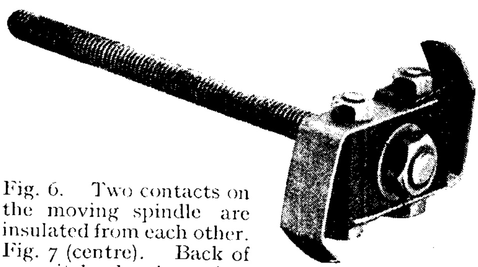
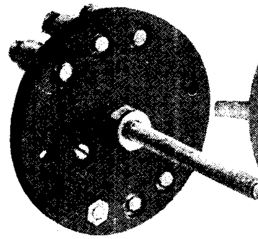


Fig. 3 (left). Valve sockets are attached by countersunk screws to an ebonite plate to form the valve-holder. Fig. 4 (centre). Three filament resistances are mounted on one panel. Fig. 5 (right). Ends of the wire of the secondary of the high frequency-transformer are threaded through the edge of the former





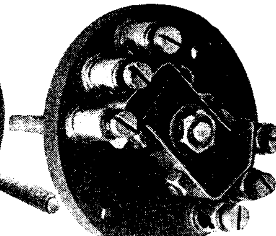


Fig. 6. Two contacts on the moving spindle are insulated from each other. Fig. 7 (centre). Back of switch, showing spindle. Fig. 8. (right). Front of switch, showing method of bolting contacts

COMPONENTS OF A NEUTRODYNE RECEIVER

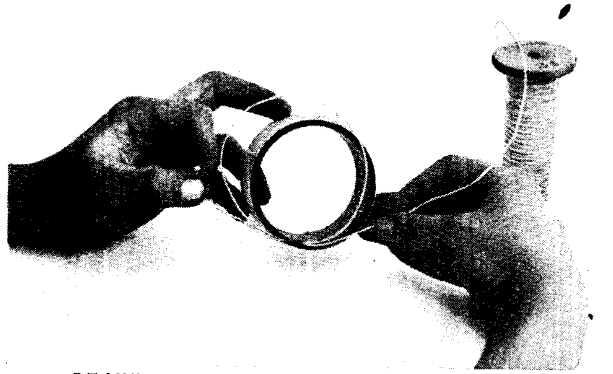
in Fig. 4. They are fixed to the top right of the panel for convenience of operation.

The battery switch is more or less self-explanatory from the illustrations in Figs. 6 to 8. Fig. 6 shows the moving contact arm, consisting of an ebonite block rigidly attached to a spindle. Two springy contact pieces are bolted on either side of the block, and are well insulated from each other by making the end hole in each piece of large diameter and fitting an insulating washer over the nut. Ordinary terminals are used for the fixed contacts and filed off flush with the back of the switch, as shown in Fig. 7. Fig. 8 shows the front of the completed switch.

The secondary of the H.F. transformers consists of 54 turns of No. 24 D.C.C wire on an ebonite former, 3 in. diameter and 2 in. wide. This is shown in Fig. 5. The same wire is used for the primary, which consists of 11 turns wound on the middle of the secondary. A neat method of fastening the ends of the primary wires is to thread a short length of insulated tubing over the ends to form a loop, as shown in Fig. 9. The completed transformer is illustrated in Fig. 12.

Each transformer is mounted to the panel by a 2 B.A. rod screwed to the panel. A piece of ebonite tube cut slantwise at one end is slipped over the spindle and enables the H.F. transformer to rest in the notch thus made. A similar tube is fitted at the other end of the transformer, this operation being shown in Fig. 11, where the tube is slipped over the rod and is then turned with the notch to the other side.

The neutrodyne condensers are made from two lengths of ½ in. brass tube, each 2¾ in. long. An ebonite rod is tightly pushed into the brass rod and drilled and



BEGINNING AND END OF PRIMARY WINDING

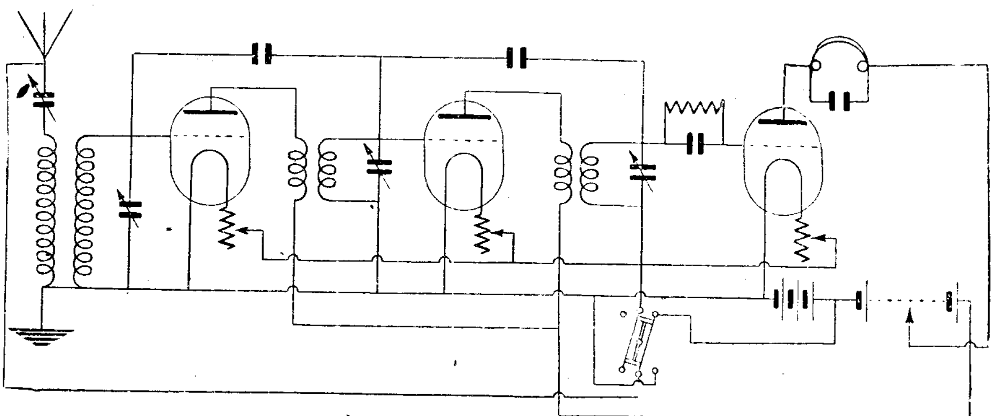
Fig. 9. Ends of the primary winding are twice threaded through a short length of sleeving to form a loop and then pulled tight

tapped 4 B.A. throughout its length. Two lengths of 4 B.A. screwed rod are fitted into the tapped hole and are fitted with small ebonite knobs at each end. A nut is threaded on each rod, and forms a method of obtaining contact with the rod. Fig. 13 shows a completed condenser in the background, while in front of it is seen a collection of parts making the condenser. Care should be taken in the construction of these condensers, as they play an important part in the neutrodyne circuit.

Any convenient type of two-coil holder may be used and placed on the base in the position shown in Fig. 14, which difficulty may be experienced at the start in picking up a station, owing to the selectivity of the set due to the arrangement of the primary and secondary coils.

If the experimenter is unaccustomed to this form of aerial tuning, the operation may be simplified by detaching the aerial wire from its normal position on the aerial terminal and connecting it up to the grid side of the aerial tuning secondary coil. This operation converts this coil to an open circuit, and although selectivity is to some extent lost, greater ease is found in picking up a signal.

Having obtained fairly strong signals, the H.F. variable condensers and the



ARRANGEMENT OF WIRING OF THE NEUTRODYNE RECEIVER

Fig. 21. Two stages of tuned high-frequency amplification are added to a detector valve in the neutrodyne receiver, for which the above is the wiring diagram. The two neutrodyne condensers connected across the grids need careful adjusting

gives an idea of the position of the components. It will be seen that the neutrodyne condensers are mounted to the panel with small brass brackets, sweated to the tubes. The grid leak and condenser are screwed to the base behind the detector valve, while the telephone condenser is fitted near its terminals.

Wiring may now be commenced, the wiring diagram being shown in Fig. 21. Assistance in the wiring and the positions of the components will be found in Figs. 14 to 19, which show different positions of the completed set. A plan view of the set fitted in its case is shown in Fig. 17, and in Fig. 20 the set, with lid raised, is seen in operation.

In operation the neutrodyne receiver will be found to be exceptionally quiet when the values of the neutrodyne condenser and of the tuning elements of the set have been correctly adjusted. Some high- and low-tension battery voltages should be regulated to bring them to its maximum strength. While the signals are still being received the neutrodyne condensers should be adjusted and set permanently in the positions where they are found to give the best results. To do this, the control knobs should be tightened up to give maximum condenser effect.

The first valve of the high-frequency amplifier is now turned out and the condensers adjusted by unscrewing the knobs until the signal is entirely lost. This indicates that the capacity of the valve and valve holder has been neutralized by the adjustment of the neutrodyne condenser. The same operation has now to be performed on the second valve, after which both the condensers will require no further adjustment.

The aerial wire may now be removed from its temporary position and the signal tuned in again by the primary tuning circuit to the same wave-length as that of the secondary already in tune with the station required. The high-frequency valves are now up to the degree of brilliance giving the best signal strength. The battery switch situated in the centre of the instrument can be used for turning out the valves when the set is not required, which obviates the necessity of interfering with the correct setting of the filament resistances.

NEWARK STATION. One of the best-known American broadcasting stations is Newark (W Y Z). It is situated in the roof of the Westinghouse factory building near to the Lackawanna railway station, Newark, N.J. The aerial is the flat-top inverted L type, and consists of six parallel wires each 150 ft. in length, and fastened to 30 ft. spreaders. The masts are 120 ft. high, and the total height of the aerial from the ground is 200 ft. The transmitting aerial is a twelve-wire counterpoise running the whole length of the aerial and 12 ft. above the roof.

The transmitting valves are four in number and the modulating valves five. Each runs on 2,000 volts direct current, provided by a single commutator generator driven by a direct connected two-phase 60-cycle 5 h.p. motor. The aerial, counterpoise, grid, and plate leads are connected to the split coil oscillation circuit and to the flat spiral inductance on the top of the set. The coil consists of flat copper strip, $\frac{1}{32}$ by $\frac{1}{2}$ in., mounted on micarta spokes, and is earthed about midway between the aerial and counterpoise, which is the point of minimum potential.

The filaments of the modulating valves are lighted by alternating current at 10 volts from the transformer. They are connected in the anode modulation circuit, and are supplied with audio-frequency current from a speech amplifier. The transmitter is enclosed in a metal and glass case, and an air blast keeps the valve temperatures down. Special filter circuits practically do away with the alternating current ripple.

NEWTON'S LAWS. Three laws of motion enunciated by Newton. They are: (1) All bodies continue in a state of rest or of uniform motion in a straight line unless acted upon by some external force that compels a change of such state. (2) Every motion or change of motion is proportional to the acting force and takes place in the direction of the straight line along which the force acts. (3) To every action there is always opposed an equal and opposite reaction.

Ni. This is the chemical symbol for the metallic element nickel.

NICKEL. A metallic element, chemical symbol Ni, average commercial specific gravity 8·8. One cubic inch weighs about 0·318 lb.

Nickel melts at a temperature about 1450° centigrade; the thermal conductivity is about 14·2 and the electrical conductivity 12·9, as compared with silver at 100·0. Nickel has magnetic properties, but these are lost at temperatures of 650° F. and over.

Nickel is alloyed with steel, and is used extensively in the industries. In electrical work nickel is alloyed with iron and is known as platinite, and used for the leading-in wires sealed into electric light bulbs. In wireless work nickel is extensively used for the plate or anode of thermionic valves, and other purposes.

When alloyed with non-ferrous metals nickel imparts a silvery-white colour to the metal, and such mixtures as nickel-silver or german-silver are used extensively for parts of wireless and other scientific apparatus.

NIGHT EFFECT. Irregularities in the strength and/or the apparent direction of arrival of radio signals observable more particularly during the hours of darkness. *See* Fading.

NITROGEN. One of the non-metallic gaseous elements, chemical symbol N, and atomic weight 14·01. It forms about 79 per cent by volume of the atmosphere. Nitrogen is more valuable for the many compounds of which it forms a part than as a gas. It is one of the constituents of nitric acid, ammonia, many explosives, etc.

NOBLE, SIR WILLIAM. British engineer. Born in 1861 and educated at Gordon's College, Aberdeen, he entered the Aberdeen telegraph office. In 1893 he was appointed engineer for the north-east area of Scotland, rising rapidly in the service until he became chief engineer, 1919. He retired from the Post Office in 1922, and became director of the General Electric Company and of the British Broadcasting Company. Sir William Noble has written many articles on telegraphy and telephony, and is one of the leading authorities on these.

NODEN VALVE. A battery which has the characteristic of allowing a negative current to pass through it but of opposing a current of positive polarity. For small power purposes it is quite a simple piece of apparatus of reasonable efficiency, and one which can be made for a few shillings.

All the pulsations in the positive direction are arrested at the aluminium plate, as illustrated in Fig. 1, by the formation of an insulating crust of aluminium compound (phosphates and oxides of zinc and aluminium). These present an enormous

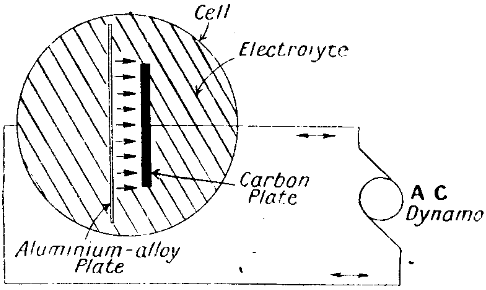
SIR WILLIAM NOBLE

One of the leading authorities of telegraphy and telephony, Sir William Noble is a director of the British Broadcasting Company. He was Chief Engineer of the Post Office from 1919 to 1922

Photo Elliott & Fry, Ltd

resistance to the passage of the positive current, but the coating dissolves again on the reversal of the charge. It was found that the action was sufficiently rapid to allow it to be employed in converting an alternating supply into a direct one, even with a periodicity of 100 cycles per second.

The apparatus should, however, be quadrupled, *i.e.* four cells should be used as one unit, and connected up as shown in the diagram, Fig. 2, so that both phases of an alternating current supply are made

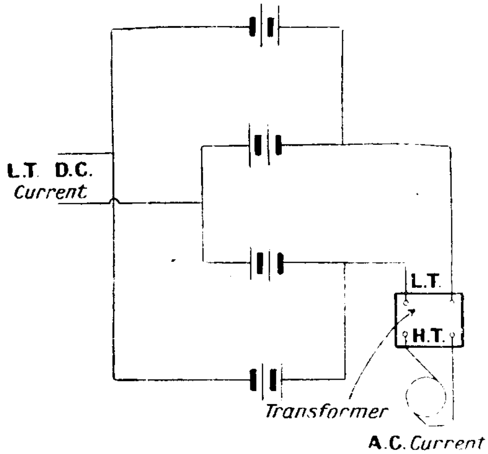


PRINCIPLE OF NODEN VALVE

Fig 1. In this diagram is shown the principle upon which the Noden valve acts as a rectifier of alternating current

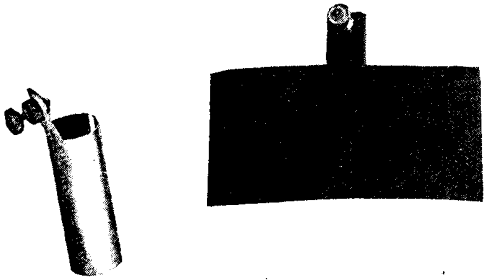
use of. The polarity of the aluminium plates is therefore reversed synchronously with the direction of the dynamo current. Noden brought the chemical rectifier to a more practical and efficient form by using iron as the passive electrode and a saturated solution of ammonium phosphate as the electrolyte. An aluminium-zinc alloy active plate was used.

Both the iron and the aluminium plates may be rolled up into cylinders and placed in jam jars, as shown in Fig. 4. Fig. 3 shows the aluminium and iron plate in the simplest form of Noden rectifier. Both plates are cut from flat sheets, a lug bearing a terminal for connecting to wires being provided at the top of one edge. Fig. 4 shows the plates assembled in a suitable glass jar. It is essential that the plates should not touch, and to prevent this possibility, wood separators may be used between the



QUADRUPLE CELLS OF NODEN VALVE

Fig. 2. Four Noden cells to form one unit are wired up in this way to act as a rectifier

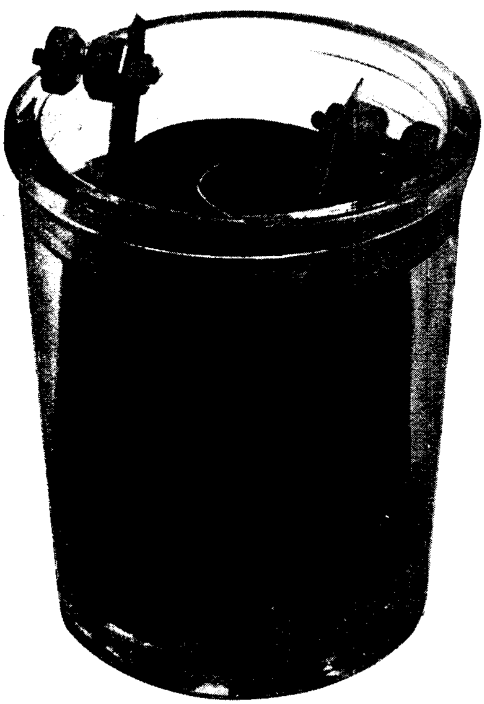


ELECTRODES OF NODEN VALVE

Fig. 3. Aluminium and iron electrodes of a home-made Noden rectifier are shown. The latter is not bent to shape. Both electrodes are used in the form of cylinders

plates. The electrolyte consists of a saturated solution of ammonium phosphate.

The life of a Noden valve is anything up to 800 working hours, so long as the cell is not overheated. The temperature should not rise above 120° F., while 100° F. is a desirable maximum. Such overheating is caused only by overloading, and therefore cells should be designed with at least 24 in. of aluminium plate area, reckoning but one side, per ampere of output.



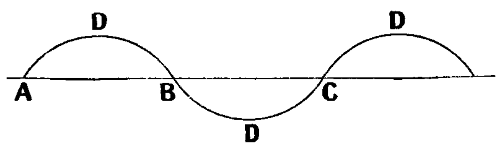
COMPLETE NODEN VALVE IN A JAM JAR

Fig. 4. Jam jars or similar vessels may be used as the containers for Noden valves With care this cell will last for 800 hours

While the current is unidirectional, it is, of course, of a pulsating character. For driving small motors this is not fatal, and it is not absolutely necessary to interpose an accumulator. The voltage of the high-tension house supply should be reduced by inserting a Bell transformer where a low-voltage direct supply is wanted. The total efficiency is then comparatively good, and much higher than that obtained by charging accumulators from a high-tension direct current house supply through resistance. The experimenter should have little trouble in using home-made rectifiers so long as they are made big enough at the outset.

The temperature must be kept down to within the limits prescribed above, otherwise the valve action fails and the current passes both ways, *i.e.* it is not properly rectified. Cells may be water-jacketed if necessary to ensure a low temperature in operation. The larger the capacity of the cell, the less will be the trouble and attention required. *See* Accumulator; Electrolytic Rectifier.

