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HARMSWORTH'S WIRELESS ENCYCLOPEDIA

For Amateur & Experimenter

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CONSULTATIVE EDITOR
SIR OLIVER LODGE, F.R.S

THIS PART CONTAINS

145 New "Action" Photos & Diagrams

Many 'How-to-Make' Articles

DRILLS AND DRILLING
DRY BATTERIES
DUAL AMPLIFICATION
EARTH SWITCHES
EBONITE & HOW TO WORK IT

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ELECTRICITY & ITS CHARACTERISTICS
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SPECIAL PHOTOGRAVURE PLATE:
DULL EMITTER VALVE SET

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

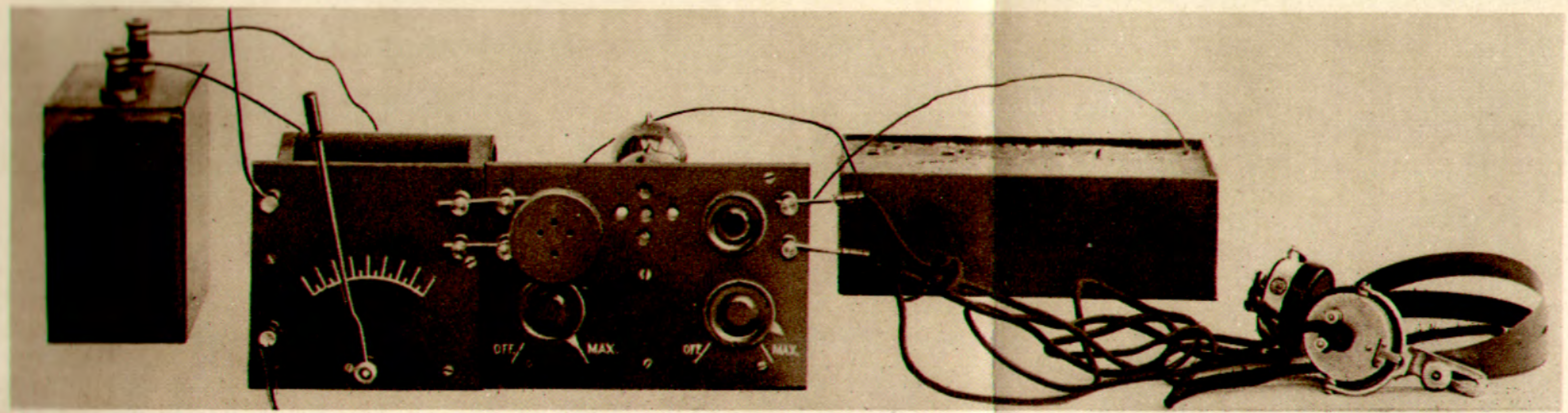


Fig. 2. The completed set with 2-volt accumulator, tuning unit, valve unit, high-tension battery, and headphones. The tuner includes an easily-made inductance, and the valve unit a plug-in H.F. transformer, and a simple variable condenser

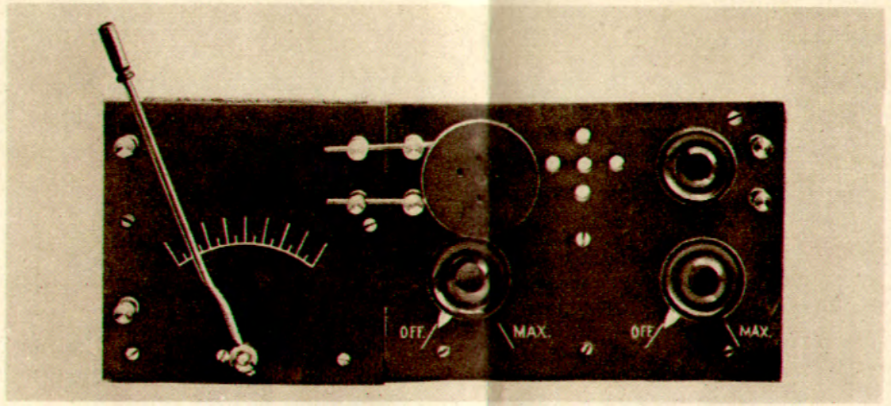


Fig. 3. Panels of the tuning and valve units. Inductance control is designed to reduce hand capacity

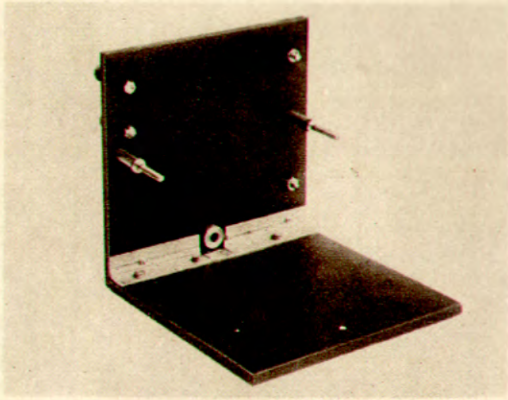


Fig. 4. Strips of angle brass hold the tuner panel and its base

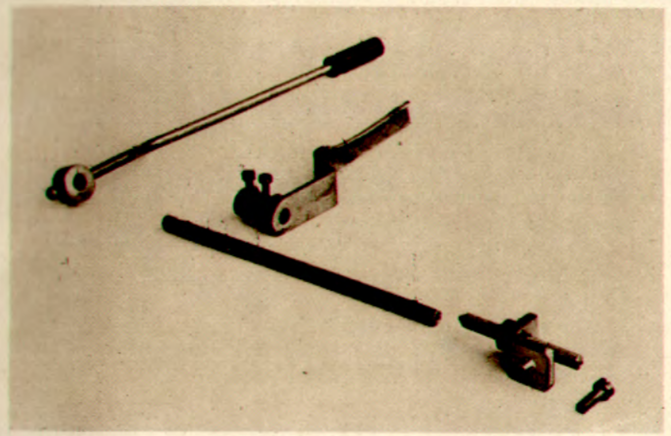


Fig. 5. Parts of the inductance contact arm laid out, including control rod and ebonite handle