NODES. In electricity, points of zero current or potential in an oscillating circuit, whether closed or open. They are



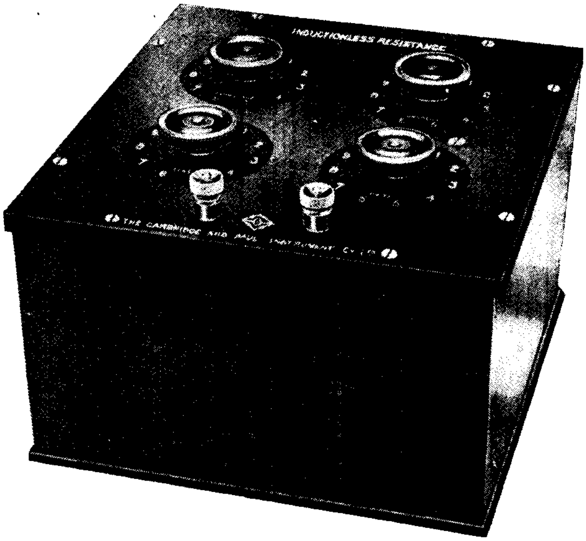
NODES AND ANTINODES

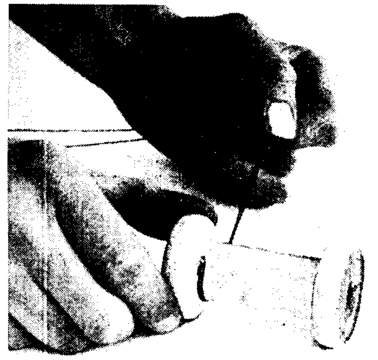
Points of zero in current or potential are nodes, and are shown at A, B, C, on the reference line. D, D, D, are antinodes

zero points in a wave-train. In the figure, for example, the points A, B, C, are nodes, and the points D antinodes, or points of maximum potential or current, if the curve represents current. *See* Antinode.

NON-CONDUCTOR. This term is often used for any substance which is an insulator, *i.e.* a non-conductor of electricity. *See* Insulation; Insulator.

NON-INDUCTIVE RESISTANCE. A resistance in which the inductance is practically negligible. It is important in wireless to know the inductance of any part of a circuit, and this is not always easy to ascertain. Since the resistance of a wire varies inversely as its diameter, it is often necessary to use a long length of very fine wire to obtain the necessary resistance. A long straight length of wire





NON-INDUCTIVE RESISTANCE

Fig. 1 (left). Four sets of resistances are included in this laboratory non-inductive resistance. Fig. 2 (above). This photograph shows how a non-inductive resistance is wound

Courtesy Cambridge and Paul Instrument Co., Ltd.

would be cumbersome, and to get over the difficulty the wire is wound in a coil, and this at once increases the inductance.

To make such a resistance coil non-inductive the wire is doubled back on itself at its middle portion to form two strands, and these are wound on the former of the coil simultaneously, thus forming two spirals of an equal number of turns. The current passing through the coil flows through one spiral, or half of the coil, in one direction, and through the other half or spiral in the other direction, the two nullifying each other's inductive effects.

Another form of non-inductive resistance is a carbon rod upon which a sliding contact moves to vary the resistance as required. The amount of inductance in such a rod is so small that in practice it can be neglected.

Fig. 1 is an illustration of a standard laboratory non-inductive resistance by the Cambridge and Paul Instrument Co. The cabinet contains four sets of resistances, these being arranged in combinations of single ohms, tens, hundreds and thousands. Thus it is possible to obtain any desired resistance of unit ohms.

The selection of the resistance required is made by the rotation of the four knobs shown at the top of the panel.

Such resistances are made to be used with very feeble currents, such as would be derived from the use of primary cells. They are only to be used for comparative measurement purposes, and not as series resistances for use in conjunction with other apparatus. It is important when using accurate resistances of this description that the leads used for connexions are of a heavy nature, otherwise their own resistance will upset calculations.

Non-inductive resistances of the wound type are very simple to make. The first step is to procure a bobbin or reel of the requisite size. This may be of wood, or preferably of some hardwood, such as teak, ebony or boxwood. The wire must necessarily be wound in the manner indicated in Fig. 2 in order to obtain the non-inductive effect. Fig. 2 shows the system to be adopted where a comparatively short length of wire is to be used. In this case sufficient wire for the job is taken from stock and bent double. The start of the coil is then made at the doubled end. Where a long length of wire is to be used, however, it will be probably more convenient to reel it from two reels. In this case the starting ends of both wires must be bared and soldered together. Whichever system is adopted, however, the subsequent procedure is the same.

A convenient way of holding the start of the wire is shown in Fig. 2. Here the top of a common domestic pin has been cut off and driven into the wood to such a depth that the head projects just sufficiently to hold the wire when the latter is placed round it. Care must be taken to

WINDING A NON-INDUCTIVE RESISTANCE
Fig. 3. Winding of the first layer is shown half complete. Note that the wire is wound double

see that the insulation is not impaired by this process. After the start of the coil has been fixed in this manner, the next step is to continue the winding.

In this process the twin wire is wound side by side, as indicated in Fig. 3. This is continued until the first layer is completed. The second and each subsequent layer is laid in its natural progressive order, *i.e.* if the first went from left to right, then the second will be from right to left, the third from left to right, etc.

When the final layer is complete the coil should be covered with some insulating sheet material, such as empire cloth, and the ends of the wire anchored by tape and left projecting through the covering. Such coils should be wound with insulated resistance wire of constant temperature coefficient, such as eureka, constantin, etc. *See* Calibrated Resistance; Eureka Wire; Resistance.

NORTH POLE. Term used in several ways. Usually it refers to the north pole of the earth. The north magnetic pole varies in position, and is situated in about latitude 70 N. and longitude 97 W. It is to this point that the north pole of a magnet or a compass needle points when the magnet or needle is freely suspended. *See* Magnetism.

NOTE MAGNIFICATION. The term used in wireless telegraphy to denote the increasing of signal strength, after rectification, by means of low-frequency amplifiers. The term is frequently misapplied to telephony receivers instead of the more correct audio-frequency amplifier, or voice amplifier.

Note magnification is not of any considerable importance for telegraphic work, because it is seldom that signals of greater strength than is reasonably necessary in the headphones are required, the loud speaker being an instrument which is very infrequently used for telegraphic reception. Furthermore, an operator's cabin or room is always made as sound-proof as possible for obvious reasons.

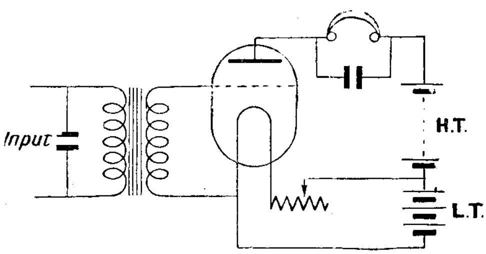
Again, the note magnification of signals after rectification does not materially affect the receiving range of an installation, this function being entirely effected by the high-frequency amplifiers. *See* Amplifier; Audio-frequency; Crystal Receivers; High-frequency Amplifier.

NOTE MAGNIFIER. Instrument used to perform the operation of note magnification (*q.v.*). There are two types of instrument in general use as note magnifiers; these are (*a*) valve amplifiers, using iron-cored transformers, and (*b*) microphone amplifiers.

As the elimination of distortion in telegraphic signals is not of any considerable importance, valve note magnifiers employ circuits of a very simple and straightforward character, and the transformers used are designed chiefly from a standpoint of robustness, little consideration being given to the strict adherence of input-current wave-form.

The circuit generally adopted is given in Fig. 1. The input terminals are connected to the telephone terminals of the receiver. The fixed condenser shown connected across the primary of the iron-cored transformer should be of ·002 mfd. capacity, but may be omitted without serious result. It will occasionally be found, however, that its presence assists the working of the rectifier, especially where the anode circuit of the latter is coupled to the aerial primary or secondary of the tuner for purposes of regeneration.

The connexion of the H.T. negative to the L.T. positive or negative is optional; both should be tried to see which gives the better results. Any of the R type valves may be used for the purpose of note magnification, or where current consumption is a matter of importance dull emitter valves will give excellent

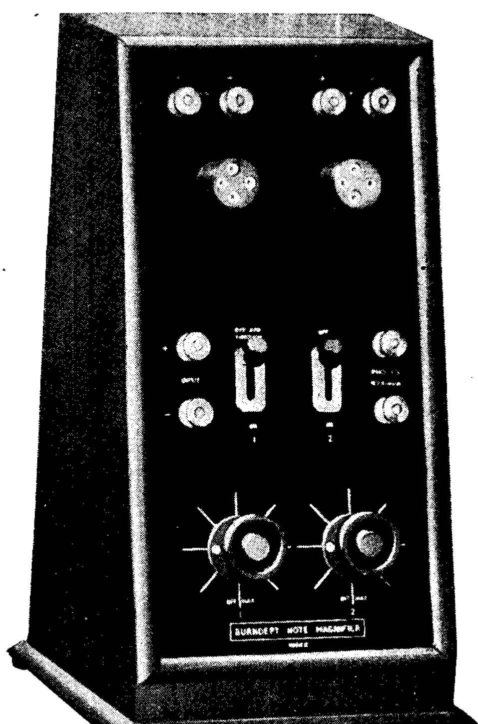


NOTE MAGNIFIER CIRCUIT

Fig. 1. Transformer-coupled to the existing set, a note magnifier of the standard type has a circuit as here shown

results. Should considerable amplification be required, then valves either of the L S or similar variety may be used.

Fig. 2 shows a typical note magnifier manufactured by Burndept Ltd. The instrument is of the sloping panel type, and switches allowing one or two valves to be used at will are fitted. Separate rheostats are applied to each valve, thus giving complete independence of working.



BURNDEPT NOTE MAGNIFIER

Fig. 2. Switches allow one or two valves to be used as required. The filament sockets are so arranged that the filaments of the R valves used may rest in a vertical position

Courtesy Burndept, Ltd

A point worthy of interest is the fact that the valve holders are arranged with the filament sockets placed above one another in order that the filament of an R valve may rest in a vertical position.

Another typical commercial example is illustrated in Fig. 3, and is known as the Fellophone. The illustration shows an upright cabinet with a sloping ebonite panel. At the lower portion are two knobs controlling the filament resistances, above them are the valve holders, while between the filament resistance knobs is a switch enabling one or two valves to be used at will.

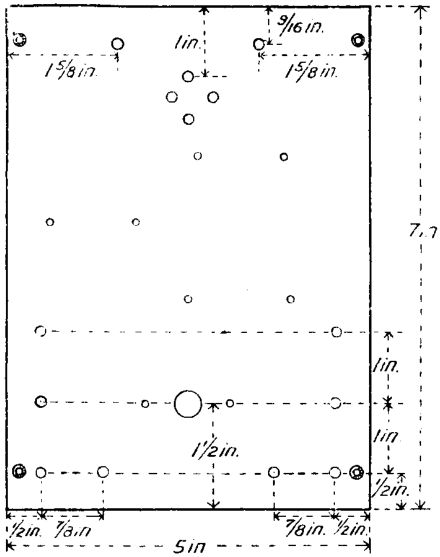
FELLOPHONE SUPER TWO AMPLIFIER

Fig. 3. This note magnifier also allows one or two valves to be used. The two lower knobs control the filament resistances

Courtesy Fellows Magneto Co., Ltd.

The low-frequency transformers (*q.v.*) are enclosed within the cabinet, and these, in conjunction with the valves, batteries, and circuit generally, magnify the music or speech, which is conducted through terminals on one side of the case, the telephones being connected to the opposite side.

The construction of a simple note magnifier is not difficult, and can be carried out by any amateur. Practically speaking, a note magnifier can be added to any existing receiving set. Important points to note are that the H.T. negative should be connected either to L.T. negative or L.T. positive in the note magnifier circuit in the same manner as they are



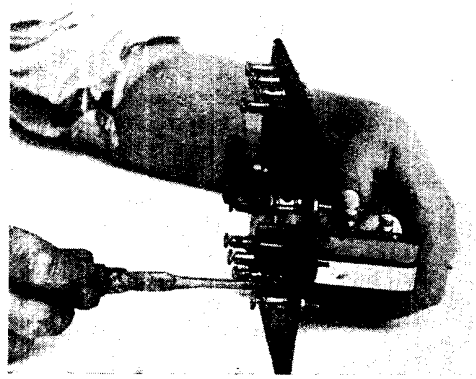
PANEL DIMENSIONS OF NOTE MAGNIFIER

Fig. 4. Dimensions for making the panel of a home-made note magnifier are given. This diagram shows the general lay-out

connected in the receiving set if a valve or valves are used. Otherwise the L.T. circuit is liable to be short-circuited. In any case, it is only necessary to reverse the L.T. battery connexions.

The appearance of a single-valve note magnifier connected to an ordinary two-valve receiving set, together with the necessary batteries and a loud speaker, is illustrated in Fig. 6. The essential requirements for the making of this single-valve note magnifier are a small case or box, an ebonite panel (which may conveniently form the top of the box), valve holder, filament resistances, L.F. transformer, and a few terminals and connecting wires. The circuit is similar to that shown in Fig. 1. The case can be constructed along the lines described in this Encyclopedia under the heading Cabinets.

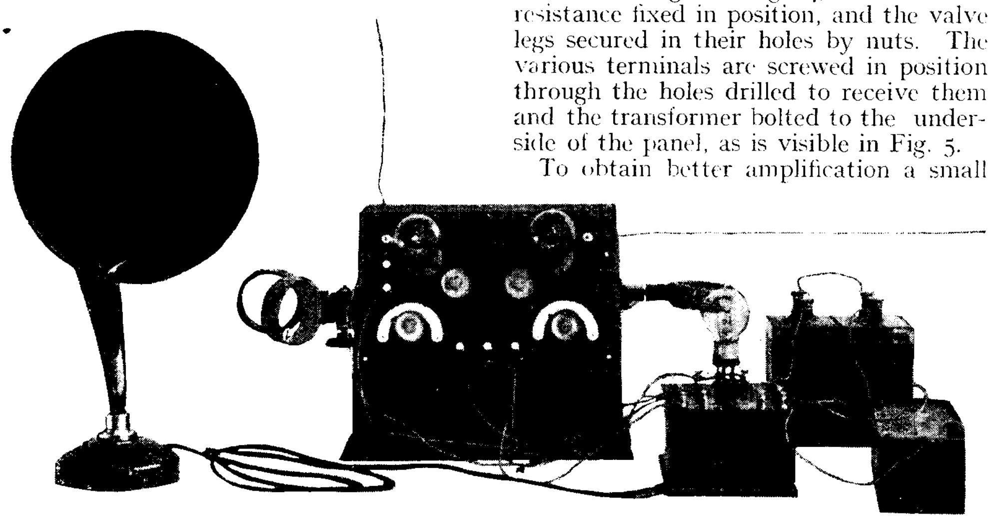
The ebonite panel may measure 7 in. long by 5 in. wide, and should be ¼ in. thick. This is marked out in accordance with the diagram Fig. 4, the filament resistance fixed in position, and the valve legs secured in their holes by nuts. The various terminals are screwed in position through the holes drilled to receive them and the transformer bolted to the underside of the panel, as is visible in Fig. 5.



FIXING THE NOTE MAGNIFIER TRANSFORMER

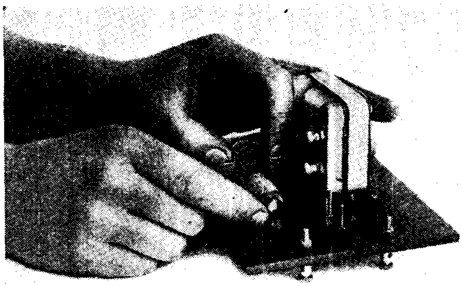
Fig. 5. In this photograph the operator is shown fixing the transformer by bolting it to the underside of the panel

To obtain better amplification a small



NOTE MAGNIFIER, RECEIVING SET AND LOUD SPEAKER

Fig. 6. On the right of the loud speaker is the receiving set, and the home-made note magnifier is shown wired up, with the valve mounted vertically. The complete apparatus is ready for the reception of signals



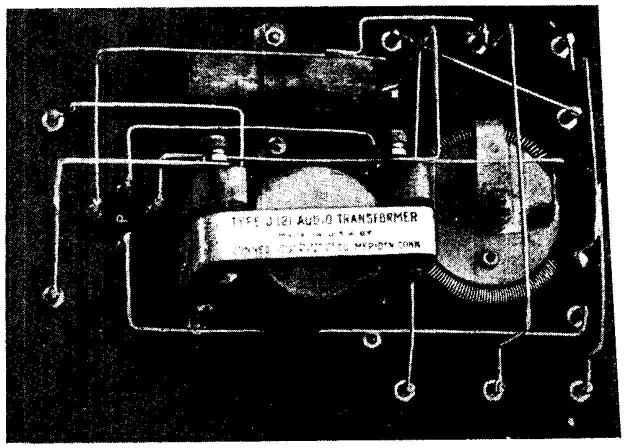
FIXING GRID BATTERY

Fig. 7. One dry cell taken from a flash-lamp battery is being fixed for grid-biasing

battery is employed in the grid circuit of the valve, and this may consist of one cell taken from an ordinary good quality pocket flash-lamp battery. It can be fixed in position with a small strap as shown in the illustration (Fig. 9), with wire, or in any other convenient manner.

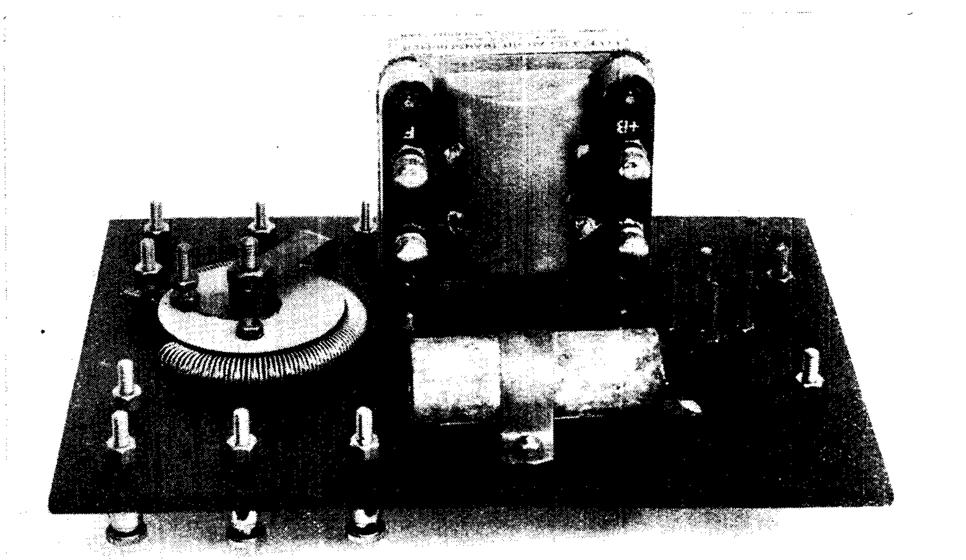
The next step is the wiring of the set. This can be carried out with No. 16 or 18 gauge tinned copper wire, preferably on the anti-capacity system—that is, the wires are widely spaced and taken from point to point by bending the wire wherever needed, soldering the ends to the various terminals. The practical disposition of the wires is clearly illustrated in Fig. 8.

It should be noted that the centre contact of the grid-biasing battery is positive, the zinc outer casing the negative. It is necessary that the latter be connected directly to the grid terminal of the valve holder. When the wiring is



WIRING OF NOTE MAGNIFIER

Fig. 8. Wiring should be as straight and as widely spaced as possible. The above photograph shows the practical wiring arrangement

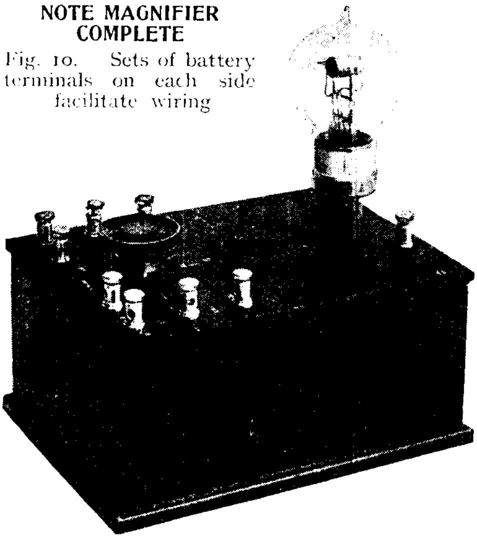


COMPONENTS OF NOTE MAGNIFIER ON PANEL

Fig. 9. On the underside of the panel of the note magnifier are the transformer, grid-biasing battery, filament rheostat, and the legs of the valve socket

NOTE MAGNIFIER COMPLETE

Fig. 10. Sets of battery terminals on each side facilitate wiring



completed it should be tested throughout for continuity and correctness. The panel is then placed on the top of the case and secured with four small brass screws, one at each corner, the note magnifier then appearing as illustrated in Fig. 10.

It may either be used in conjunction with the high and low tension batteries employed for the receiving set, or independent batteries may be employed. The latter is sometimes preferable, as it is then possible to utilize a small power valve or valves of a make and character specially adapted to low-frequency amplification.—*E. W. Hobbs and R. B. Hurton.*

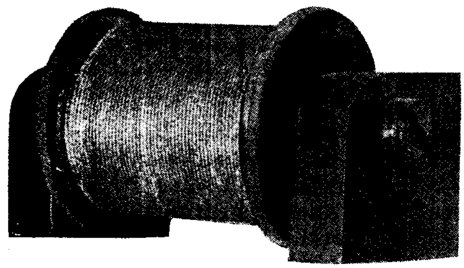
See Amplifier; Crystal Receiver; High-frequency Amplifier; Low-frequency Amplifier; Microphone Amplifier.

NOTE TUNING or TONE TUNING. Tuning the parts of a set of receiving instruments to the note frequency of the transmitter, or to the beat frequency when the beat, or heterodyne, method of reception is in use. *See* Amplifier; Crystal Receiver; Heterodyne; High-frequency Amplifier; Low-frequency Amplifier; Note Magnifier; Tuning.

NO-VOLT RELEASE. Device applied to the controlling gear or starter of an electric motor which automatically cuts out the motor when the current fails, and thus prevents damage through a sudden onrush of current, should the latter come on again.

It will be seen that as the back electromotive force (*q.v.*) of a motor does not attain its full value until its final speed is reached, the sudden application of the full line pressure will probably cause the motor windings to be burnt out. Motors are, therefore, always connected with a variable resistance for starting purposes, which is cut out gradually, or sometimes in definite stages, as the motor accelerates.

This is done by means of a handle moving over a series of studs. A spring is attached to the handle in such a manner that considerable pressure must be applied to move it over the studs. Thus the handle



NO-VOLT RELEASE

Cast-iron shoes are fitted to the core of the no-volt release. The windings are connected in the field circuit of the motor

would normally fly back to zero when it was released, were not means taken to prevent it.

The handle is made of iron and is therefore magnetic. An electro-magnet, such as that in the figure, is fitted to the starter base, so that when the handle rests on the last or "all on" stud, the magnet holds it in position. This magnet is connected in the field circuit of the motor, so that it is only energized when current from the mains is actually passing. The result is that should the current fail, the magnet becomes de-energized and the handle is released. The latter immediately flies back to zero, due to the force exerted by the spring. *See* Back E.M.F.; Overload Release.

NUTS AND BOLTS. Fastening devices. The nut is in essence a block of material, usually metal, with a cylindrical hole through the centre of it. The walls of the hole have a spiral or helix formed upon them, known as a screw thread. The bolt is a cylindrical piece of metal or other material. One end is usually enlarged and is known as the head, and the opposite end has a screw thread upon it. A nut and bolt intended to be used in conjunction with each other have screw threads of similar dimensions and form. Consequently, the nut, when rotated, travels along the bolt.

In wireless work, nuts and bolts are comparatively small in size. They are generally made of brass, and some types are shown in Fig. 1. The screw threads adopted are mostly known as B.A., and the details of this system of screw threads are described in this Encyclopedia under the heading B.A. (*q.v.*). There are many other systems of screw threads in various branches of engineering. The Whitworth system is perhaps the most largely adopted for such purposes as the threads on nuts and bolts used on machinery, and also for general use when building up an aerial mast and other construction work.

The nuts are variously shaped. Some typical examples are illustrated in Fig. 2. Those of most interest to the wireless experimenter are the knurled nuts used on terminals, the ordinary hexagonal nuts, lock nuts, which are hexagonal in shape but much thinner than the ordinary nut, and for constructive purposes the slotted and castle nuts.

It is generally presupposed that nuts will be tightened up with a spanner of some kind. But when only comparatively low pressure is to be exerted by the nut, or it is to be frequently removed, a means of unfastening it with the fingers is an advantage, and nuts of this character include wing or thumb nuts, which have conveniently shaped projections formed upon them to enable them to be rotated with the hand.

Bolts are as diverse in dimensions and form as the nuts. A group of those of interest to the wireless worker is illustrated in Fig. 3, and in addition to the ordinary types of engineer's bolts and nuts and small brass bolts and nuts, examples are shown of the coach bolt, which has a

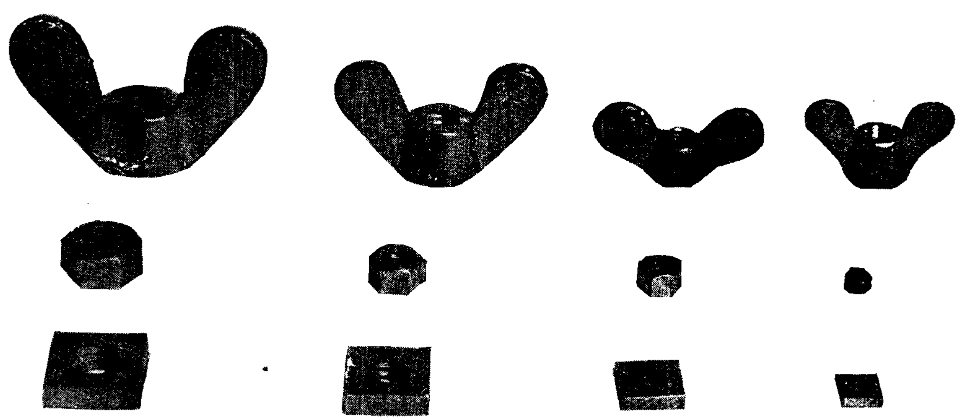


Fig. 1. Three classes of nuts are illustrated: those in the top row are known as winged nuts, those in the centre row are hexagonal, and in the bottom row square nuts are seen

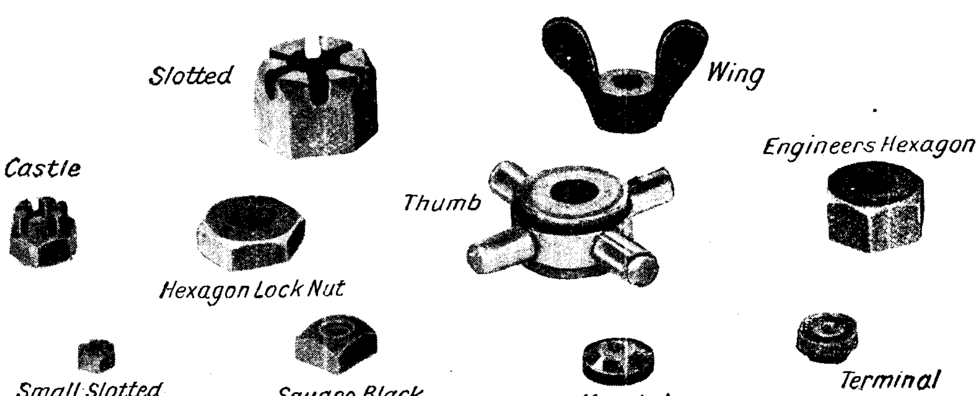
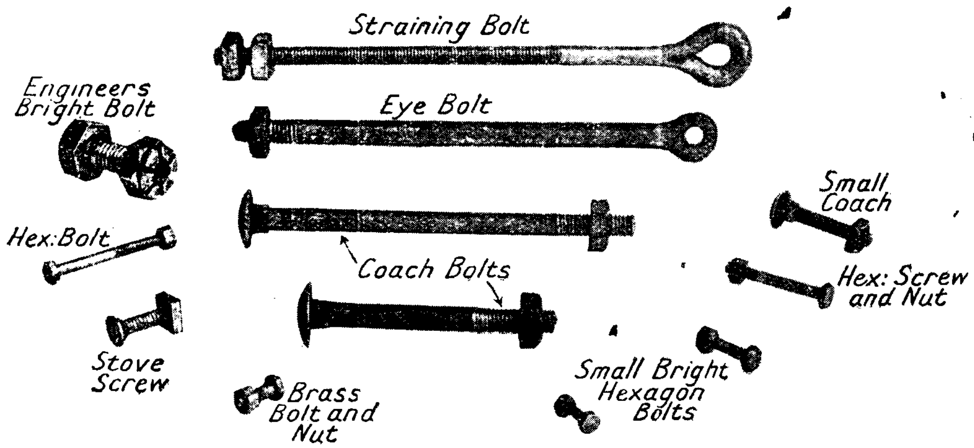


Fig. 2. Reference to this photograph will give the amateur the correct definition of the nuts most commonly used. The nuts shown are all used in various forms of wireless apparatus

EXAMPLES OF STANDARD NUTS USED BY WIRELESS EXPERIMENTERS



BOLTS USED IN BUILDING WIRELESS CONSTRUCTIONS

Fig. 3. All kinds of bolts and nuts are used in making masts and constructing other wireless apparatus. Some of the most common in use, with their names attached, are illustrated in this photograph. Appropriate nuts are shown with the bolts

rounded head and a squared portion immediately beneath it. This type is extensively used in woodwork, as, for example, when metal plates or strips have to be bolted to an aerial mast.

Another type of bolt used for fastening has the head forged and a hole drilled and

FIXED SPANNER FOR NUT

Fig. 4. Certain standard size nuts are employed for which fixed spanners are used. A spanner of this kind is seen in use

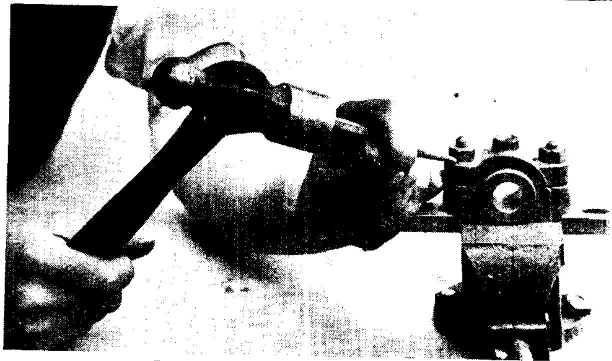
countersunk through it at right angles to the axis of the bolt. It is used for fastening machinery into packing cases and other purposes where the bolt is passed through a piece of wood and secured to another with a wood screw, the nut being tightened on to the object to be secured.

Another commonly used and very serviceable type of bolt is known as an eye-bolt, and is illustrated in Fig. 3. It consists essentially of a screwed shank provided with a nut or nuts, the opposite end being forged into a circular shape known as the eye, and is used for exerting pressure upon a guy wire and other work of a like nature.

Generally, nuts are tightened up with a spanner, and in light work it is usually possible to hold the parts to be bolted together in one hand while the nut is tightened with a spanner manipulated in the other hand, somewhat in the manner illustrated in Fig. 4. When two nuts are to be screwed one above the other, the outside nut keeping both of them secure,

NUT AND LOCKING NUT

Fig. 5. One nut is used to lock another. In the photograph the primary nut is being held by one flat spanner while the locking nut is tightened by another. Ordinary pliers are not convenient for this purpose



PUNCHING OFF A TIGHT NUT

Fig. 6. For punching off a tight nut a soft steel punch should be used. This will usually remove the most stubborn nut

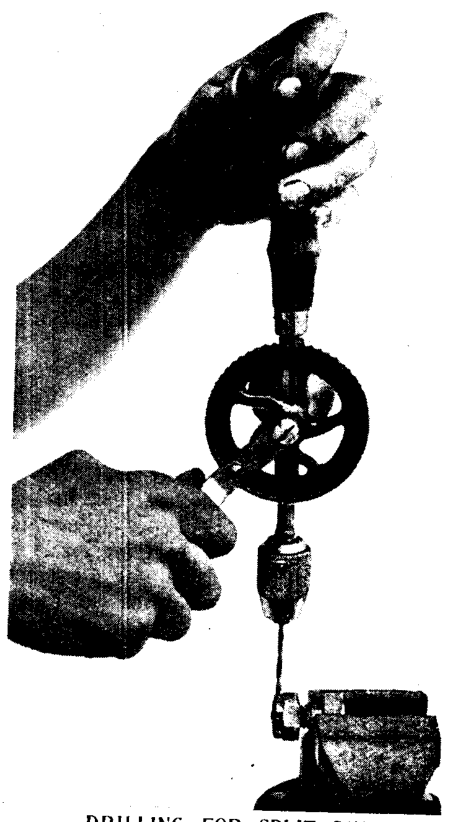
as for instance, two brass lock nuts used on the spindle of a variable air condenser, it is necessary to use two spanners, which must be sufficiently thin to clear each other.

This is shown in Fig. 5, and the method of use is to first tighten the lower one on to the condenser plates, washer, or whatever else is to be fastened, and screw the second nut on to it. The two nuts are then locked against each other by holding a spanner on the lower nut while a second spanner is used to tighten further the upper or lock nut. Both spanners may be employed simultaneously, drawing them together to lock the nuts and forcing them apart to unlock them.

When a spanner is insufficient to move a nut owing to it having rusted on to the bolt, a most effective plan is to loosen the nut with the aid of a soft steel punch. The punch should be applied at one corner or angle on the nut and be driven with a heavy hammer in the direction in which the nut is to be rotated, thus unfastening it, as is clearly shown in Fig. 6. This will usually result in removing the most stubborn nut.

There are many ways of fastening a nut on to a bolt by the use of special washers and patented devices, and probably one of the most secure and certain of all the various methods is to use a slotted or castle nut. This has a raised portion on its outer or upper faces and slots cut across it. To prevent the nut unscrewing, a hole for a split pin is drilled through the bolt in line with any opposite pair of slots. Sometimes a hole has to be drilled through the bolt while both the nut and bolt are in position, but, if possible, the bolt and nut should be held in a vice and the split-pin hole drilled with a hand drill, or any small drill brace, the former method being illustrated in Fig. 7.

If the hole is carefully drilled, the split pin can be passed through it, and the head of the pin will rest in one slot and the split portion of the pin will pass through the opposite slot and be secured by bending out the prongs. If the nut is to be removed, the prongs are pressed together, the pin removed, and the nut unfastened in the usual way. The nut must be securely tightened before the split pin is put into position, and the pin must fit snugly into the hole, otherwise it is liable to work loose. The method is chiefly used on machinery or in any position exposed to vibration, as, for example, the bolts used on the upper parts of aerial masts.—*E. W. Hobbs.*



DRILLING FOR SPLIT PIN

Fig. 7. Here the bolt is shown being drilled for the insertion of a split pin

O

O. This is the chemical symbol for the gaseous element oxygen (*q.v*).

OCTAHEDRITE. This is an alternative name for oxide of titanium, one of the rectifying crystals. It is also known as anastace (*q.v.*). *See* Crystal.

OERSTED. Name given to the unit of reluctance. The reluctance in a magnetic circuit corresponds to the resistance in an electrical circuit, and is inversely proportional to its permeability (*q.v.*). *See* Reluctance.

OHM. The name given by international agreement to the standard unit of resistance, viz. the ratio of unit E.M.F. to unit current. To determine the ohm absolutely, a calculable E.M.F. has to be generated by revolving a coil in a magnetic field, that same magnetic field being used to control the needle which is deflected by the current generated. The whole apparatus is elaborate; and the measurement is one that can only be done with advantage in the National Physical Laboratory. Copies of the standard thus obtained are issued to manufacturers of resistance coils, since resistances can be compared with great ease and accuracy, though the absolute determination is very difficult. Suffice it to say, therefore, that absolute resistance is μ times a velocity, which may be thought of as the velocity of the conductor when it generates a current by cutting lines of magnetic force. Thirty ohms correspond to μ times the velocity of light.