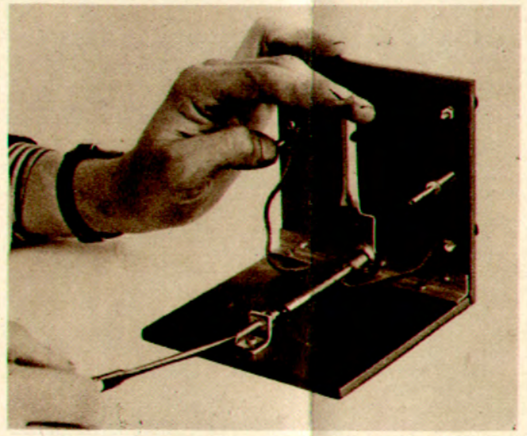


Fig. 6. How contact arm and spindle for tuning inductance are mounted

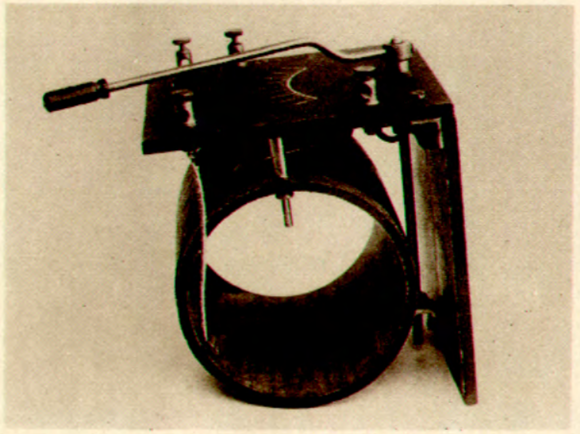


Fig. 7. Side view of completed tuner with contact arm

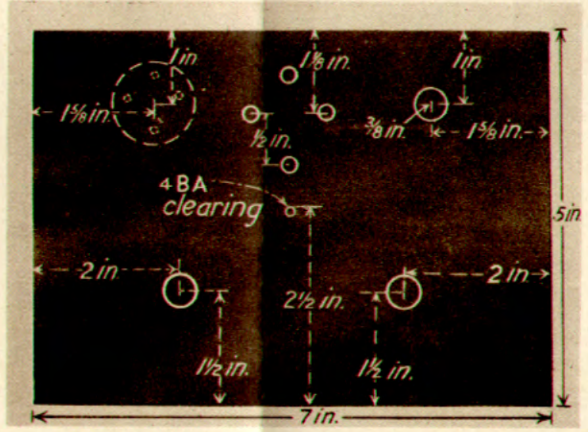


Fig. 8. Dimensions of the valve unit panel marked out for guidance in drilling

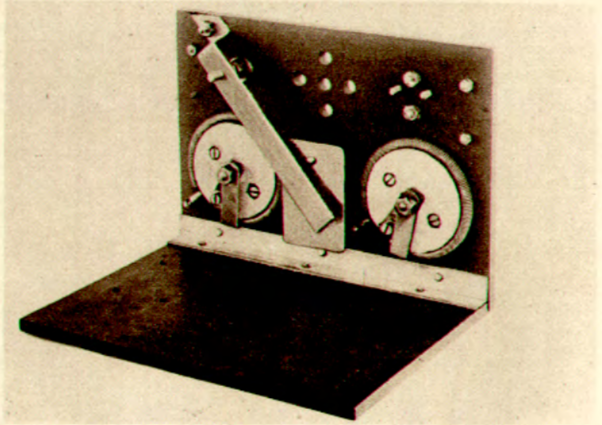


Fig. 9. Back view of valve unit panel with filament resistances mounted

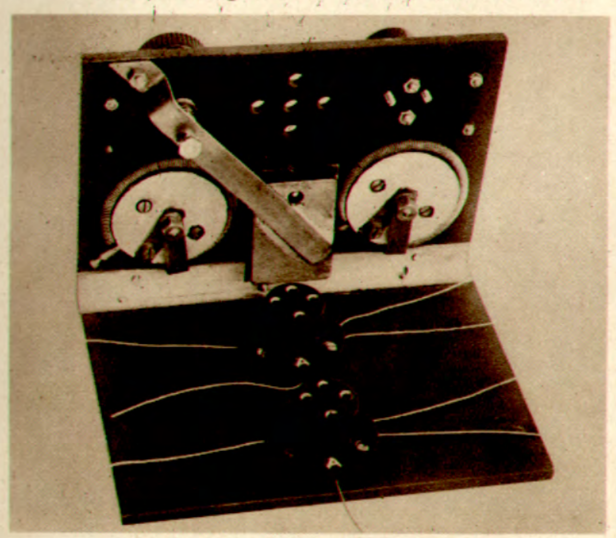


Fig. 10. Valve holders with connecting wires and completed condenser in position.

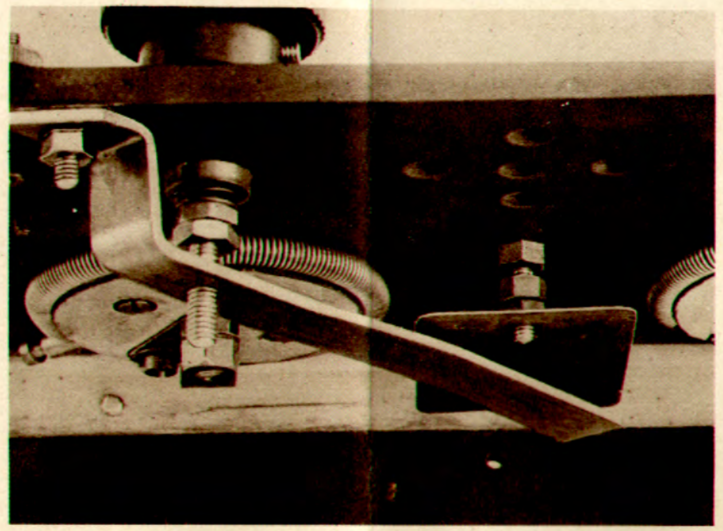


Fig. 11. How the fixed plate of the variable condenser is attached. One nut locks the screw rigid to the panel, the next locks that soldered to the fixed plate

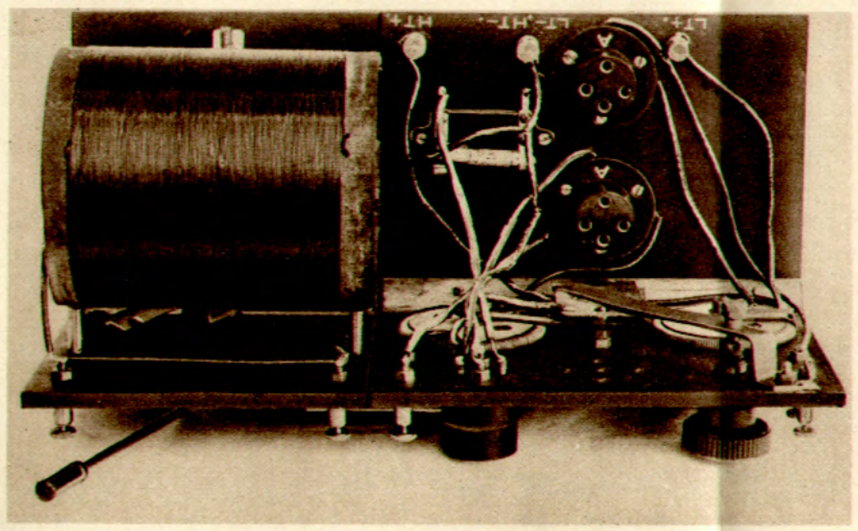


Fig. 12. Top view of the back of the complete set. Battery terminals are distinguished by engraved letters. The grid leak and condenser and general wiring are shown

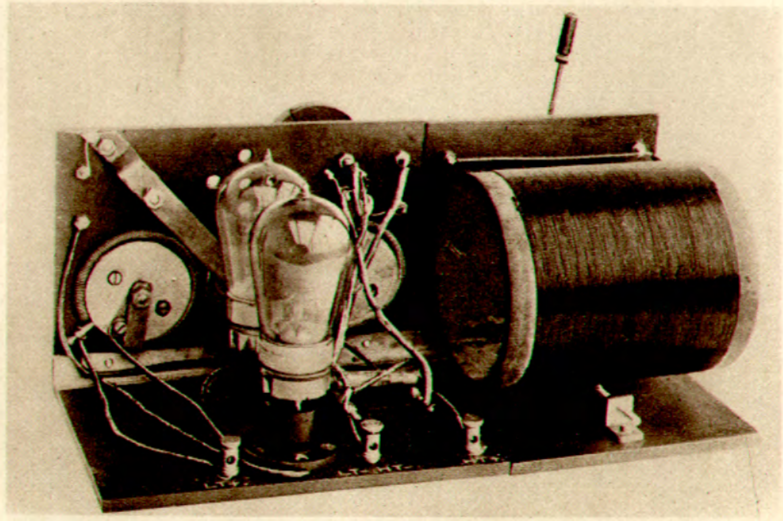


Fig. 13. Second view showing the two valves mounted completing the two units. The plug-in transformer projects over the top of the valve unit panel

DULL EMITTER VALVE SET: HOW TO BUILD A SIMPLE TWO-VALVE UNIT RECEIVING SET USING LOW CONSUMPTION VALVES

To face page 762

From photos specially taken for HARMSWORTH'S WIRELESS ENCYCLOPEDIA

HARMSWORTH'S WIRELESS ENCYCLOPEDIA

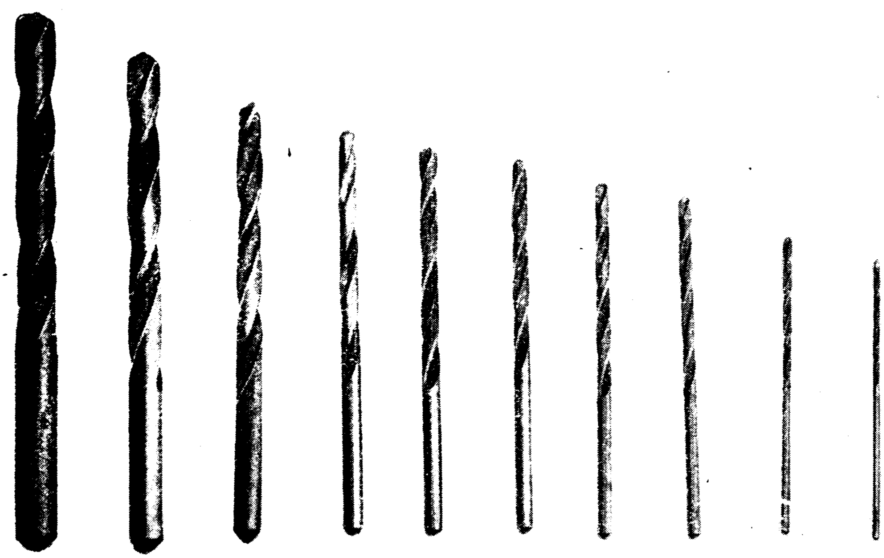
Second Volume

DRILLS AND DRILLING. Drills are small steel implements which when rotated form a hole in a material, by pressure, in which they are introduced. The drills are used with a suitable instrument for their control and rotation. The latter is variously known as a drilling stock, drilling machine, or brace. The wireless amateur should be well acquainted with drills and their use, as they are important in all constructive work.

There are various sizes of drill, from one little more than the thickness of a hair, up to those several inches in diameter. So far as the amateur is concerned, those ranging from about $\frac{1}{16}$ in. in diameter up to 1 in. in diameter should be sufficient for all ordinary purposes.

The size of a drill is gauged by its diameter—that is, the diameter of the cutting part. In other words, the size of the hole which the drill produces. It is customary for the length of the drill to increase with increase in diameter. The diameter of the drill is defined either by a fraction of the unit, as, for example, $\frac{1}{16}$ in., $\frac{5}{8}$ in., etc., by a gauge number, as, for example, 1, 2, 3, etc., or by letter, A, B, C, etc. Other drills are also defined by their size in millimetres, and a few drills are sold in which the size is defined in $\frac{1}{1000}$ in. For wireless work the drills generally used are defined by their fractional size, and by their number size. The former for all ordinary work, and the latter for certain sizes of B.A. screw threads.

For convenience, it is desirable to have drills in three different sizes, all of them having reference to one actual dimension. For example, suppose a hole is to be drilled



TWIST DRILLS AS USED BY WIRELESS WORKERS

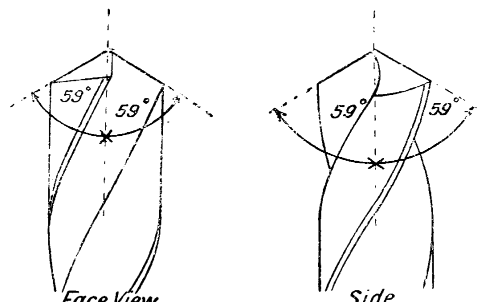
Fig. 1. Although the name of twist drill is given to the tools shown in this photograph the metal is not actually twisted. Two helical flutes are cut in them, and these give the twisted appearance. Twist drills are of great importance in wireless work. The cutting point is at the same angle to the axis of the drill, 59°, throughout the whole series of sizes

through which a spindle of some given size, say, ¼ in., is to pass sufficiently freely for it to just rotate in the hole. The drill for this hole would be spoken of as "¼ in. clearing," meaning that the drill actually made a hole rather over ¼ in. in diameter. The ordinary, or actual ¼ in. diameter drill should make a hole of such a size that a ¼ in. diameter spindle would fit tightly into it. This size of drill is consequently known as a ¼ in. drill, with the addition of any other necessary description as to its nature. Supposing, however, it is necessary to tap the hole, that is, to form a screw thread in it, a drill that is less than ¼ in. in diameter must be used, and this size is then spoken of as a "¼ in. tapping drill."

Most engineering textbooks and handbooks give tables giving the exact size of the drills for these different duties.

There are several different types of drill which the amateur will have to use, all of them conforming to the statement as regards their diameter, but otherwise different in shape, mode of construction, and purpose. By far the most popular and most commonly used drills are those illustrated in Fig. 1, and known as twist drills, the name being given to them from the fact that two helical flutes are machined on them which give the effect of a twist.

The cutting points are formed by grinding the terminations of the two blades to an angle of 59°, and the same angles are maintained through the whole range of sizes with practically all circular-sectioned drills. The standard angles are shown in the diagram, Fig. 2. Some other types of drills are shown in Fig. 3. These include the straight-fluted drills, which should be used for drilling brass and ebonite, the flat or diamond-point drills are used for countersinking, and occasionally for drilling large diameter holes in sheet metal. Two forms of twist drill are shown, one with

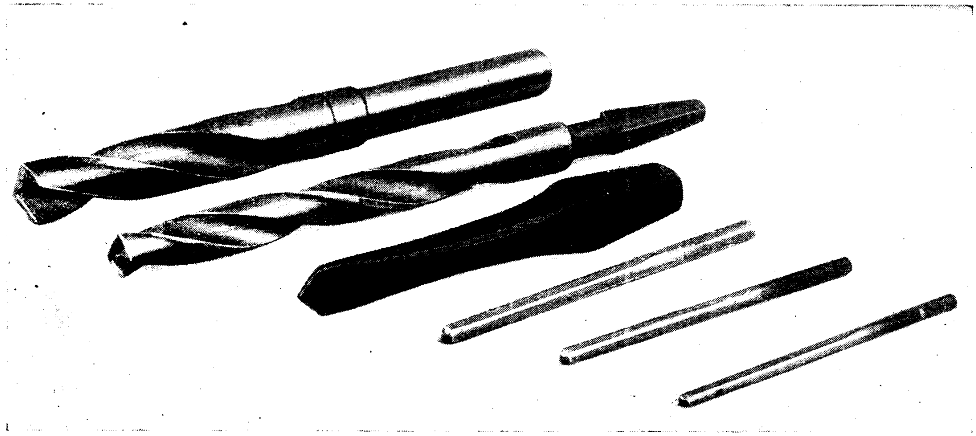


STANDARD ANGLE OF TWIST DRILL

Fig. 2. Cutting points are shown in these two diagrams. On the left is a face view, and on the right the same drill seen from the side. The angle is, of course, the same in both instances

square-shaped end or shank, known as a brace shank, the other with a parallel part, known as a straight-shank drill.