The first standards ever issued were issued by a committee of the British Association to the world. They were called B.A. Units, and were in the custody of Sir Richard Glazebrook, who kept careful watch on their constancy or amount of variation for many years; and they were still under his charge when he became first Director of the National Physical Laboratory, which was founded in 1901, and where they are now. They were intended to represent a velocity of one earth-quadrant per second, that is 10^9 centimetres per second. But the determination was difficult, and not quite exact at first. It has been re-determined many times now: and one unit, determined as correctly as possible, and expressed in terms of a mercury column of specified length containing a given mass of mercury, has been agreed on throughout the world as the standard ohm.

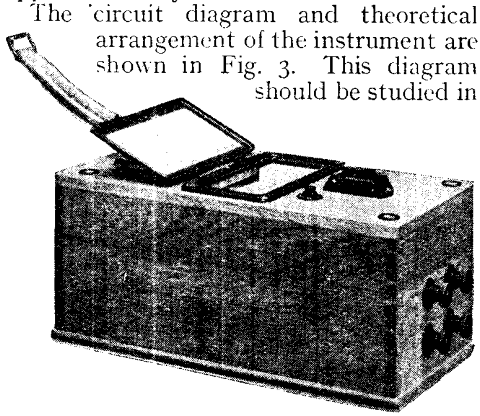
The ohm is the foundation of the whole electrical system of units, as used in practice: the volt and the ampere are defined in relation to it. Because it is a concrete thing that can be locked up in a cupboard, and carried about; whereas a current and an E.M.F. cannot be so treated. Standard ohms are so made that their temperature can be kept constant and determined. For this purpose they are always immersed in liquid, and the terminals are thick copper rods, which are bent round and flattened and amalgamated at the ends, so that they can dip into mercury, or otherwise make perfect and reliable contact.

Perhaps the most satisfactory definition of the ohm, for practical purposes, is that which can be given in terms of energy and Joule's law (*q.v.*).—*Oliver Lodge.*

OHMIC COUPLING. Another name for resistance coupling, which arises in consequence of the potential difference brought about in a resistance when traversed by a current. *See* Coupling; Resistance-capacity Coupling.

OHMMETER. Instrument for measuring resistance directly on a scale reading in ohms. The megger is a form of instrument peculiarly adapted for measuring resistances of a high value, and here is given a description of Evershed's ductor form of ohmmeter, which is convenient for measuring lower resistances. Illustrations of two types of Evershed ohmmeter appear in Figs. 1 and 2, from which their general appearance may be noted.

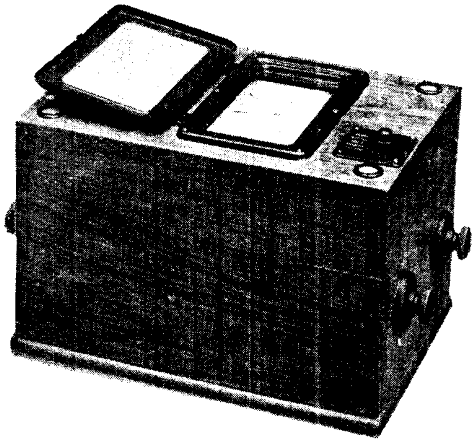
The circuit diagram and theoretical arrangement of the instrument are shown in Fig. 3. This diagram should be studied in



EVERSHED OHMMETER

Fig 1. Low resistances are measured by this instrument, the record being read direct on a scale

Courtesy Evershed & Vignoles, Ltd.



RESISTANCE-MEASURING INSTRUMENT

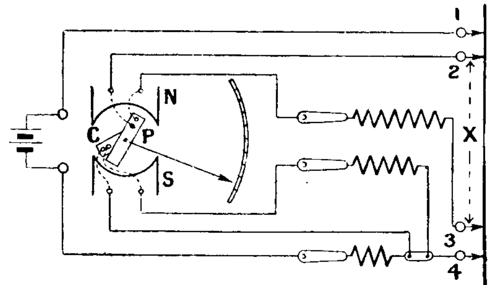
Fig. 2. Ohms are read direct on a scale in this instrument, which is used for measuring resistances

Courtesy Evershed & Vignoles, Ltd.

conjunction with the photograph, Fig. 4, which is a view of the spindle and moving coils. Referring now to Fig. 3, it will be seen that two coils, P and C, are situated at an angle with respect to one another, on a spindle, the whole being arranged between the magnetic poles N and S. The unknown resistance is designated by the letter X. The coil P is designed and connected in such a manner that it is virtually a pressure coil, and is energized by a current proportional to the potential difference across X.

The coil C is energized by a current whose strength is dependent upon the current flowing through X, for the battery is used for this purpose. From this it will be apparent that on the value of X depends the ratio of the two currents in the coils P and C respectively. The result of these currents is to cause a deflection of the coils, for they are in a strong magnetic field in the same manner as other moving coil instruments. Thus the deflection is proportional to the current, and as the latter is in turn proportional to the unknown resistance, it follows that the deflection is proportional to the resistance.

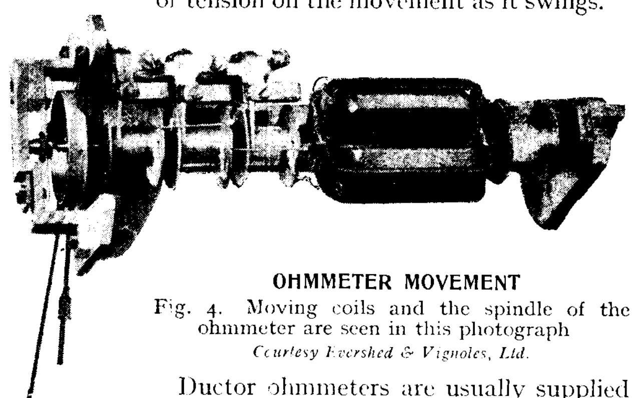
The moving system of the ohmmeter is a very interesting piece of instrument work, for despite its bulk and weight, its movement is so free that practically no



CIRCUIT DIAGRAM OF OHMMETER

Fig. 3. In this circuit diagram the theoretical arrangement of the instrument is seen

control in the form of springs is required. Above and below the coils, Fig. 4, are shown the ligaments, four in number, which conduct the current to the moving coils. These ligaments consist of extremely fine metal strips which exert practically no pressure or tension on the movement as it swings.



OHMMETER MOVEMENT

Fig. 4. Moving coils and the spindle of the ohmmeter are seen in this photograph

Courtesy Evershed & Vignoles, Ltd.

Ductor ohmmeters are usually supplied in four ranges controlled by a switch. The scale is a very even one, and allows of extreme accuracy in reading. As the latter is practically entirely independent of the strength of the operating current, the value of this is relatively unimportant. These ohmmeters are extremely simple in operation. All that is necessary is to connect the instrument with the battery and press the duplex contact spikes (supplied with the instrument) against the resistance to be measured. This completes the circuit, and the pointer immediately indicates the resistance. The spikes are shown in the diagram as connexions 1, 2, 3, and 4, where 1 and 4 are current contacts and 2 and 3 pressure contacts. A similar instrument may be used for testing the insulation of an aerial and the earth resistance of a receiving set, as explained under the heading Testing. *See* Ammeter; Megger.

OHM'S LAW: ITS MEANING & APPLICATIONS

By Sir Oliver Lodge, F.R.S., D.Sc.

One of the two or three fundamental "laws" or rules of electricity is here explained by simple analogy and mathematical statement by our distinguished Consultative Editor, who has also written the previous note on Ohm. See Volt; also Ampere; Force; Joule's Law; Resistance

When water flows through a pipe it meets with resistance, which will be greater or less according to the bore of the pipe. And if the pipe were filled with sand or some other porous material, the resistance would be very high, and it might be called a "bad conductor." If a watertight partition were stretched across the pipe, it would be an insulator. The partition might bend like an elastic membrane, and give the phenomena of charge and discharge; or it might be burst by sufficient pressure and imitate the disruptive discharge which in the electrical case evolves the heat and light which we call a spark. One might also have a leaky partition. In fact it is easy to make hydraulic analogies to the different kinds of electric conduction and displacement.

What, then, is the law of flow through a given pipe? It must depend on the head of water, and if water-gauges are arranged at each end of the pipe, the difference of level at which the water stands at either end is a measure of the "head." But in order to specify a law, we must know whether the flow is proportional to the head or not.

Complexity of Resistance in Water

If you double the head which is driving the water through a given channel, will the flow be doubled? It will be increased, certainly, but in general it will not be doubled. The flow of water through a pipe is rather complex, especially when it is rapid. It is liable to make eddies and to become what is called turbulent, which means spinning like a top. And, accordingly, it is found that to get double the flow you may have to quadruple the head. But no such accurate statement can be made. If the flow is exceedingly rapid to begin with, an immense increase would be needed to double the flow. The resistance of water is complicated; it does not matter whether you are driving water through a pipe or driving a solid through water, the law of speed is not simple. Everyone knows that to propel a ship at 16 knots requires a great horse-power. To increase the speed to 20 knots would take far more than double the horse-power, and to drive it at 30 knots might be impossible.

On the other hand, if the flow is very gentle, as it would be if the pipe were full of sand, this doubling the head does double the flow, at any rate approximately; and trebling the head trebles the flow. The current of water would be then proportional to the difference of level which was driving it.

This has close analogy with the electrical case. The flow of electrons through a metal wire is interfered with by the atoms of that wire. You maintain a certain difference of potential or voltage between the ends of the wire, and if you measure the current you find that the amperes are proportional to the volts.

Essential Simplicity of Ohm's Law

This is called Ohm's law. And in so far as Ohm's law is accurately obeyed the flow of electricity is much simpler than the flow of water. No such simple law as that of Ohm can there be for water. The current of water is approximately proportional to the head for very low speeds, to the square of the head for higher speeds, to the cube of the head for very high speeds, and so on; all these terms entering into the expression in different proportions, according to circumstances.

Fortunately the law of flow of electricity is much simpler, and is as formulated by Dr. G. S. Ohm early in the last century; provided the current is not allowed to heat the wire—that is to say, provided the wire retains all its properties constant. If the wire is heated, the simple law is no longer obeyed; it becomes complex, like the flow of water.

This law of Ohm, which is applicable to all conductors at constant temperature, was not arrived at by him experimentally; it was thrown out as a sort of guess or working hypothesis, and it was based on the analogy of heat. If you maintain a difference of temperature between two surfaces of a slab—as you might by letting steam play on one face while the other was covered with ice—heat will flow through the slab at a rate proportional to the difference of temperature. If you double the difference of temperature, the flow of heat is doubled; as might be measured by the rate at which the ice melted under the action of the steam at the other side. In other words, Ohm's law is obeyed by the flow of heat. He therefore assumed that it might be obeyed by the flow of electricity, and all experiment since has proved that he was right. The working hypothesis was verified by careful observation and measurement.

Professor Chrystal, in Clerk-Maxwell's laboratory, made careful experiments to determine whether the law was exact or only an approximation. The difficulty was to avoid the generation of heat. The current could only be allowed on for the fraction of a second, when the flow was made very intense. But when all precautions were taken, Ohm's law was found true for solids.

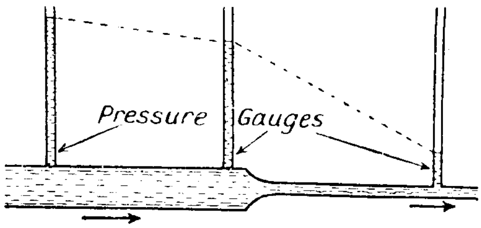
But would it be true for liquids, that is to say, for electrolytic conduction? This was tested with equal care by Professor FitzGerald, of Dublin, and again Ohm's law was found to hold good.

The flow of electricity, therefore, is governed by an extremely simple law. We may say that the resistance of a given conductor, at constant temperature, as measured by the ratio of the volts to the amperes, is absolutely constant. Another way of stating it is that the opposition force encountered by electrons is proportional to the first power of their speed and not to the square of the speed, or any other complications such as are necessary in dealing with liquids.

Analogies between Heat and Electricity

The flow of electricity and the flow of heat are analogous. This is true to such an extent that good conductors of electricity are also good conductors of heat, which looks as if electrons governed the transmission in both cases. But really we know almost more about the manner of the flow of electricity than of the manner of the flow of heat. Heat has to do with matter; while electricity has to do mainly with the ether: and, as usual, the properties of the ether are so perfect that the laws depending on it are simple.

The introduction of Ohm's law into electrical science clarified people's ideas very much, and removed a great deal of confusion. When two conductors are put in series, the same current must flow through both: and the head or difference of potential applied to each conductor is a measure of their respective resistances. This can be illustrated hydraulically by the diagram, where the water is driven through two pipes of different bore, placed in series, by a gentle head applied to both. Most of this head is employed to drive the water through the narrow pipe.



HYDRAULIC ANALOGY OF RESISTANCE

Water flows through two pipes of different bore in the direction of the arrows from a cistern. Three pressure gauges, corresponding to voltmeters in the electrical sense, are shown with the gradient of potential indicated by a dotted line. The resistances are proportional to the applied differences of level or potential

The other typical case is to split a flow of water into two channels which afterwards reunite. The two channels are then said to be connected in parallel. In that case the head applied to both is the same, but the flow in each is different. The wide pipe obviously carries more current; and if you compare the currents which they convey, you have a measure of their relative conductances, conductance being the inverse of resistance.

A hydraulic analogy of this latter example is not so easy to carry out, because it is not so easy to measure the quantity of water passing per second as it is to measure the potential or head which is driving it. The level at which water stands in a lateral tube, or any other form of pressure-gauge, gives an easy measure of the head, and does not interfere with it. Whereas to measure the flow would require some sort of water-wheel or turbine, which could hardly fail to interfere with the flow, and, moreover, is more complicated than a simple gauge.

But all this applies only to steady currents, when the acceleration period is over and when the resistance is equal and opposite to the propelling force, so that the current is obeying the First Law of Motion, as explained under the heading Force. When the current is variable, and during the period when it is getting up strength or weakening, inertia has to be taken into account. Another term has to be introduced besides resistance or friction. Part of the force is dependent on mass acceleration.

This applies in mechanics and hydraulics equally well. Only, to imitate the simplicity of the electrical example, we must take the resistance as proportional to the first power of the velocity. We can then write an expression for the propelling force or head necessary to drive water slowly through an obstructed channel, even during the variable stages of the current, thus :

$$F = rv + m\frac{dv}{dt}$$

where $\frac{dv}{dt}$ represents the rate of change of velocity, or the acceleration ; m is the mass or inertia ; r is the resistance coefficient, commonly called resistance, of the channel ; and v represents the speed of the water or the strength of the current.

This same equation holds in the electrical case. Only it would be written

$$E = RI + L\frac{dI}{dt}$$

Here I is the strength of current ; R is the resistance coefficient, or resistance ; $\frac{dI}{dt}$ is the rate of change of current, which if the current is steady is, of course, zero ; and L is the mass or inertia coefficient, commonly called inductance ; while E is the electromotive force or difference of potential which is propelling the current. We see that this electro-motive force is accounted for by two terms. The first is the resistance term, obedient to Ohm's law ; the second is the acceleration term, which involves the magnetic properties of a current, and may be called a self-induced opposition electromotive force. That is why L is called the coefficient of self-induction, or, briefly, the inductance; to correspond with R, the resistance.

Ohm's law is represented by the first term. It is applicable in its simplicity to steady currents only, viz. E = RI, where R is a constant of the conductor, measured by the ratio E : I, the ratio of volts to amperes ; the ratio 1 volt : 1 ampere being called an " ohm " in honour of the formulator of the law.

OIL. A neutral liquid of either animal, vegetable, or mineral origin, which is insoluble in water, but soluble in ether. Oil as used in wireless work is employed for its lubricating properties, in the moving and bearing parts of mechanism, and varies considerably in its constituency, composition, and physical properties.

For very small machines the oil is a thin, dull yellowish-coloured liquid and is not very resistant to the effects of heat. For use on machine tools or oiling the bearings of a lathe, drilling machine, hand drills and similar implements, a heavier grade of oil is used, commonly known as light machine oil. Water-cooled internal combustion engines employ a much heavier and more viscous oil, a special feature of which is that it withstands the effects of heat and retains its lubricating properties at high temperatures. A still heavier oil, exhibiting similar characteristics, is used for air-cooled engines, and is known under the class name of air-cooled engine oil.

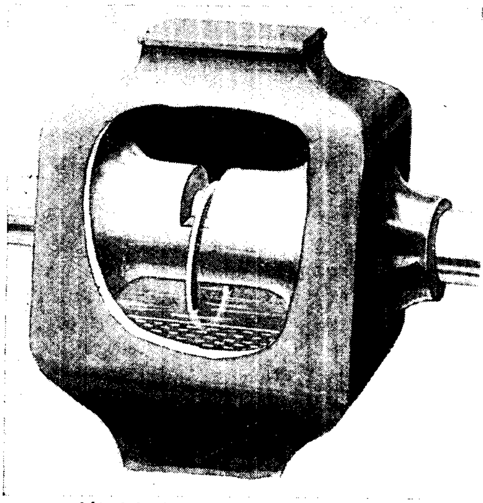
Another application of oil is in the oil-cooled transformer, and as a lubricant in some high power transformers.

Oil is used in many forms of spark gap, as the Penkert spark gap. In the Fleming arc oscillation generator, heavy lubricating oil is used to provide the atmosphere of hydrocarbon gas in which the arc burns. The arc is struck just over the surface of a quantity of oil, one electrode being immersed in the oil, so that it only just appears above the surface. The heat of the arc evaporates the oil. In some forms of vacuum oscillation generators the whole valves are immersed in a cooling oil bath.

OIL KEY. A form of Morse tapping key which has its contacts immersed in a bath containing oil of a very high flash-point. This construction absolutely eliminates any possibilities of sparking or arcing occurring at the key points getting to the surrounding atmosphere. Keys of this type were largely used in transmitting sets for tank ships carrying loads of oil or petroleum yielding inflammable gases. In such cases every precaution has to be taken against the risk of fire or explosion due to the released gases becoming ignited.

OIL OF VITRIOL. This is the popular name for sulphuric acid (*q.v.*).

OIL RINGS. Term used to describe a shallow groove or grooves cut in the face of journal and other bearings employed in machinery generally. The oil rings are only cut in plain bearings, the purpose being to provide a channel whereby the lubricating oil may be distributed over the whole of the surfaces of which the



OIL RING LUBRICATING DEVICE
Oil is distributed by means of the ring, which lies in a slot in the journal. The outer box is represented cut away to show the ring in position

bearing is composed, so that it may be as uniformly lubricated as is possible. In the factory the oil rings are cut by machines made specially for the purpose, and the amateur can produce them by careful chipping with a cold chisel and hammer, and finishing the edges with a scraper with which to remove any burrs or excrescences which may be forced up above the normal surface.