The brace-shank drills are used in the carpenter's brace, or engineer's ratchet brace, and in some forms of small drilling machine. The straight-shank drills are generally used with hand-power drilling machines, as thereby it is possible to fit



EXAMPLES OF DIFFERENT TYPES OF DRILL

Fig. 3. Left to right are a straight-shank twist, brace-shank twist, diamond-point brace-shank drill, and three straight-fluted drills. Straight-shank drills are used with hand-power machines. Diamond-pointed drills are often used for countersinking. Brace-shank drills are used with a carpenter's brace. Brass and ebonite are drilled with straight-fluted drills

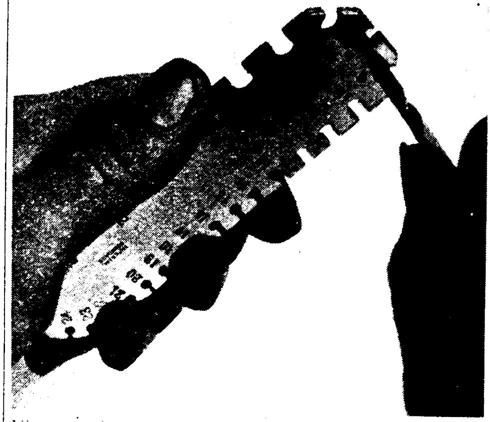


Fig. 4. Gauges are made for wire-testing which serve the same purpose for drills. A gauge is shown in use with a twist drill

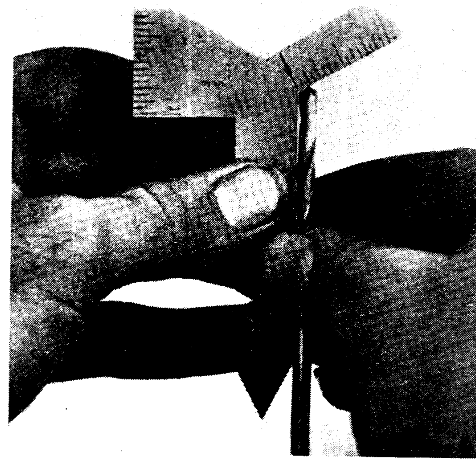


Fig. 6. Special gauges for the cutting angle of the drills are employed. The stem of the drill is laid along the upright portion of the gauge, and the drill edge should fit the angle piece accurately

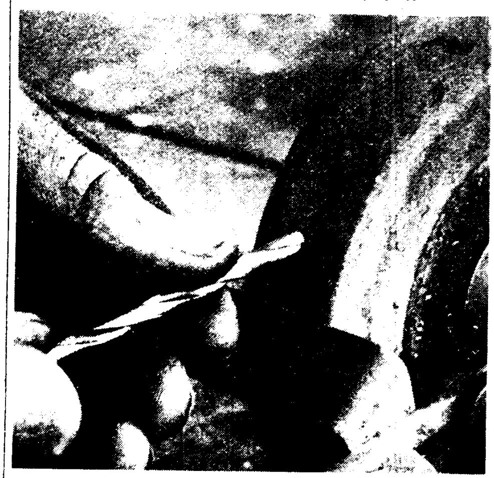


Fig. 5. Drills are sharpened by grinding. Here the operator is seen applying the face of the cutting edge to the stone, the grinding being checked with the gauge shown in Fig. 6

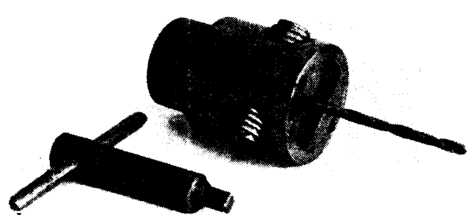


Fig. 7. Good drills are useless unless suitably held. One of the best means of holding a drill is with screw-action self-centring jaws, as shown above

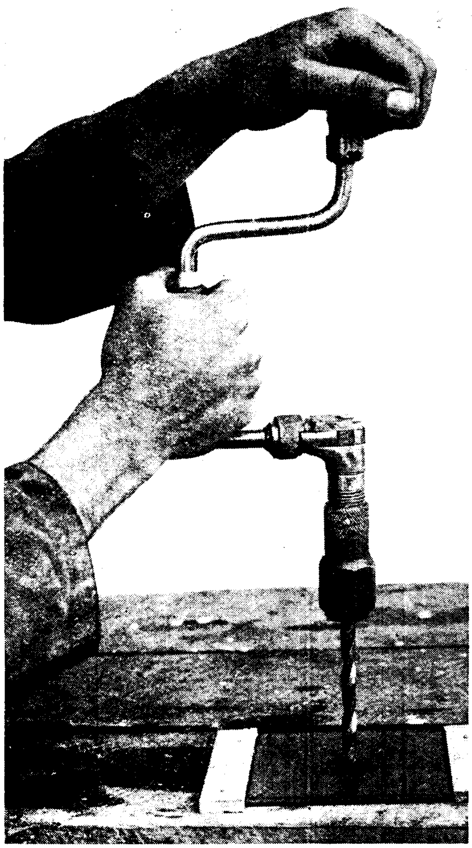
GRINDING, TESTING, AND METHOD OF USING DRILLS

a range of different-sized drills, all of which fit into one uniform-sized hole in the spindle of the drilling machine.

To gauge the size of a drill to ascertain if it is correct for its purpose, the ordinary drill or wire gauge may be used, and the drill tested by inserting it between the jaws or into the hole in the gauge plate, in the manner shown in Fig. 4. This is sometimes necessary, as drills are not always marked clearly with their size.

After the drills have been in use for some time they will require resharpening. This may be accomplished in the manner illustrated in Fig. 5, by grinding the point on an emery wheel or grindstone, gauging the result of the grinding process with an angle or universal gauge, obtainable at small cost and used as illustrated in Fig. 6. The angle of the drill is gauged by placing it against the upright part of the drill and comparing it with the inclined arm at the top.

Drills are held in the drilling instrument either with a set-screw or by means of a tapered hole, but generally by means of the instrument known as a drill chuck, a standard example of which is illustrated in Fig. 7. In this case, a right- and left-handed screw, which is rotated by means



CARPENTER'S BRACE AND TWIST DRILL

Fig. 8. In this photograph the operator is using a twist drill in a carpenter's brace for making a hole in a base plate

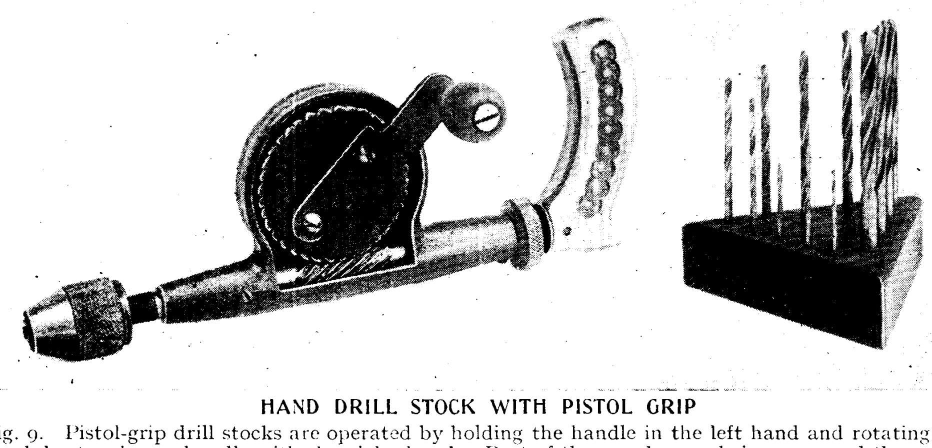
of a key, shown in the illustration, opens or closes two jaws uniformly. The drill is gripped between them and is brought into the centre to make it run true.

Modifications of this type are used in the brace and in most forms of hand drill. In the latter the chuck is rotated by hand and may have a knurled surface, or be made hexagonal in shape to provide a better grip.

A regular drilling operation is shown in Fig. 8, illustrating a ratchet brace holding a brace-shank twist drill, drilling a centre hole in an ebonite panel. It is preferable to use a fluted or flat drill, but when only a twist drill is available, it may be used, but care must be taken to secure the panel by means of two wooden jacks and to fit the drill very cautiously into the work, so that it does not run or tear.

A modern form of hand drill with set of drills is illustrated in Fig. 9 and has a pistol-grip handle. The method of using this drill is to grip the handle firmly with the left hand and rotate the drill by turning the crank with the right. This drives the drill through a worm gear wheel, while the drill is held in a three-jaw self-centring chuck. The work to be drilled is held securely in the vice and the drill started by making a centre pop or similar depression exactly at the centre of the desired hole, doing this with the aid of a centre punch (*q.v.*).