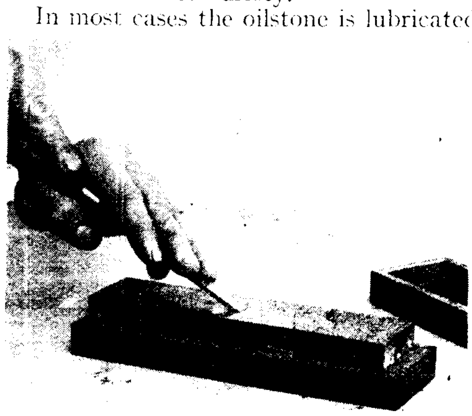
The term is also applied to the actual ring which forms the oil distributor in the so-called ring-oiling bearing. In this case there is incorporated in the bearing a cavity known as the oil sump, which is filled with oil to just below the level of the shaft. The oil ring, which is about 30 per cent larger than the shaft, is free to rotate in a groove or ring cut through the bearing lining, the lower part of the ring dipping into the oil. As the ring rotates it raises a small quantity of oil and distributes it on the shaft, whence it makes its way through the oil grooves to all parts of the bearing, and returns through channels, cut for the purpose, to the sump. This type of ring oiler is extensively used in dynamos and small machinery.

OILSTONE. Name given to a close-grained stone used for sharpening tools and for removing small quantities of metal in metal-fitting operations. The wireless experimenter will find it imperative to have one or two oilstones available. These should include one mounted stone about 9 in. in length for tool-sharpening purposes, a small slip for sharpening the hollows of gouges and putting a keen edge on curved tools generally, and a rectangular slip about 3 in. long, $\frac{1}{8}$ in. wide and $\frac{1}{4}$ in. or so in thickness, the latter for metal-fitting operations.

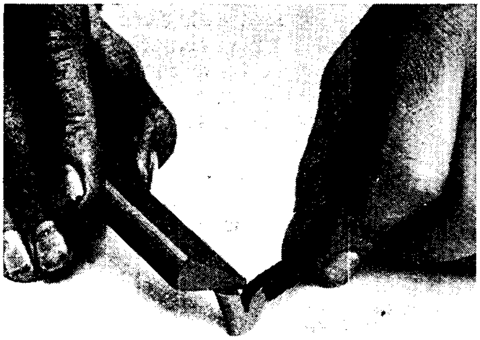
In choosing an oilstone, the following points should be noted. For general amateur use, for sharpening tools such as chisels, plane irons, gouges and the like, it will be found that the type of stone known as Washita will be as suitable as any. This stone is generally obtainable in blocks about 9 in. long, 2 in. wide, and about 1 in. in thickness. The stone should be as finely grained as possible, and absolutely free from cracks and spots of different hardness. It should cut freely and not exhibit a tendency to choke quickly. Most of these points only become apparent after the oilstone has been in use for some time, so that when a good stone is found, it should be cared for and kept free from damage, and it can generally be used until it is worn almost away.

For sharpening edges required to be particularly keen, a rather finer grain of oilstone, of the type known as the Arkansas, should be used. This and the Washita stone are both natural stones, but other types of stone, generally of a coarser nature, are formed of compositions generally employing emery and carborundum. It will be found a very good plan, if much work is to be done with the tools, to rub them first on the coarse variety and to finish off to a very keen smooth edge on a stone of the finer variety.

In most cases the oilstone is lubricated



HOW TO USE AN OILSTONE
Fig. 1. Cutting tools, especially chisels, are sharpened on an oilstone, which should be mounted. This photograph shows the position in which the tool is held for sharpening



SHARPENING A LATHE TOOL

Fig. 2. How a lathe tool is sharpened with an oilstone slip is illustrated

with ordinary machine oil, although in a few cases it is better to use water.

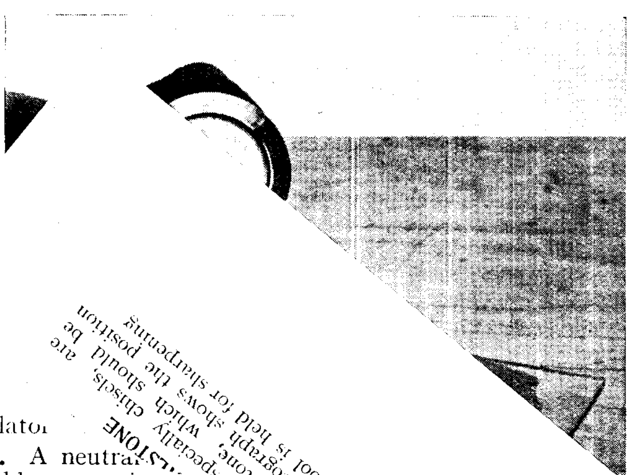
The ordinary oilstone, for use on the bench, should be mounted in a wooden case, somewhat as illustrated in Fig. 1. The base of the case keeps the stone in position and prevents its rocking, and the top cover serves to keep the surface clean and free from grit and dirt, the presence of which is absolutely detrimental to successful tool sharpening.

The small oilstone slips vary in size and shape. One about 2½ in. in length, 1¼ in. wide and ½ in. thick on one side and ¼ in. thick on the other, and having rounded edges, is a very useful acquisition. It should be employed for putting a keen edge on slide-rest tools, in the manner illustrated in Fig. 2, particularly when these tools are needed for fine work or for turning ebonite.

In many cases where an accurate fit between two pieces of metal is needed, or when surfacing a disk or ring for contact purposes, it will be found that the flat oilstone slip, used as illustrated in Fig. 3, is extremely valuable. The general procedure is to use a surface plate, or in its absence a piece of plate glass, and lightly cover the surface with reddle, which is a fine mixture of red lead and oil. The work to be trued up is then pressed on to the reddle and lifted straight off. It will then be noticed that there are two or more high places, indicated by the presence of the reddle. The latter should be wiped off and the high parts carefully rubbed with the oilstone slip, very much as if using a small file.

This has the effect of removing a very small amount of the metal, as will be evidenced by repeating the test. This plan has the advantage over the ordinary filing and the use of emery cloth or buff sticks, in that it keeps the work flat and imparts a high degree of finish.

OMNIBUS BAR. Name given to the long conducting strips arranged at the back of electrical switchboards and other apparatus from which connexion is taken to any number of instruments or circuits. The omnibus bar is most often found in large generating and distributing stations, and takes the form of solid copper rod, bolted securely to the back of switch or distribution board.



...LSTONE
especially chisels, are
oilstone, which should be
photograph shows the position
This ... tool is held for sharpening
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The size of the omnibus bar varies according to the amount of current it will be required to carry. In large stations sizes of 4 in. across and 1 in. in thickness are common. In mounting the bars particular care is taken to use very strong supports and at frequent intervals, as the magnetic attraction of two bars on the same board is very considerable. Connexion to the various circuits from the omnibus bars is made by drilling and bolting the metals where contact is required. The omnibus bar may be extended at any time when the size of the switch-...ard needs to be increased ...olting a similar strip at

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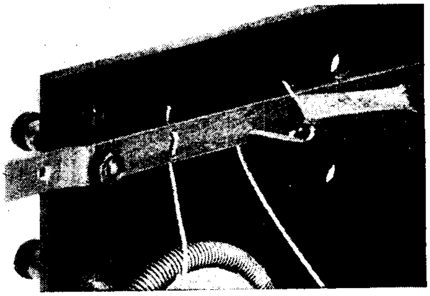
OIL. A neutra... vegetable, or mineral ... insoluble in water, but solub... Oil as used in wireless work is emp... for its lubricating properties, in the moving ...

either end. For this reason the bars usually extend throughout the whole length of the switchboard. A type of omnibus bar used in fairly small switchboards is shown in Fig. 1, where arrangements are made for seven connexions.

The principle of the omnibus bar lends itself extremely well to wiring up multi-valve wireless sets, where connexion to a common wire is often required. The earth wire affords an example of this, as very often one side of the high- and low-tension battery, the grid leak, tuning coil and condenser, one side of the high- and low-frequency transformers, as well as various fixed condensers, may be attached to it. Wiring up to bars or stout wires running the length of the set considerably improves the appearance of the set, in addition to simplifying the wiring.



WIRING AN OMNIBUS BAR

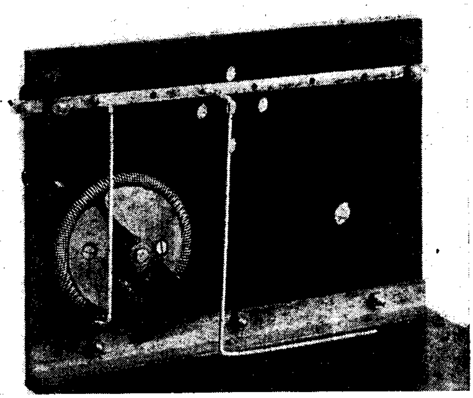
Fig. 3. An alternative method of wiring an omnibus bar for connecting a multi-valve set is shown. Pairs of holes are drilled in the bar and the wire threaded and gripped with the aid of a pair of pliers

OMNIBUS BAR AND CONNECTING STRIPS

Fig. 1. Long conducting strips of heavy gauge are employed at the back of switchboards to connect various circuits and instruments. Seven connexions are shown on this omnibus bar

Courtesy General Electric Co., Ltd.

Fig. 2 shows the commencement of the wiring of a multi-valve set of the unit system, using a common omnibus bar. The bar extends the whole length of the vertical panel, and a hole is drilled at either end of it for connexion to a similar bar on adjoining units. The bar to the right has a double bend in order to keep the adjoining panel flush with the one to which it is connected. The bar is $\frac{1}{2}$ in. in width and $\frac{1}{16}$th in. in thickness, and is mounted by two holes drilled towards each end which fit over the stems of terminals attached to the front of the panel. Small blocks of ebonite are used to keep the bar from contact with the panel, and both blocks and omnibus bar are rigidly held with nuts screwed to the terminal stems. Small holes to the number of the connexions required are drilled along the bar, to which soldered connexions are made.

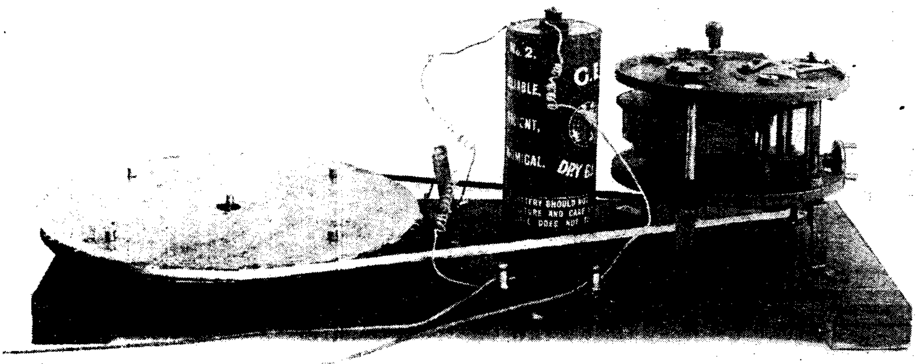


HOW AN OMNIBUS BAR IS USED

Fig. 2. In wiring up a multi-valve set an omnibus bar may be used in this way for common earth or other connexions. The bar extends the whole length of the panel, and is drilled at either end for connexions to a similar bar on adjoining units

An alternative plan for connecting the wires is shown in Fig. 3. This consists of a number of pairs of holes, each pair being arranged vertically so that one comes over the other. Each pair of holes is drilled so that they are closer to each other on the opposite side of the bar, that is to say, they are drilled at an angle instead of square with the surface of the bar. Connexion is made by threading the wire through the lower hole and bending it round with a pair of pliers to enter the corresponding hole at the top. This end is then pulled up and any surplus cut off. Good electrical connexion results, and this method has the advantage that an unwanted wire can be pulled off with a minimum of trouble.

The drill used for drilling these holes should be slightly larger than the gauge of the wire, which should not be too thick, to permit easy bending. In Fig. 3 one connexion is seen completed, while a second is being bent round preparatory to insertion in the second hole.

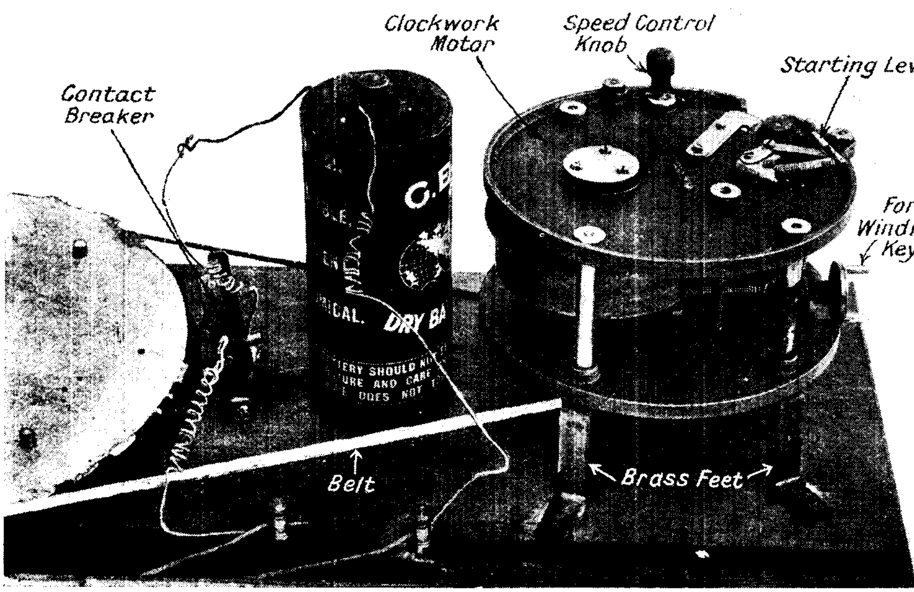


HOME-MADE OMNIGRAPH FOR PRACTICE IN RECEIVING MORSE MESSAGES

Fig. 1. Amateurs who wish to practise receiving as well as sending in the Morse code can make their own omnigraph. The above photograph gives the general appearance of the apparatus, which permits messages to be received at any speed

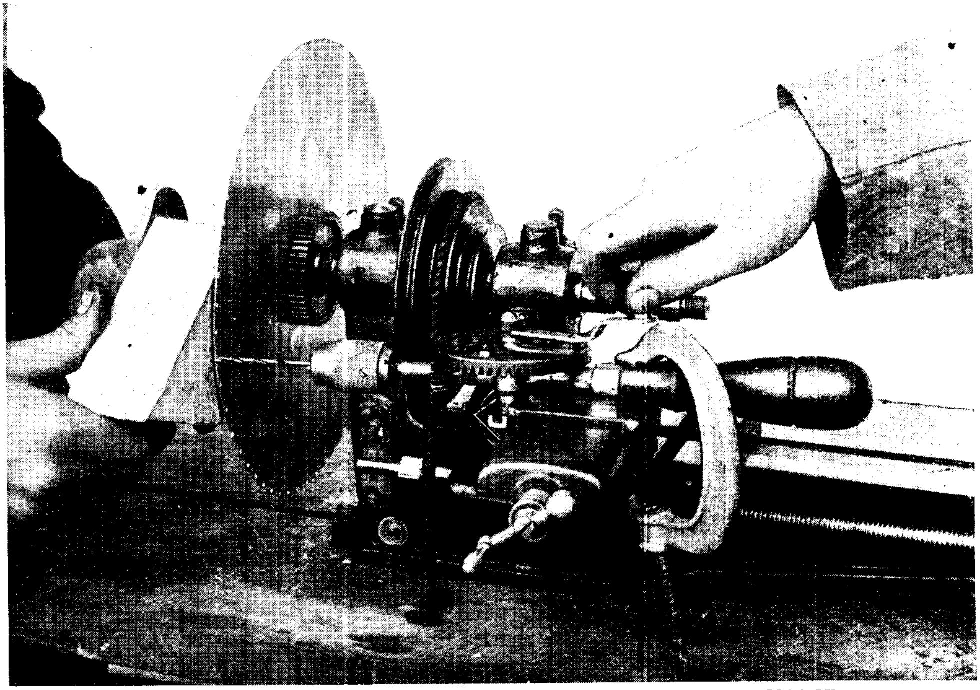
OMNIGRAPH. An instrument for assisting beginners in learning the Morse code. It consists of a notched disk which is revolved by clockwork against a spring contact. This contact is connected to a battery and buzzer. The notches in the revolving disk are cut to give the necessary dot and dash sounds of a series of letters of a message and the spaces in between the words. By this means a message can be sent at any speed which is required, and a large number of disks being available with the instrument, a learner can practise not only sending, but receiving Morse by the instrument.

How to make an Omnigraph. The construction of a practical omnigraph, such as that shown in Fig. 1, is not beyond the scope of the amateur if care be exercised in the adaptation of available parts. The chief requirement is a good powerful clockwork motor, and one from a



GRAMOPHONE CLOCKWORK DRIVING THE OMNIGRAPH

Fig. 2. In this photograph is shown how the motor which drives the omnigraph disk is mounted on the baseboard by brass feet. The speed is controlled by a knob on the top of the clockwork apparatus, which may be taken from a disused gramophone



HOW TO CUT AN OMNIGRAPH DISK FOR PRACTISING MORSE

Fig. 3. Mounted on the back of the mandrel is a metal disk, and a hand drill is fixed in position as shown. When the disk is revolved into position holes are drilled in the edge at intervals spaced to correspond with the code message

disused gramophone would answer well if the mechanism be perfect. The requirements are a reasonable length of run on one winding, say three or four minutes, steadiness of running, and means for accurate control of the speed of revolution.