Another commonly used form of drill is shown in use in Fig. 10. In this case



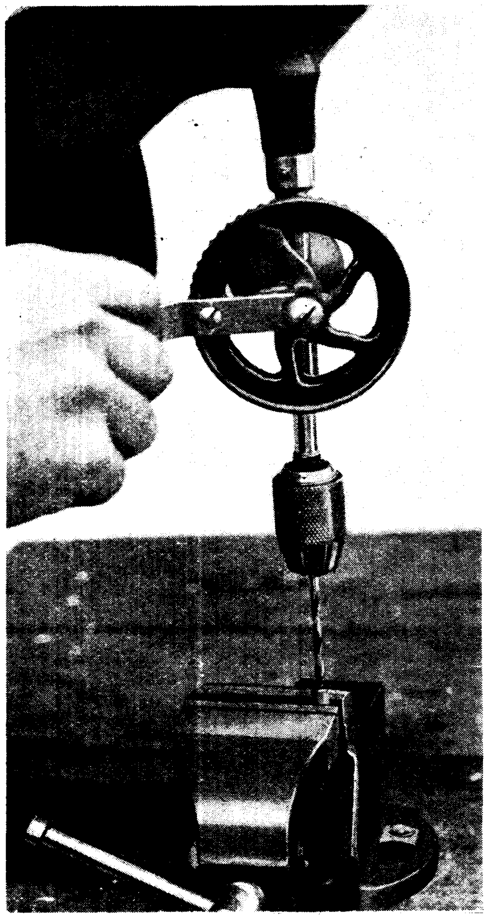
HAND DRILL STOCK WITH PISTOL GRIP

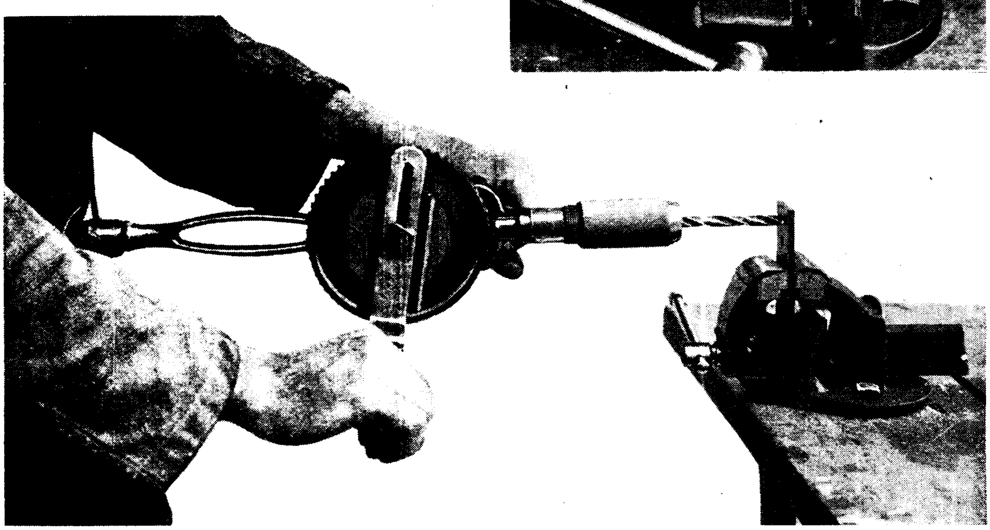
Fig. 9. Pistol-grip drill stocks are operated by holding the handle in the left hand and rotating the crank by turning a handle with the right hand. Part of the crank case being removed the action is apparent. Drills should be kept in a range according to gauge by using a wood block as accommodation. This facilitates rapid selection

a hardwood handle is attached to the end of the drill, while the spindle is rotated by means of bevel gearing. The illustration shows such a small hand drill operated in a vertical position enlarging the bore of a small bearing for a condenser spindle. The work is held in the jaws of a vice in an upright position. The drill must be held perfectly upright and steady with the left hand, while the right hand rotates the bevel gearing by means of the crank handle. Such small hand drills are only suitable for drills up to about ¼ in. or rather less in diameter.

For heavier work the breast drill, of the type illustrated in Fig. 11, is preferable. This is usually provided with a two-speed arrangement whereby small drills can be rotated at a higher speed and larger drills at a lower speed. When drilling in a horizontal position, as illustrated in Fig. 11, it is customary to apply pressure to the drill by leaning the body against the pad on the end of the drill and holding it steady with the left hand while rotating it with the right. With a drill of this type, holes up to ½ in. or so in diameter can be drilled in steel and other metals.

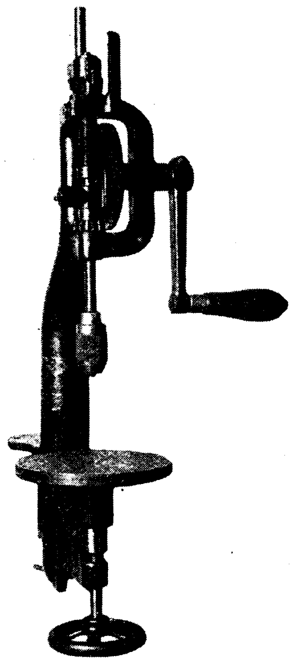
The experimenter will soon find that the work to be done with a hand drill stock is strictly limited, and a small bench drilling machine, such as that shown in





BEVEL-GEARED HAND DRILL AND BREAST DRILL

Fig. 10 (above). This type of drill is very frequently employed by amateurs and serves a large proportion of his requirements. Fig. 11 (beneath). When sufficient pressure cannot be applied by the lighter type of hand drill, a breast drill, as here seen in operation, is used. This forms a substitute for the drilling machine, provided the work permits. There are many instances in which a drill of this kind is to be preferred, and the amateur who does not possess a machine will find it very useful



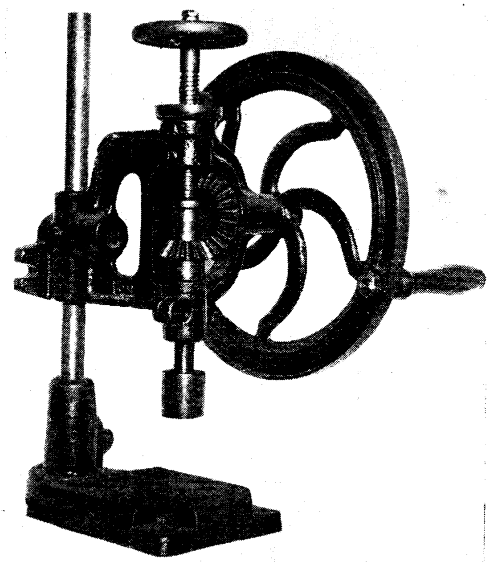
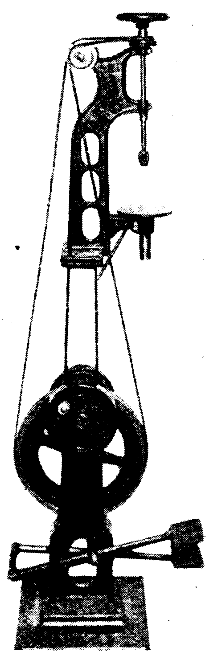


Fig. 12. Work may be carried out with a light pattern hand-power bench drilling machine which would be very difficult with a hand drill. In this pattern the feed is automatic. Fig. 13. Drilling of a heavier nature can be accomplished with this sturdy bench drilling machine