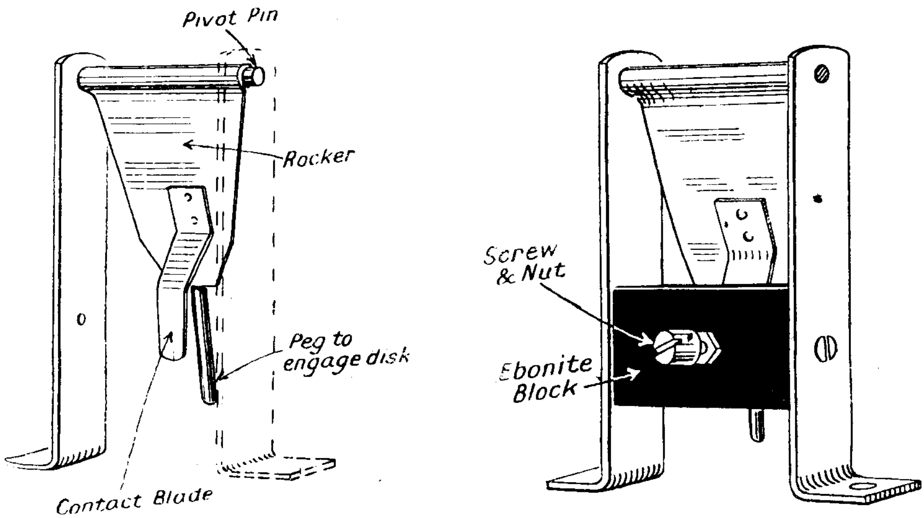
These requirements are generally to be found in a gramophone motor, in greater or less degree, according to the size and quality.

Having obtained the motor, it has to be mounted on a wooden baseboard, which can conveniently measure 9 in. wide and 24 in. long. Screw two battens beneath it to keep it from warping, and plane the top and sides smooth and true. Mount the motor by means of three or four brass feet, seen in Fig. 2, screwed to the main columns of the motor by the nuts which fix them to the framework. The height of the legs should be in the neighbourhood of 2 in., but must be adjusted to the particular type of mechanism. The essential requirement is that the main spindle, when the motor is turned upside down, shall just clear the top of the baseboard, as shown in Fig. 2. The next step is to turn up a small diameter ebonite or brass pulley with a flat face and two good flanges on it, and secure it to the main spindle in place of the turntable.

Next fit a knob or lever control to the stopping and starting device on the motor, and also to the speed-regulating spindle, somewhat as shown in Fig. 2, where a knob controls the speed, and the small flat lever the starting and stopping of the mechanism.

The next requirement is a large-diameter disk to act as a rotating table, and the turntable of the gramophone mechanism will answer well if about 10 in. diameter or larger. This has to be mounted at the opposite end of the base to the motor, and should turn freely on a shouldered steel pin, which is attached to the base either with a flange or with nuts, as may be found most convenient.

The height of the disk should be equal to that of the pulley on the main shaft of the motor, as the latter has to drive the disk by means of a flat rubber belt. To keep the belt on the rim of the disk requires that a plain disk of card or sheet metal be secured to the underside of the turntable, as shown in Fig. 1, to act as the lower of

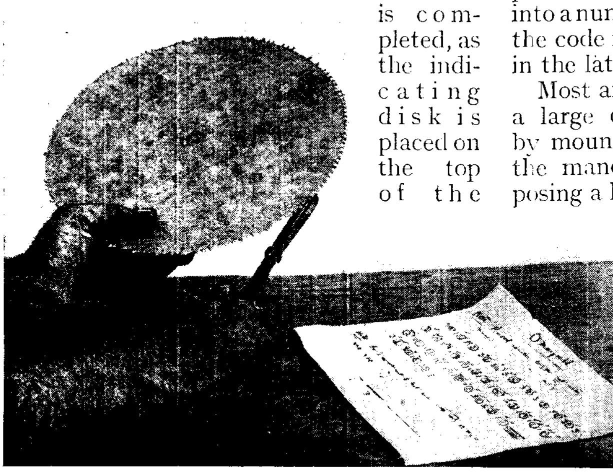


DETAILS OF OMNIGRAPH CONTACT BLADE AND PEG

Fig. 4 (left). Mounted on the rocker the contact blade and peg to engage the disk are seen in this sectional view. Fig. 5 (right). In this diagram is shown an ebonite block on which are mounted a screw and nut. The screw meets the contact arm on the rocker

the flanges. This disk should be about $\frac{1}{4}$ in. larger in diameter than the turntable, and may be fixed to it with three or four screws.

The motor should be wound up and the belt placed over the pulley and around the rim of the turntable, and the whole tested. The motor should then drive the turntable at a very slow speed. Any tendency for the belt to run off at this stage is checked by controlling the approaching side of the belt with a pencil or other round piece of wood. It will not run off when the work is completed, as the indicating disk is placed on the top of the turntable and acts as a second or upper flange. This disk should be at least $\frac{1}{2}$ in. larger in diameter than the turntable, and is secured to it with three screws, or in any way that permits of easy removal and interchangeability, since practising should be carried out with as many disks as possible.



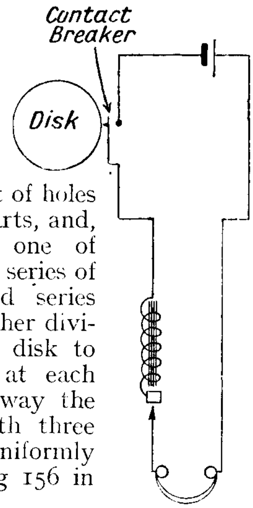
CUTTING OUT AN OMNIGRAPH DISK

Fig. 6. With the aid of a pair of tinman's snips the edge of the drilled disk is cut away very carefully, leaving projections at intervals corresponding with the Morse dots and dashes

The disk has to be made as true as possible on the rim, and this can be tested and corrected in place as the turntable revolves by carefully filing away any high places. The next step is to divide the disk into a number of equal divisions according to the code in use. This is most readily done in the lathe with the aid of a division plate.

Most amateur lathes will not swing such a large disk, and this is best overcome by mounting the disk on the back end of the mandrel, as shown in Fig. 3, interposing a lathe change wheel between it and the mandrel shoulder. This wheel should bear some definite relationship to the desired number of divisions, say a 52-tooth wheel for 156 divisions.

The divisions are easily made by clamping a hand drill to the lathe slide rest, as shown in Fig. 3, and drilling a fine hole near the rim as shown. A packing piece of wood has to be held at the back to prevent the disk buckling. A simple pointer is attached to some part of the headstock and acts as divider, as it drops regularly into the teeth of the change wheel. The next proceeding is to divide the space between the first set of holes into three equal parts, and, commencing from one of them, drill a second series of holes, and a third series starting from the other division, adjusting the disk to the change wheel at each restart. In this way the disk is drilled with three sets of holes, all uniformly spaced and totalling 156 in all.



OMNIGRAPH CIRCUIT

Fig. 7. Wiring of an omnigraph to a buzzer and battery is represented in this circuit diagram

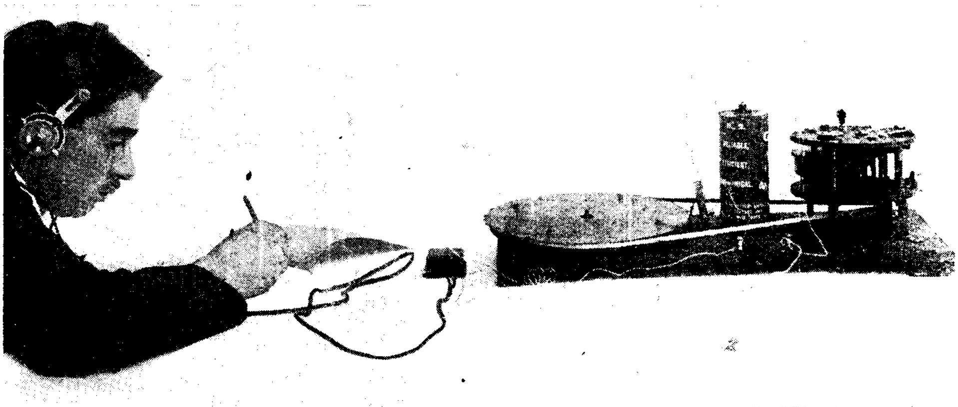
The holes have next to be cut out according to the code, remembering that a notch made by cutting away the rim of the disk to the bottom of the hole will make a silent place, and the projecting part a dot or dash, according to the length of the solid part at the rim. Most of the holes can be cut with tinman's shears, as shown in Fig. 6, and trimming the edges with a fine file. The approaching edge of the disk should be filed to an angle to facilitate passing the peg on the contact breaker. The latter is simply two uprights of strip brass, some $\frac{1}{2}$ in. wide and $\frac{1}{16}$ in. thick, shaped as shown in Figs. 4 and 5 and about $2\frac{1}{2}$ in. high. The lower ends are bent to act as feet and screwed to the base, the upper ends joined by a pivot pin which supports a rocker. The latter has a small pin at the lower part, and this engages the disk. The upper part moves freely on the pivot pin. The side pieces or brackets are tilted forwards to get the necessary clearance, and to make the rocker swing towards the disk.

A separate contact blade of springy metal is attached to the inner side and presses against the contact screw when the passing projection on the disk forces it into engagement. The contact screw is simply screwed through the centre of a block of ebonite screwed between the two side pieces, as shown in Fig. 5.

This part needs careful adjustment so that the device operates with certainty, but once adjusted, seldom needs attention. The disposition of these parts is clearly shown in Figs. 1 and 2.

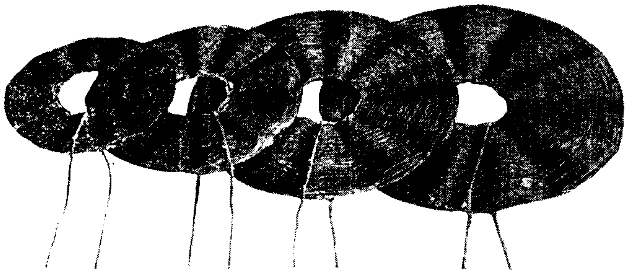
The connexions are simple and can be arranged in several ways. A useful circuit is shown in Fig. 7. The dry battery stands on the base and is connected by one wire to the contact breaker and by one wire to the terminal on the front of the base. Another wire connects the other side of the contact breaker to the other terminal. The completed appliance in use is shown in Fig. 8, although in practice a longer pair of leads is used so that the disk cannot be seen and read directly.—*E. W. Hobbs.*

OOJAH COILS. Name given to a series of proprietary inductance coils. The standard basket coil inductances are shown in Fig. 1, where four different sizes are shown. These Oojah coils are



OMNIGRAPH IN USE, SHOWING HOW MORSE IS PRACTISED

Fig. 8. Omnigraph and telephones are here seen in use, but in actual practice a long pair of telephone leads may be employed, and the omnigraph disk placed in some convenient position out of sight of the person receiving the messages

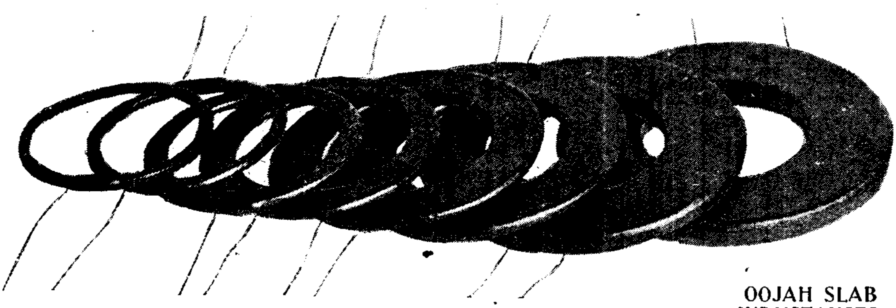


OOJAH BASKET COILS

Fig. 1. These are a well-known proprietary brand of basket coil with wave-length ranges of from 150 to 4,500 metres

Courtesy Greenslade & Brown, Ltd.

generally sold in sets of seven, and can be used for aerial tuning inductances, reaction coils, loose couplers, variometers, etc. They are very efficient on short wave-lengths and possess very small self-capacity. The range of these coils is from 150 metres to 4,500 metres, so they cover the whole range from amateur transmission to commercial telegraphy. To obtain the low range with No. 1 coil an aerial tuning condenser of ·001 mfd. capacity must be placed in series in the aerial instead of in shunt.



OOJAH SLAB INDUCTANCES

Fig. 2. Slab inductances of the Oojah type are more efficient on long wave-lengths than the basket coils, and cover wave-lengths from 300 to 30,000 metres

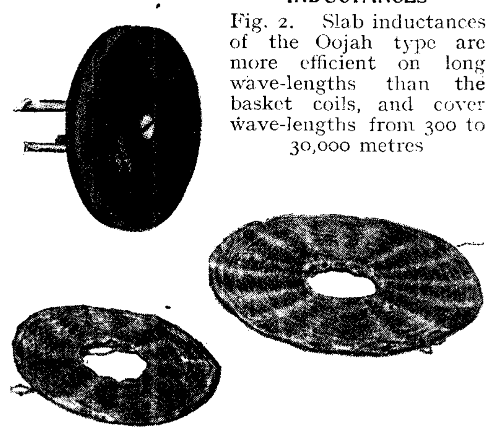
Fig. 2 shows the series of Oojah slab inductances. These inductances are more efficient for longer wave-lengths, covering a range from 300 to 30,000 metres. The following table gives the ranges covered by the various coils.

Coil Number	Range (Basket Coil)	Range (Slab Coil)
1	150–600 metres	300–1000 metres
2	600–1000 ,,	1000–2100 ,,
3	800–1100 ,,	2000–4300 ,,
4	1000–1600 ,,	3000–4300 ,,
5	1600–2600 ,,	4000–7000 ,,
6	2500–3800 ,,	6000–10,000 ,,
7	3600–4500 ,,	9000–17,000 ,,
8	———	15,000–30,000 ,,

A special holder is designed for these basket coils and slab coils, and coil holders for such types of coils are fully illustrated on pages 207–212. Fig. 3 shows two basket coils and an Oojah high-frequency inter-valve transformer. These transformers are made in a number of sizes covering wave-length ranges of from 150–24,000 metres. They are wound between two ebonite disks, and are fitted with valve legs spaced unequally, so that there is no possibility of fitting the transformers in their sockets the wrong way round. *See* Basket Coils.

O.P. This is an abbreviation for "out primary." This lettering is found on one of the four terminals of a transformer, and indicates the end of the primary winding. *See* Inter-valve Transformer; Transformer.

OPEN CIRCUIT. One in which inductance and capacity are distributed throughout its length instead of being concentrated as in the case of closed



OOJAH COILS AND TRANSFORMER

Fig. 3. Two Oojah basket coils are shown beneath an Oojah high-frequency transformer, the legs of which fit standard valve holders

circuits in coils and condensers. An example of an open circuit is one including an aerial which has both inductance in itself and distributed capacity to earth, this inductance and capacity being spread over the whole circuit in addition to any localized inductance or capacity which the circuit may contain. An open circuit is the exact opposite of the closed circuit in being a good radiator but poor oscillator.

An open circuit may be coupled with a closed circuit by arranging their respective inductances, in the form of coils, so that the energy in one is transferred to the other by electro-magnetic induction, and this system is adopted in the case of both transmitters and receivers. *See* Circuit; Coupling; Oscillatory Circuit.

OPEN-CORE TRANSFORMER. One in which the arrangement of the coils is identical with that of an induction coil (*q.v.*), a hollow core filled with soft iron wires being used to concentrate the magnetic field. A transformer of this type is employed for modulation or control in transmission.

The photograph shows another type of open-core transformer manufactured by Burndept Ltd. It is a telephone transformer, and is designed for use with 120 ohm telephones and loud speakers. At note frequency the input impedance approximates 30,000 ohms, and the output impedance is equivalent to that of a pair of 120 ohm telephone receivers. *See* Inter-valve Transformer; Modulator Transformer; Transformer.

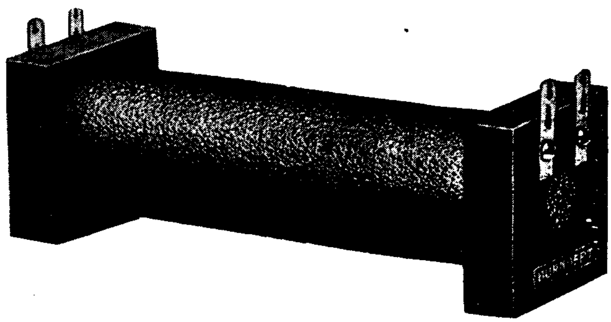
OPEN OSCILLATORY CIRCUIT. An expression used to denote a circuit having the properties of inductance and capacity capable of carrying an oscillating current, and one where the ends of the circuit do not meet. An oscillating current is an alternating current where the alternations have a frequency of hundreds of thousands up to millions per second.

Circuits in which radio-frequency currents flow are oscillatory circuits, and such circuits of the open type are largely used in aerial systems for transmission and reception. In an open circuit of this nature one end terminates in the aerial and the other in the earth, and thus there is no electrical continuity apparent. It is considered by some authorities that the continuity of an open oscillatory circuit in an aerial system is completed by the capacity between the wires forming the aerial and the earth underneath. In this case it would be regarded as a closed oscillatory circuit.

The alternative to an open circuit is a closed circuit, the chief difference being that in the former the capacity and inductance are more equally distributed through the length of the circuit, while in the latter case the inductance and capacity are usually grouped at two units in the circuit.

The open oscillatory circuit produces waves of large amplitude, and is consequently a good radiator of energy, and is more suitable for an aerial system than the closed circuit, where oscillations have a small amplitude. *See* Closed Circuit.

OPPOSING E.M.F. This is an alternative name to counter E.M.F. or back E.M.F., the electro-motive force due to opposite



BURNDEPT OPEN-CORE TRANSFORMER

Telephones and loud speakers of 120 ohms resistance may be equipped with this kind of step-down transformer

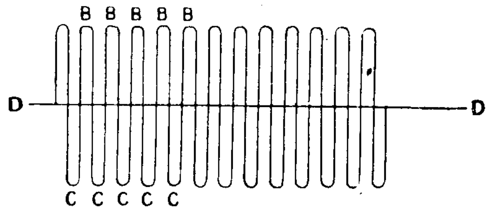
Courtesy Burndept, Ltd.

and opposing current produced by self-induction set up in a circuit by a changing supply current. In a cell it is the current due to polarization. *See* Back Electro-motive Force; Electro-motive Force.

OPTIMUM HETERODYNE. When signals from a continuous wave transmitter induce currents in the aerial of a receiving set, these currents may flow through the various circuits of the receiver without producing any audible effect in the telephones.