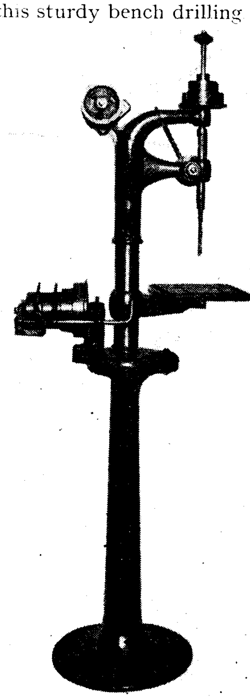


Fig. 14. Treadles are fitted to this type of drilling machine, which is driven by means of a geared flywheel. Fig. 15. Pillar drilling machines are very useful, especially when there is a source of power. This sensitive type has three-speed gear, and occupies very small space

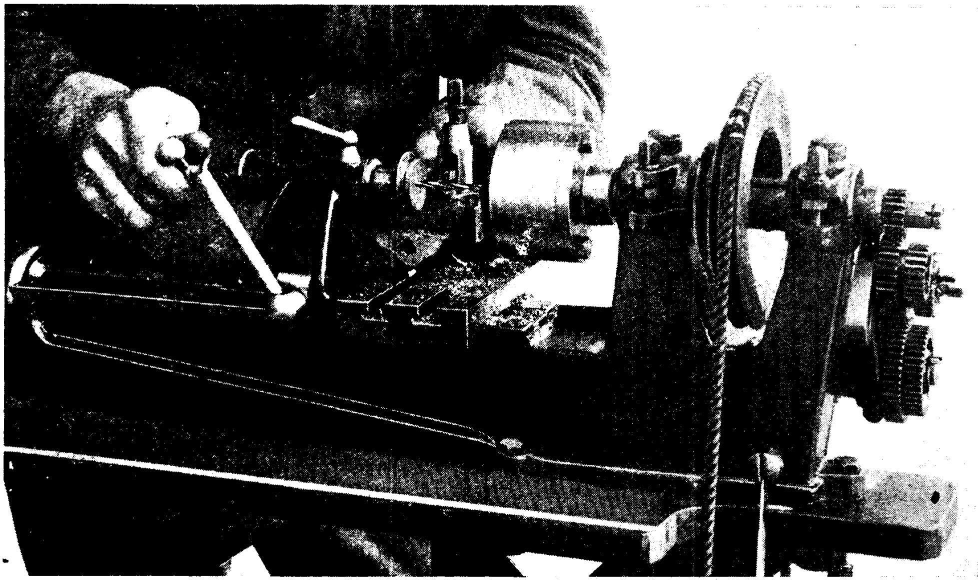
Courtesy Richard Melhuish, Ltd.

LIGHT POWER HAND AND PEDAL DRILLS

Fig. 12, is a most desirable acquisition; the most convenient types are driven by a crank and clamped to the edge of the work-bench. The work to be drilled is held to the table by a vice or a set of clamps and the drill rotated by hand through the agency of the crank handle seen at the right.

Fig. 15. Three speeds are provided, and the drive is through flat belts. A rack and pinion feed controlled by the handle on the right is used to drive the drill down into the work.

When choosing a drilling machine, always study those points that are of the most importance for the work in hand.



SIMPLE OPERATION WITH DRILL AND LATHE

Fig. 16. Amateurs possessing a lathe can do many drilling jobs beyond the power of a hand drill. On the lathe very careful work can be carried out, as fine and accurate adjustment is readily made, and during the whole process the material worked upon and the tool in operation are under complete control. This photograph shows one of the simplest methods of lathe drilling

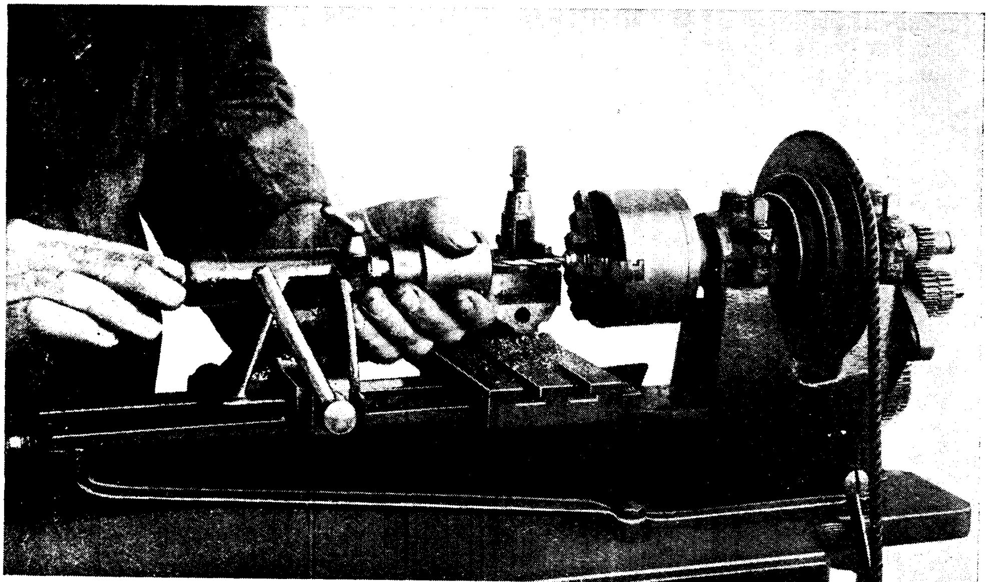
A more robust type is illustrated in Fig. 13, and shows an adjustable model that can be used as a bench drill or as a wall drill. The base is provided with slotted holes for a vice or a set of clamps. The head is adjustable for height on the post, and when removed and replaced at right angles the base can be bolted to the wall and the machine used to drill holes in the top of a column or other part that would otherwise be too long to go under the drill.

One of the most useful drilling machines for use on wireless work is a small treadle machine of a type as illustrated in Fig. 14, which is driven by foot power through the treadle and geared flywheel drive. A round belt conveys the motion from the flywheel to the drill, and is guided and tensioned by the jockey pulleys.

When a power drive is available it is desirable to employ a pillar type of drill, and a sensitive pattern is illustrated in

For small holes a sensitive and light drill will suffice. Holes above $\frac{1}{2}$ in. diameter are better dealt with by a machine of the type shown in Fig. 13, as it has good driving power. For the most accurate work a small sensitive drill is essential. The sensitive types have a special form of spindle and an outer part known as a quill. The latter is fed down by the feed lever or handle and the spindle only has to revolve in this casing or quill, consequently it is a more reliable and accurate pattern. This type of spindle is found on several hand drills and is illustrated in Fig. 15, which shows a power-driven type.

Excellent drilling can be carried out on a lathe. In this case the drill can either be held in a drill chuck, or the commonly used three-jaw, self-centring lathe chuck, and Fig. 16 shows a typical operation. In this case the drill is held in the chuck and the work to be drilled rested against the end of the tail stock,



DRILLING A SMALL COMPONENT ON A LATHE

Fig. 17. Metal components such as nuts, bushes, and other parts of wireless apparatus which cannot be held conveniently in a vice or cannot be drilled with a lighter drilling device may be held in the chuck and drilled on a lathe. Such an operation is shown in progress above. The drill is supported in the drill chuck from the tail stock

after interposing a piece of wood or brass between it and the back of the work and holding the work by hand or with the aid of gas tongs. The lathe is then set in motion and the work effected by means of the drill in the tail stock.

When small objects such as terminal nuts, bushes, and other small circular parts are to be drilled, it is preferable to put them in the lathe chuck, as in Fig. 17, and support the drill in a drill chuck mounted on the end of the tail stock spindle. The centre pop for the drill is formed by turning a small conical hole or recess in the centre of work and feeding the drill up to it. In this case the drill remains stationary and the work revolves.