The reason for this is that the frequency of the received waves is far too high for the telephone diaphragm to respond to them.

Take the case of reception of continuous waves of a wave-length of 300 metres. The frequency of this wave is 1,000,000 cycles per second (*see* Fig. 1). The amplitude



OPTIMUM HETERODYNE C.W. RECEPTION

Fig. 1. Continuous wave reception is considered in this diagram, which should be studied in connexion with Fig. 2, where the wave is modified by local oscillations

of the wave is constant, as we are considering the case of a transmitting station sending out a long dash, *i.e.* a continuous train of uninterrupted and unmodulated continuous waves. Therefore the height of each point B will be exactly the same, and the distance from any point B to the datum line D D will be the same. The points C C C will also be equidistant one from another, and their depth below the line D D will be constant, and equal to the height of the points B above the line.

A distinctive but comfortably high note for reception is 1,000 cycles per second. This note can be produced by the heterodyne method in two ways:

(1) By means of an independent oscillator, and (2) By means of a self-heterodyne.

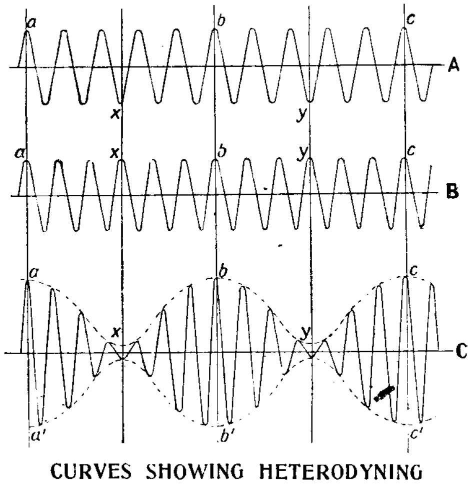
In both cases it may be produced by generating oscillations of a frequency which is either 1,000 cycles greater, or 1,000 cycles less than the frequency of the incoming waves, *i.e.* in case (1) the local oscillator will have to be adjusted to oscillate at a frequency of 1,001,000 or of 999,000 cycles per second.

When this is the case the incoming wave may be passed through a circuit where it is affected by the locally produced frequency, with the result that at equal distances the two waves will assist one another, *i.e.* the amplitude of the incoming wave will be increased to a maximum, whilst at points equidistant between these points of maximum amplitude the waves will oppose one another, so that the amplitude of the incoming waves is reduced to a minimum. At all intermediate points the effects will be proportional to the phase relationship of the two wave trains. This is shown in Fig. 2, which only represents a few cycles of (A) the incoming oscillations and (B) the local oscillations. In considering these diagrams it should be remembered that really the two frequencies are 1,000,000 per second and 1,001,000, whereas the diagram shows a much greater difference of frequency.

From the diagram it will be noticed that at the points *a*, *b*, *c*, the two frequencies are in phase with one another, and the curves at these points may therefore be added together as shown in curve C at points *a*, *b*, *c*, whilst at points *x*, *y*, the waves shown in A, B, are opposed, so that they nearly cancel one another, as shown at *x*, *y*, in curve C. If now the two curves A and B are added at all other points, the curve C is obtained, which is a graphical representation of the summation of the two curves. In curve C a dotted line has been drawn joining the crests of all the waves.

It will be noticed that this dotted line in itself forms a curve. This curve is known as the "envelope," and is a symmetrical curve, having a frequency equal to the difference of frequency of the two curves A and B. Whilst for clearness of illustration this curve is drawn at a frequency which is far too near to that of A and B, it should be remembered that in the actual case under consideration its frequency will be 1,000, whilst A is 1,000,000, and B 1,001,000 cycles per second.

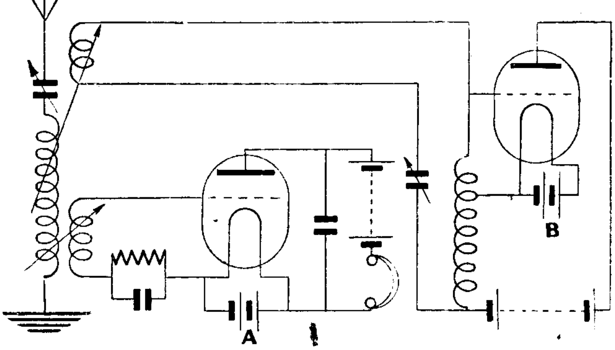
Now the curve C (considering the envelope only, *a b c*, *a′ b′ c′*) would in our case be of the audio-frequency of 1,000, but as *a a′*, *b b′*, *c c′* are still in opposition, nothing would be heard in the telephones if the current corresponding to this curve was passed through them. If, however, this current is passed through a rectifier valve,



CURVES SHOWING HETERODYNING

Fig. 2. Two different frequencies are represented by A and B; C shows how the two are combined or heterodyned

then $a' b' c'$ will be suppressed, and we have a uniform varying current at a frequency of 1,000 as the top half of curve C, *a x b y c*. This current will produce a musical vibration of the diaphragm of the telephones.



OPTIMUM HETERODYNE RECEIVER

Fig. 3. A is the receiver, B the local oscillator. Here the tuner is tuned to the wave it is desired to receive

In Fig. 2, curves A and B, the incoming oscillations and the locally produced oscillations are shown as of the same amplitude; they are therefore represented in C as coming almost to zero when in opposition. In actual practice this is not the case.

The strength of the local oscillations is adjusted relative to the strength of the incoming signals, and there is an optimum value for the strength of heterodyne employed.

If a local independent oscillator is used the strength of heterodyne is adjusted by bringing the oscillator nearer to or farther from the receiver.

When the receiver is a self-oscillator, the adjustment of strength of heterodyne is made by adjusting the reaction coil of the receiver. The two methods of reception are illustrated in Figs. 3 and 4, where Fig. 3 shows A, the receiver, and B, the local oscillator, whilst Fig. 4 shows the self-heterodyne receiver, now generally known as an "autodyne" receiver.

In considering the relative advantages of these two methods of reception, there is one point which stands out as a fundamental advantage of the separate local oscillator.

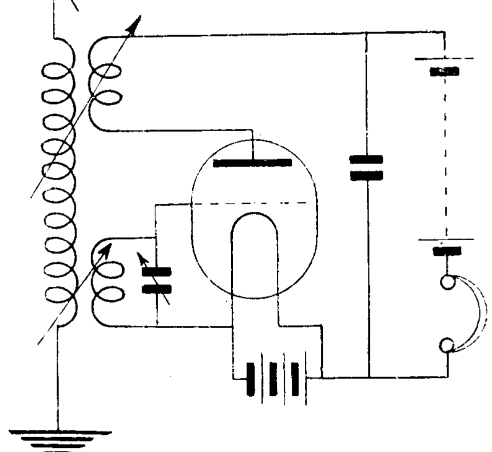
When a local oscillator is to be used, the receiver is tuned to the wave which it is desired to receive. In the case we have been considering, the receiver would be tuned to 300 metres, *i.e.* 1,000,000 cycles. The local oscillator has to force its oscillations into the receiver although it is slightly out of tune. This is not, however, difficult, as the local oscillator may be coupled with the receiver as tightly as desired.

On the other hand, with the autodyne or self-heterodyne, the receiver, which is also oscillating, has to be tuned to a wave either above or below the frequency of the incoming wave, therefore the feeble incoming signal has to push its way into a circuit which is slightly out of tune with it.

The autodyne is certainly convenient. There need only be one valve in use; it is simple to use, and for reliable working with signals at moderate strength it has much to recommend it.

For work under difficult conditions and with weak signals the independent heterodyne is, however, to be preferred.

To state definitely what strength of heterodyne should be used in either case (self-heterodyne or autodyne) is difficult, as it will depend on the characteristics of the valve employed. The maximum value of signals is, however, obtained when the amplitude of the local oscillations is equal to the amplitude of the

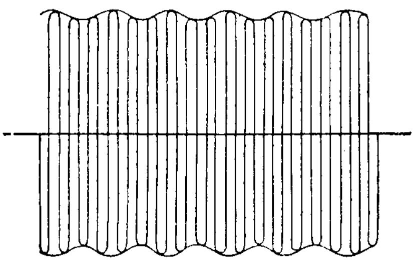


AUTODYNE CIRCUIT

Fig. 4. In this self-heterodyning or autodyne circuit the receiver is tuned to a wave frequency slightly above or below that which it is desired to receive

oscillations produced by the incoming signal. In that case, assuming an ideal receiver, the amplitude of final oscillations in the receiver would be twice that due to the incoming signal, and would reduce to zero between the beats, so that we have an energy amplification of four times.

This, however, assumes an ideal receiver. It may well happen in practice



RIPPLE IN OPTIMUM HETERODYNE RECEIVER

Fig. 5. Compare this diagram with Fig. 1, and it will be seen how the beat in heterodyne reception forms a ripple on the top of the wave

that increasing the strength of the local oscillator will give stronger signals. This is not because the amplitude of the beats is greater: it is in fact less, for the beats now become a ripple on the top of a curve, as shown in Fig. 5. There is, however, a larger current flowing in the receiver, and the grid potential of the valve is changed. This may have had the effect of moving the rectification point nearer to the ideal rectification point on the characteristic curve of the particular valve which is in use, which would give better rectification, and so stronger signals, although the amplitude of the beats is reduced. The matter is best summarized as follows:

With a perfect receiver and perfect valve the optimum value for heterodyne is that which gives a local signal equal in amplitude to the incoming one, but that under other and ordinary working conditions the optimum value of heterodyne is that value which gives the loudest signals.—*R. H. White.*

See Beat Reception; Heterodyne.

ORA VALVE. Name given to a series of valves made by the Mullard Radio Valve Company. *See* Mullard Valve.

ORDINATE. The distance of any point from the axis of an abscissa. Usually in geometry the ordinates are measured along the y axis and the abscissae along the x axis. *See* Abscissa; Curve; Graph.

O. S. This is an abbreviation for "out secondary." The letters appear on one of the four terminals of a transformer, and indicate the terminal connected to the end of the secondary winding. *See* Inter-valve Transformer; Transformer.

OSCILLATION: A WIRELESS FUNDAMENTAL

By Sir Oliver Lodge, F.R.S., D.Sc.

Without electrical oscillations the propagation of wireless waves would be an impossibility. Here the principles and applications of oscillation in electricity are clearly explained, with simple analogies, by our Consultative Editor. His article on Free Oscillation should also be consulted. See Syntony; Tuning

Wireless telegraphy depends entirely on electrical oscillations, their production at one station and their detection at another. The fact that an electric discharge must in some cases have an oscillatory character was foreshadowed in 1847 by Helmholtz, who deduced it from the law of the Conservation of Energy, in a most remarkable paper, in which he deduced many other things of equal interest.

The full theory of electric oscillations, as concerns the discharge of a Leyden jar or condenser or other capacity, was given mathematically by Lord Kelvin (then Sir William Thomson) in an illuminating paper, 1853, called "Transient Currents." In those early days the names "inductance" and "self-induction" had not been invented, and it was many years afterwards before they even began to be really understood. The experimental fact of an oscillatory discharge was verified by Feddersen some years later. It had been observed indistinctly by Joseph Henry, at Washington, many years earlier; but it had attracted little attention, because it was not then understood.

Now that we know, so to speak, all about it, it is not difficult to demonstrate, and is an interesting experiment. The oscillations of an ordinary discharge are too rapid for observation, but by taking a large capacity and discharging it through a large inductance, the oscillations may be brought down until they can by optical means be demonstrated, and even still lower, when they can be heard. The spark in that case gives a short musical note or whistle.

Suppose we take a condenser of ·01 mfd. and discharge it through a coil of inductance 1 henry, the oscillations will be at the rate of 1,600 per second. And if the potential is high enough to give a spark, and that spark be looked at in a revolving mirror, it will be seen to be spread out into a beaded band, the beads or luminous portions each representing one oscillation. The current, if plotted, would be represented by a sine curve, with the pulses alternatively positive and negative, and with intervals of no current at the end of each swing; just as a pendulum when oscillating is at rest at the end of each swing for an instant, and is moving with maximum speed at the middle of the swing or lowest point, which is the position corresponding to maximum current. In the middle of the swing the condenser is discharged; it has for an instant no potential, and the current is a maximum. At the end of each swing or half-swing the condenser is fully charged, and for an instant there is no current.

Oscillatory Charges and Discharges of a Condenser

Suppose the condenser to start positively charged, then when the terminals are brought together the charge rushes out of the condenser through the wire, the current increasing in strength till it reaches a maximum. But the action does not stop there. The current prolongs itself by its inertia or self-induction, due to the magnetic field which surrounds it.

This compels it to continue until its energy is reconverted into an electric charge of opposite sign and is piled up once more in the condenser, which is now negatively charged. Then the electricity surges back again, giving once more a maximum current in the opposite direction, until it piles itself up again in the condenser, with a charge of the same sign as at first. One whole swing is now complete, but the action does not stop there. It goes on repeating itself until, by reason of resistance and other dissipating causes, the energy is all converted into heat, or, as we now know, partly into electric waves.

We will omit the consideration of waves for the present, and treat them under that head. The thing that wipes out the current is, then, only resistance, the resistance of the wire, which therefore gets heated; though the amount of heat is imperceptible, since the whole series of swings only occupy a very small fraction of a second.

Mechanical oscillations and electric oscillations have many points in common. The analogies are very close, and thinking of the one helps to elucidate the other. Everyone knows that the oscillations of a pendulum depend on the length of the pendulum and on the force of gravity. It is also well known that un-maintained pendulum oscillations gradually die out, chiefly because of the friction or resistance of the air. If, instead of air, the pendulum is made to swing in water or some other more resisting material, the oscillations will die out much more rapidly. To prolong the oscillations would need a heavier bob to the pendulum, that is, greater inertia.

And so also in the electrical case, increase of self-induction prolongs the oscillations, enabling them to overcome resistance for a time. A really long pendulum with a massive bob will continue swinging for the better part of a day.

It would be quite possible to have the resisting medium so adjusted that the swings of the pendulum should stop, or should never really occur; that is to say, that the bob of the pendulum, raised and let go, should merely return to its lowest position, and stay there without overshooting the mark or rising on the opposite side. If this is just accomplished, the swing is "dead beat," and the discharge is accomplished in the minimum of time.

Pendulum Analogy of a Leaky Condenser

If the medium is still more resisting—for instance, if the pendulum were swung in treacle—there would be no attempt at oscillation, or anything of the nature of a swing. The pendulum would dribble back slowly into its position of rest, taking perhaps quite a long time in the process; and this would be analogous to a leak: as when a condenser is discharged, not through a good conducting wire, but through a piece of wood or damp string, or other imperfect conductor.

A leaky condenser is often useful, and is made by shunting it through a megohm or other enormous resistance. It is thus insured against accumulating too much charge, and can be depended on to keep empty and ready for any rapid operation desired of it. For so far as rapid oscillations are concerned, the leak is practically inoperative. The frequencies most commonly dealt with in wireless are of the order of several millions a second; and as the total number of swings is usually between ten and thirty, the whole operation is over in the hundred-thousandth part of a second, during which time a leak has no chance to act.

A good analogy of an electric oscillator is a tuning fork. If its prongs are bent, they spring back by reason of elasticity, overshoot their original position by reason of inertia, and continue to swing till friction dissipates the energy. If the tuning fork is mounted on a sound-box, or pressed on a sounding-board, that corresponds to an aerial; for energy is then partly utilized and consumed in emitting waves, the waves having the same frequency as the vibrations of the fork.

Capacity and Inductance Essential to Oscillation

In every case of oscillation there must be two things concerned. In the fork they are elasticity and inertia. In the aerial they are capacity and inductance. Inductance is very like inertia, probably because it really does depend on etherial inertia. Capacity is like the inverse of elasticity, what might be called pliability, the opposite of rigidity. A thing of great capacity is like an easily stretched elastic.

A thing of moderate capacity might be likened to a steel spring, of a stiffness which could be adjusted to represent the capacity. And a very small capacity would be like a stiff rod which could only be bent with difficulty, or would only yield appreciably to a considerable force, but which would spring back with great rapidity when the force was removed. By clamping a steel spring vertically in a vice and then loading its top with different pieces of lead, a mechanical analogue to an electric oscillator is easily made. The pliability of the spring represents capacity; the load on the top represents inductance. The more the pliability and the greater the load, the slower will it oscillate. A stiff spring with a small load oscillates very quickly.

A microfarad in circuit with a coil of inductance one henry oscillates 160 times a second.

A tenth of a microfarad in circuit with a tenth of a henry oscillates ten times as fast, because the rate depends on the inverse square root of their product.

A hundredth of a microfarad joined up to a hundredth of a henry oscillates 16,000 times a second; and if it emitted waves, those waves would be nearly 19 kilometres long.

The waves from the tenth of a millimicrofarad discharging through the tenth of a millihenry would emit waves 190 metres long, and the rate of vibration would be 1·6 million per second.

We must now write down the equations, which were virtually given by Lord Kelvin in 1853, and which summarize completely the whole theory; only we can express them in more modern terms and symbols than he at that distant date was able to use.

If Q is the charge in a condenser at any instant during its discharge, and if we write a dot instead of d/dt, then Sir William Thomson's equation is

$$LQ''+RQ'+Q/C=0$$

It equals 0 for free oscillations, whereas for forced oscillations it equals $E \cos pt$, where E is the amplitude of the supplied and maintaining alternating E.M.F., of frequency $p/2\pi$; which may or may not agree with the natural frequency of the oscillations which are being forced. In a discharging condenser no artificial E.M.F. is supplied, so the expression above is equated to zero. That is the difference between free and forced oscillations (*q.v.*).

Equation for Free Oscillations

The solution of the above differential equation for free oscillations of any kind is

$$Q = Q_0 e^{-\frac{R}{2L}t} \cos \sqrt{\left(\frac{1}{CL} - \frac{R^2}{4L^2}\right)}\,t$$

where Q_0 is the initial charge.