When drilling ebonite tubes—as, for example, the operation shown in Fig. 18, where a former for a variometer is being drilled for one of the spindles—it will suffice to chuck the drill in the lathe and, after having marked out the former, lightly centre punch for the drill holes. One of these centre pops is then placed against the point of the drill and the opposite one against the point centre of the tail stock. The work is prevented from rotating by holding it with both hands, and by gently screwing, sufficient pressure is brought to bear on the drill to force it through when the drill is revolving.

In all operations on metal such as iron and steel it is necessary to use a saponaceous lubricant, such as soft soap and water, one of the proprietary lubricating compounds, or more generally for amateur work a light machine oil. This should be fed on to the drill from time to time to keep it moist, so that it thereby facilitates the disposal of the chips formed by the cutting action of the drill. It is not as a rule necessary to use a lubricant when drilling brass or cast iron, nor is it generally necessary with ebonite.

Drills should be stored by mounting them in holes in a block of wood or metal so that the right size drill can be picked out without delay. This method is also convenient for preserving the drills and avoiding damage to them, as would occur if they were simply left lying loose in a drawer or box.

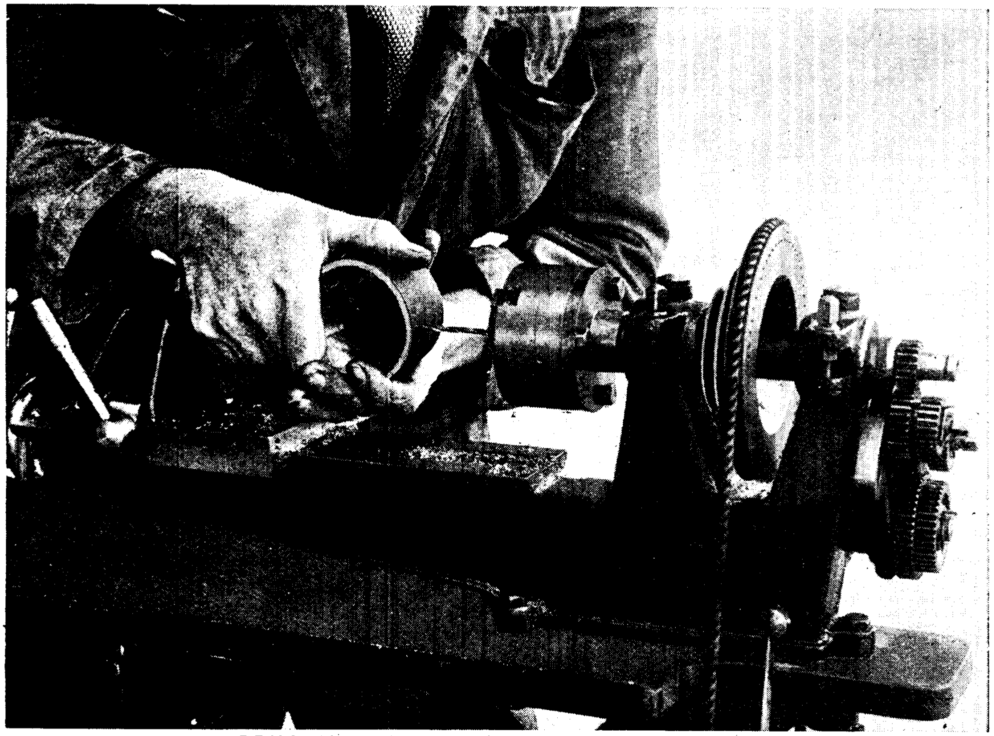
The drills should be rotated at their proper speed. Generally speaking, the smaller the drill the higher the speed, and when power drive is available approximate speeds for $\frac{1}{8}$, $\frac{1}{4}$, and $\frac{1}{2}$ in. drills, drilling in steel, are 900, 460, and 230 revolutions per minute respectively.

Brass may be drilled at rather higher speed, cast iron about two-thirds this speed. When hand drills are used, the drill should be run as fast as is practicable while keeping the drill steady. It is preferable to run it a little slower and keep it steady, rather than to run at top speed and vibrate badly. To drill a straight hole it is imperative that the hand drill should be quite steady and absolutely in line with the intended path of the hole. The importance of this cannot be insisted upon too greatly. If the drill is not held steady the hole is made larger than it should be, with the result that a terminal, or other part to be fitted in it, is loose, and this is always detrimental.

It is possible to drill square and other shaped holes by the use of suitably proportioned tools. These are, however, seldom called for in amateur work, except possibly the square holes which are formed by using the triangular-shaped drills very much like a three-square file in operation. In all drilling operations the pressure exerted should be regulated by observation of the chips. When these come away freely, the drill can be pressed a little more, but otherwise the pressure should be relieved, the drill ground, or the speed increased according to the nature of the material being drilled.

Amongst other materials that the experimenter in wireless will be called on to drill is paper, which can be drilled with a hollow drill like a tube with a sharp cutting edge at the end. This is rotated by any convenient means, and the paper is cut through very quickly. The bore of the drill will have to be cleared of the wads from time to time.

Holes can be drilled in glass with a diamond drill. This is a taper-ended drill, circular in form. The actual cutting is accomplished by the aid of diamond dust for making small holes. Larger holes, such as those for a condenser plate, can be cut by placing a brass tube vertically over the hole and revolving it while the glass is served with powdered carborundum. Drill about half-way through the glass and reverse it and complete the work from the opposite side. Support the work on a pad of felt or other similar material.



DRILLING A VARIOMETER ROTOR ON A LATHE

Fig. 18. In drilling a former, the operator must use both hands to hold the work steady, for the work cannot be held in a chuck, and a vice might cause damage. The operator is holding the work with his hands resting firmly on the lathe while the drill is engaged. The drill is held in the lathe chuck

Marble, as used for an insulating base for a piece of apparatus, can be drilled with an ordinary hard steel twist drill with a slot formed in the centre cut across between the flutes.

Hardwood can be drilled as if it were brass by using a twist drill, but it has to be reversed in rotational direction and also withdrawn from the hole from time to time or the wood chips will clog it and the drill will overheat and be spoiled.

Holes are drilled in brickwork by means of a jumper, a cross-shaped steel punch with cutting edges at the end driven by means of a hammer and rotated a quarter of a turn between each blow. —*E. W. Hobbs.*

See Aluminium; Brace and Bit; Lathe.

DRY BATTERIES: THEIR VARIETIES AND USES

Units of Great Importance and General Service in Wireless Work

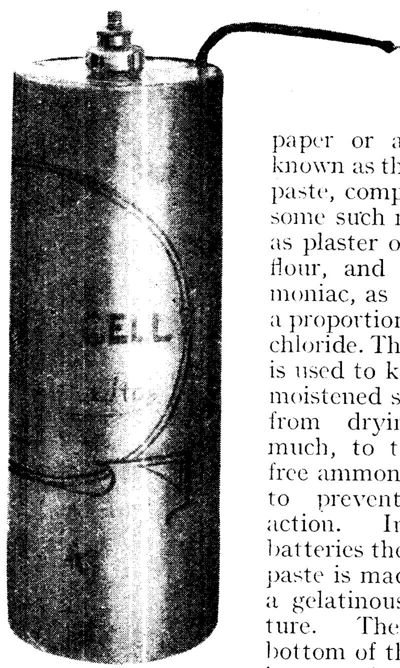
With the extended use of dull emitter valves using currents of small amperage dry batteries have become increasingly useful in amateur wireless work, largely displacing the expensive and troublesome accumulator. See Accumulator; Battery; Cell; High-tension Battery; Leclanché Cell, etc.

A dry battery consists of a number of primary cells made up into a battery; that is a set of units, each of low or minimum voltage, the distinguishing characteristic of which is the use of a paste or semi-solid electrolyte.

Virtually all dry cells are of the Leclanché type. The elements are composed of zinc and carbon and the paste is a mixture of crushed manganese dioxide and crushed carbon. The mixture is kept moist by a lining of plaster of paris, blotting-paper, or the like, saturated with a solution of sal-ammoniac.