Thus the logarithmic decrement (*q.v.*) is $R/2L$, and the frequency is rather a complicated expression involving L and C and R. But the effect of R on the frequency is but slight in ordinary cases, its chief effect is exerted on the decay of the oscillations; it does not much influence their frequency or the corresponding wave-length. Usually R/L is quite small, and in that case the frequency constant (the factor of t above) is $n = \frac{1}{\sqrt{(CL)}}$, the reciprocal of the geometric mean of capacity and inductance. So the above equation may usually be written

$$Q = Q_0 e^{-kt} \cos nt$$

where k stands for $R/2L$, and where n stands for $1/\sqrt{(CL)}$. If R is not small, it may happen that $\frac{1}{CL} = \frac{R^2}{4L^2}$ so that the quantity under the square root in the above long equation is zero. Oscillations then altogether cease, and the discharge becomes dead beat (*q.v.*). The condition for the dead-beat condition is

$$R = 2\sqrt{(L/C)}$$

If R is greater than this, oscillations are impossible, and the discharge becomes a leak (*q.v.*).

When there are oscillations, waves are emitted, which Sir William Thomson did not at all expect. FitzGerald, much later, suggested them on a basis of Maxwell's theory, and Hertz and Lodge simultaneously, though in different ways, proved their existence. The wave-length is

$$\lambda = 2\pi \sqrt{\frac{L}{\mu} \times \frac{C}{K}}$$

that is to say, it is the geometric mean of the inductance and capacity, both expressed as lengths. For we know that L is μ times a length, and that C is K times a length (*see* Units); so we have λ represented here as 2π times the square root of the product of two lengths.

The speed with which the waves travel was shown by Maxwell to be $1/\sqrt{(\mu K)}$, and this was found experimentally, though indirectly, to be the same as the velocity of light. If a railway locomotive wheel is imagined of radius equal to the geometric mean of the inductance and capacity of a circuit, both specified as lengths, and it be driven by a crank and piston oscillating at the natural frequency of the circuit, the wheel will roll along and the engine will travel with the speed of light.

Equations for Forced Oscillations and Coupled Circuits. If we consider the equation for forced oscillations—that is, with the right-hand side not zero—

$$LQ'' + RQ' + Q/C = E \cos pt,$$

we are dealing with a circuit in which oscillations are maintained—driven or forced, as by an alternator or a Poulsen arc, or any other continuous wave generator—with the arbitrary frequency-constant p. We may think of the right-hand side of this equation as representing an emitting aerial, maintained in vibration; and we may think of the left-hand side as concerned with a receiving aerial at a distant station, actuated by the received waves. In that case the coupling, if it can be called coupling, is so loose that there is no reaction on the first circuit, unless the oscillations are reinforced by a local battery and valve devices such as may nowadays be used to reinforce the swings.

The simplest and most important case is when the resulting oscillation has an expression like

$$\frac{E' \sin pt}{n^2 - p^2}$$

where n is the natural frequency-constant of the responder $1\sqrt{(CL)}$ and p is the forcing frequency-constant of the sender; only E′ will be very small because of the distance between them. But obviously when n and p agree something important is bound to occur! The denominator is then zero.

When an otherwise freely oscillating circuit is coupled inductively to a maintained and stimulating circuit it is no longer quite free; the secondary reacts on the primary in a curious way, lessening its inductance and increasing its resistance. It alters its natural frequency somewhat, and damps out the swings more quickly, making tuning more difficult.

The primary resistance becomes

$$R + \frac{p^2M^2S}{p^2N^2 + S^2}$$

while its inductance becomes

$$L - \frac{p^2M^2N}{p^2N^2 + S^2}$$

where L and R belong to the primary circuit, N and S to the secondary, and where M is the mutual inductance between them. There is a corresponding effect on the secondary circuit.

But the main effect is to give a double note, and consequent beats, because the second circuit has its own frequency of vibration $n/2\pi$ as well as the forced vibration of frequency $p/2\pi$, so that the resulting current in it is a double vibration neither wholly the one frequency nor wholly the other, but a compromise,

$$x = a' \cos pt - ac^{-kt} \cos nt$$

in the coupled case. Hence there is a double vibration, so long as the secondary circuit's own vibrations are not damped out by the decrement constant k. And these react on the primary, with a power depending on M^2, complicating its vibrations too. Hence usually loose coupling—that is, small M—is preferred to tight coupling, and for accurate tuning loose coupling is essential. The reinforcement by resonance can more than compensate for the loss of power transmission, and the reinforcement has the advantage of being limited to the one desired wave-length or rate of vibration.

When two circuits are coupled together, with vibrations maintained in one and excited inductively in the other, the two sets of vibrations will be out of phase by an amount θ such that

$$\tan\theta = \frac{2kp}{n^2 - p^2}$$

and the solution for the charge at any instant in the second circuit is

$$Q = \frac{2LE\sin\theta}{pR}\cos(pt - \theta).$$

For the important cases when the R is kept small, which may be managed in an aerial by a lower capacity instead of earth connexion, and is easily managed in an ordinary condenser circuit, θ is a right angle; so the oscillations in primary and secondary differ in phase by a quarter period, like the piston and slide valve of an engine, or like the tides and tide-generating force of the moon. The equation then becomes

$$Q = \frac{2LE}{pR}\sin pt$$

which may have a great amplitude, because R is small.

The extreme case of no resistance is

$$\frac{E\sin pt,}{n^2 - p^2}$$

and so if the resistance of a receiving circuit could be made nil, and if its natural frequency n agreed with the forcing frequency p, which corresponds to precise tuning, the induced and excited oscillations in that circuit could become of infinite amplitude! Which means, in practice, that the amplitude of the swing in an accurately tuned receiving circuit, or aerial of low resistance, can rise to a high value, and at exact tune is surprisingly great. This is the principle of all syntonic or tuned telegraphy.

OSCILLATION CONSTANT. The oscillation constant of a circuit is the square root of the product of the capacity and the inductance of the circuit. The capacity and inductance of a circuit determine the natural period of electrical oscillation just as the natural vibration of a springy strip of steel clamped at one end is governed by its mass and its springiness.

Owing to the presence of stray capacities and other factors entering into the determination of the natural frequency of a circuit, the exact mathematical measurement of the oscillation constant becomes a matter of considerable difficulty.

Having found the oscillation constant of an aerial, it is a simple matter to find the length of a wave radiated from it provided a simple aerial is used. The velocity of electro-magnetic radiation is roughly 3×10^{10} cm. per second, from which it may be seen that the length of wave radiated is about sixty times the oscillation constant where the wave-length is measured in metres. *See* previous entry; Capacity; Frequency.

OSCILLATION FREQUENCY. Expression used to convey the number of complete cycles of oscillating current flowing in a circuit per second. Given the oscillation of an electro-magnetic wave, its wave-length may be found from the equation $\lambda = \frac{c}{f}$, where f is the frequency and c the velocity of the wave. The velocity of an electro-magnetic wave is a fixed constant which is the same as the velocity of light waves, which travel at 300,000,000 metres per second. Assuming the oscillating frequency of a valve-transmitting circuit to be 100,000 cycles per second, the wave-length resulting will be 3,000 metres. This is shown as follows:

$$\lambda = \frac{c}{f} = \frac{300000000}{100000} = 3000.$$

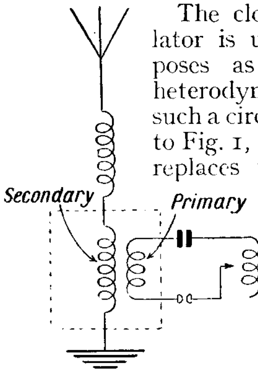
The oscillation frequency of a circuit varies inversely as the square root of the product of the inductance and the capacity of the circuit, the inductance being measured in henrys and the capacity in farads. The frequency is inversely proportional to the wave-length, so that the addition of either capacity or inductance to the oscillatory circuit will result in an increase of wave-length. *See* Capacity; Frequency; Inductance; Wave-length.

OSCILLATION TRANSFORMER. Name given to a special transformer used in spark transmitters. A circuit diagram of this system is given in the figure. Here it will be seen that a primary winding is placed in series with the gap, primary tuning inductance, and fixed condenser.

This primary is inductively coupled to a longer secondary winding connected in series with the aerial tuning inductance, and so to aerial and earth. *See* Jigger.

OSCILLATOR. Oscillators may be of two principal types, closed and open.

Closed oscillators consist of a loop or coil of wire, the two ends of which are brought to the two opposite sides of a condenser. A familiar example is the wave-meter (Fig. 1), excited by a dry cell, the current from which is interrupted by a buzzer. Such an oscillator is a feeble radiator of electro-magnetic waves.



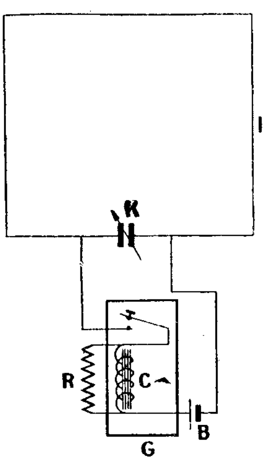
OSCILLATION TRANSFORMER

Spark transmitters use an oscillation transformer as shown in this circuit diagram in the dotted square

The closed type of oscillator is used for such purposes as that of a local heterodyne. In construction such a circuit may be similar to Fig. 1, except that a valve replaces the buzzer, and if the heterodyne is for use on long waves inductance coils must be added (*see* Fig. 2). Longer loops may be used for the closed coils, they then become loop aerials, and are more fully described under that heading.

Oscillators of the open type were first used by Hertz. They consisted of two rods or wire, R_1, R_2, having a spark gap between their adjusted ends, whilst their distant ends were terminated in plates or balls, which increased the capacity of the system (*see* Fig. 3). In general these oscillators were excited by connecting them across the terminals of an induction coil.

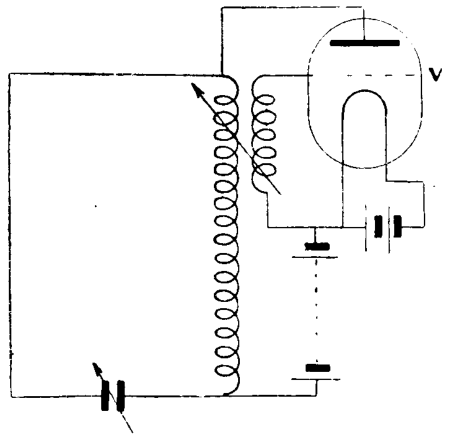
The earthed open oscillator, which was invented by Marconi, and made possible the radiation and detection of electro-magnetic waves, consisted of an elevated wire (which was often terminated at the top by a cylinder or plate) and a buried earth connexion, spark balls being provided between the aerial wire and the earth wire (Fig. 4). As longer waves came into use the length of aerial wire was extended, the top cylinder or plate being replaced by wires covering large areas.



OSCILLATORY CLOSED CIRCUIT

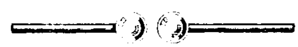
Fig. 1. G is a buzzer, B a battery R a non-inductive shunt, I the inductance and K a variable condenser. This diagram represents a closed circuit oscillator

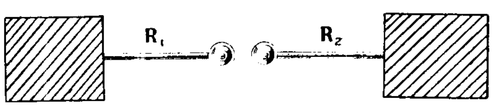
An early type of oscillator is illustrated in Fig. 5. This is in reality a form of multi-spark gap, consisting of three gaps in series, the centre one of which is immersed in a bath containing oil of a high flash-point. Each electrode is mounted upon a heavy ebonite pillar.



OSCILLATOR WITH VALVE GENERATOR

Fig. 2. Employed with a valve generator is a closed oscillator. This arrangement is used for long waves

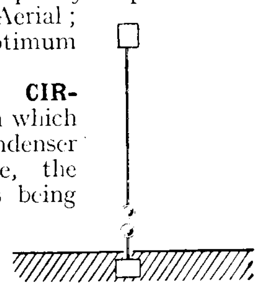




HERTZ OPEN OSCILLATORS

Fig. 3. Oscillators of this type were first used by Hertz. The plates were introduced to increase the capacity

This instrument was used in the early days of wireless with a spark coil for the transmitter and a coherer. It was, of course, purely experimental. *See* Aerial; Fan Aerial; Heterodyne; Optimum Heterodyne.

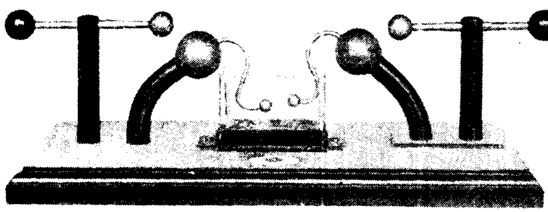


MARCONI OPEN OSCILLATOR

Fig. 4. Modern wireless was largely made possible by the Marconi earthed open oscillator

OSCILLATORY CIRCUIT. A circuit in which is included a condenser and an inductance, the electrical constants being such that an oscillatory current can be set up in the circuit.

Let L in the figure represent an inductance, K a condenser, and S a



EARLY FORM OF OSCILLATOR

Fig. 5. In reality this early form of oscillator is a multi-spark gap consisting of three gaps in series. The centre one is immersed in an oil bath

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spark gap as shown. If a source of high potential is connected across the spark gap and the length of the spark gap is suitably adjusted, the condenser will become charged and a spark will occur across the gap. If the resistance of the circuit is below a certain critical value the discharge current will decrease to zero, and increase in the opposite direction. The reversed current will charge the condenser to a lower potential than the initial potential, and this cycle will be repeated until the condenser becomes finally discharged. The current, in fact, instead of being continuous, becomes alternating with high frequency.

The decrease in amplitude of each alternation is known as the decrement of the circuit, usually signified by δ, and depends on the resistance of the circuit. The decrement of the circuit can be obtained from the formula $\delta = \frac{R}{4nL}$ where R is the high-frequency resistance and L the inductance of the circuit for the frequency n.

The oscillations occur during equal periods of time, and if T = the time period, then n the frequency $= \frac{1}{T}$

If K = the capacity, R the resistance, and L the inductance, then

$$2\pi n = \sqrt{\frac{1}{KL} - \frac{R^2}{4L^2}}$$

$$T = \frac{1}{n} = \frac{2\pi}{\sqrt{\frac{1}{KL} - \frac{R^2}{4L^2}}}$$

If $\frac{R^2}{4L^2}$ is small compared with $\frac{1}{KL}$ then

$$n = \frac{1}{2\pi\sqrt{KL}}$$

and $T = 2\pi\sqrt{KL}$

where L is in henries and K is in farads.

The factor $\sqrt{LK}$ is known as the oscillation constant of the circuit. The circuit is resonant to the frequency n, which is the natural frequency of the circuit.

From the formula

$$n = \frac{1}{2\pi\sqrt{KL}}$$

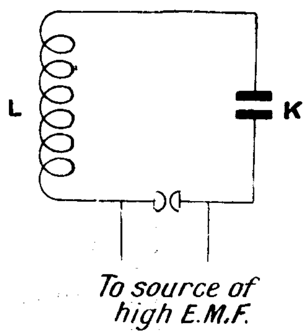
the wave-length of the circuit can be obtained, since

$$\text{Wave-length } \lambda = \frac{\text{velocity}}{\text{frequency}}$$

The velocity of electro-magnetic waves is 3×10^8 metres per second, and if λ is expressed in metres, L in henries, and K in farads,

then $\lambda \text{ metres} = 1885\sqrt{LK}$

An oscillatory circuit can be of the "closed" type, as shown in the figure, where the inductance and capacity are concentrated, or the capacity may be an "open" oscillator. An aerial system is an example of an open oscillatory circuit, and when the system comprises a simple aerial, with no tuning inductance or condenser, both the inductance and the capacity are distributed in the circuit. If the system includes a tuning inductance and a condenser, then there are both distributed and concentrated inductances and capacities. Such a case occurs in the ordinary tuned aerial, where the adjustment of the concentrated inductance and capacity enables the natural frequency of the aerial circuit to be brought into resonance with the frequency of the desired signals. The formulae given for closed oscillatory circuits also hold good for open oscillatory circuits.



OSCILLATORY CIRCUIT

Composed chiefly of an inductance spark gap and condenser, the above is an oscillatory circuit

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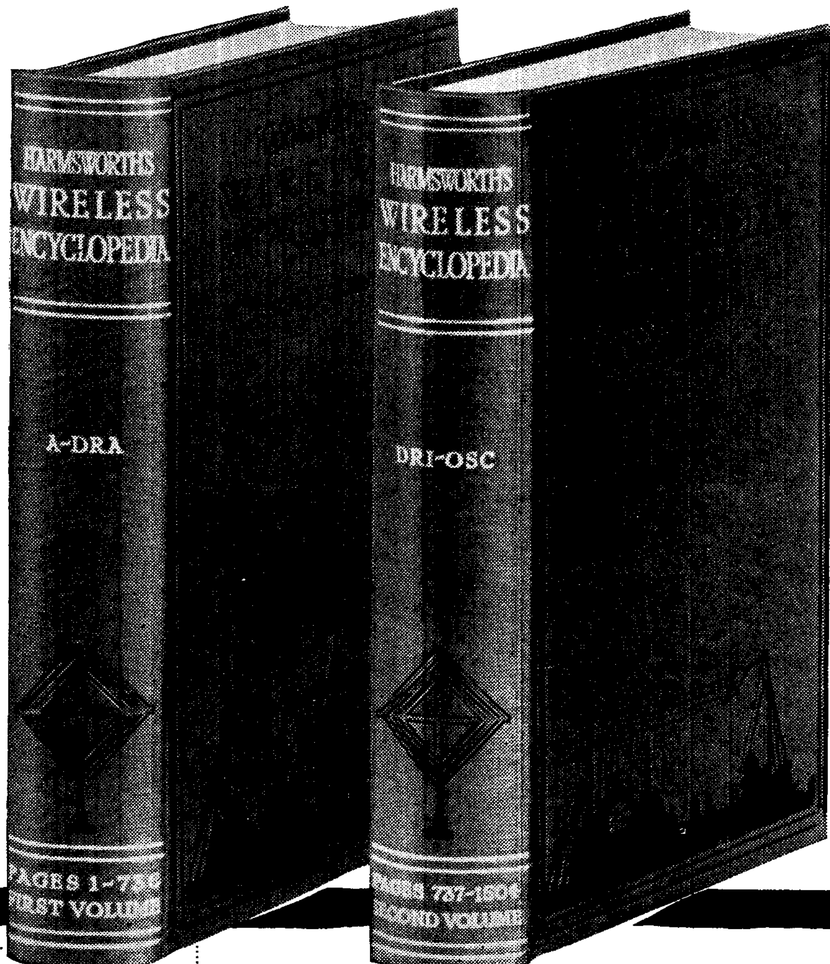

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