The great advantage of dry cells from a practical point of view is that there are no noticeable fumes, and there is nothing to spill should the cell be overturned. Such batteries are increasing in use for all manner of purposes as, for example, for pocket flash-lamps and electric torches, their best-known use. In wireless work they are found as the agent for supply of energy for heating the filaments of dull emitter valves and the Weconomy valves, or peanut valves. Another point in their favour is that they can readily be made up into convenient sizes and combinations, giving a range of voltages as required, as, for example, the high-tension batteries with separate tapping points employed for the anode circuits of most receiving sets.

As a battery is nothing more than a set of cells made up in a convenient form, it is as well to consider the construction of a single cell or element of a battery. The exterior appearance of a simple cell is shown in Fig. 1, and is typical of many excellent patterns and makes now on the market and obtainable in a wide variety of sizes and shapes. The simple cylindrical cell is composed of an outer case made of zinc, covered on the outside with cardboard or other stout paper. The bottom is closed with a disk of zinc, and the whole soldered to make it acid-proof. This container is used as the zinc plate or element, and has the negative terminal attached to it. This zinc is seen in Fig. 3 detached from the cardboard case, which is visible on the left. The inner face of the zinc tube is lined with an absorbent material, either good quality thick blotting-paper or a paste known as the white paste, composed of some such mixture as plaster of paris, flour, and sal-ammoniac, as well as a proportion of zinc chloride. The latter is used to keep the moistened solution from drying too much, to take up free ammonia, and to prevent local action. In some batteries the white paste is made with a gelatinous mixture. The inner bottom of the zinc is covered with an insulating material and the walls coated with the white paste made sufficiently moist with water.



DRY CELL

Fig. 1. Cells of this kind can be connected in series to give any voltage in steps of $1\frac{1}{2}$ volts. This example was made by the Economic Electric Co

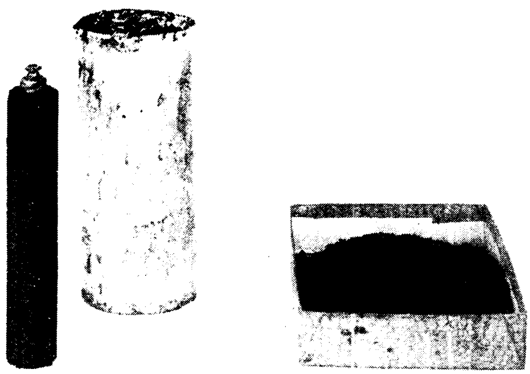


Fig. 2. Components of a circular type of dry cell; the mixture of which the paste is composed is in the cardboard box

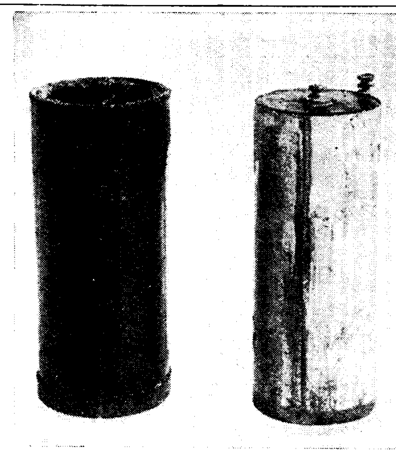


Fig. 3. Cardboard case of a circular type of dry cell and the zinc plate with carbon in place, the top being filled with wax

Fig. 4. Internal construction of a dry cell, with the depolarizing paste surrounding the carbon rod retained in place by a canvas sack

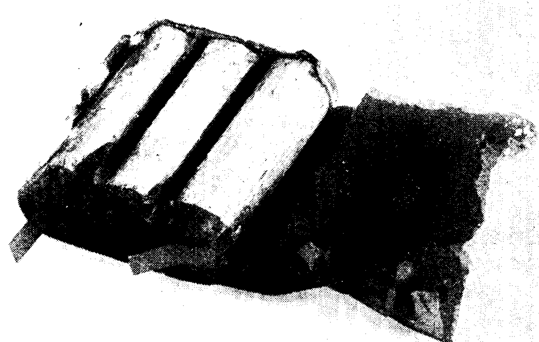


Fig. 5. Three cells of an ordinary pocket-lamp-type battery are here seen in the position they occupy within their covering, which has been broken away to show the internal construction

DRY BATTERIES CUT UP TO SHOW THEIR COMPOSITION

Alternatively the zinc is lined with the blotting-paper. This reduces the internal resistance, but is more liable to allow the depolarizing paste to touch the zinc.

The positive terminal is attached to the centre of a carbon rod, which may be moulded or cut, and this stands in the centre of the zinc case and rests upon and is surrounded by the depolarizing paste, composed of a mixture of manganese peroxide, carbon or graphite, sal-ammoniac and zinc chloride, with sufficient water to make a paste. The proportion of the mixtures in dry cells are of the order of ten parts of the first two mentioned ingredients and two of the sal-ammoniac and one of the zinc chloride. This mixture is then packed around the carbon, and the zinc case filled to within about $\frac{3}{4}$ in. or so of the top, according to the size of the case. The mixture is covered with sawdust, blotting-paper, or some similar material, and the whole enclosed with pitch and the top finished off with a hard wax. A very small vent-hole is sometimes left through the pitch and wax filling to permit of the escape of any free gases. In Fig. 2 these components are illustrated separately.

In some constructions the carbon and the depolarizing mixture are made up into a sack form, and surrounded with the sacking material or coarse linen, as shown in Fig. 4. This method is extensively used with very small batteries of the flash-lamp type.

This type is made up into a convenient number of units, and by connecting the carbon of the first cell to the zinc of the next, and so on, any desired voltage in reason can be provided for, and the whole enclosed in one cardboard case. The internal appearance of three such cells made up into a small battery, as used in the construction of many high-tension batteries, is shown in Fig. 5, where the outer cardboard case has been cut away to reveal the connexions and other details.

When a number of such cells are put up in a cardboard case, the connexions are generally tapped or provided with a socket for the reception of a wander plug or other form of detachable connexion, which can be put into any desired socket and the output voltage controlled. Such a battery is illustrated in Fig. 6, and has a total capacity of 15 volts, with tappings at every three volts.

Fig. 6

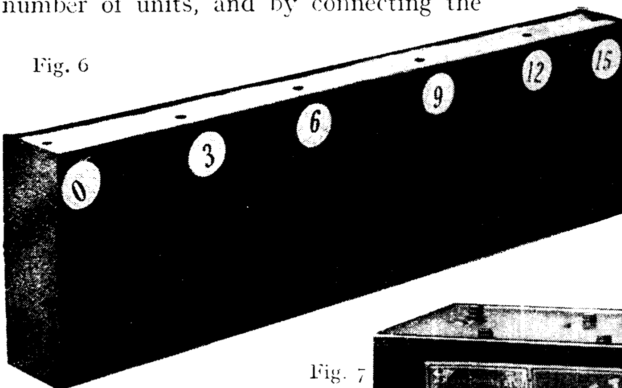


Fig. 7

HIGH-TENSION DRY BATTERIES

Fig. 6. Five tappings are possible in this high-tension battery. Fig. 7. Voltages up to 200 or more are obtainable in Hellesen batteries, tappings advancing by 6 volts for each tap

Several such batteries may be used to give sufficient voltage by connecting the negative of one to the positive of the other, and so on. A more convenient plan is to obtain one of the well-known brands of dry battery, made up into convenient form and size, such as the Hellesen, shown in Fig. 7, obtainable in various appropriate voltages, for the supply of current to ordinary anode circuits, as well as for the anode circuits of amplifiers for loud speakers, where the anode voltage may be as high as 200 or more.

Larger dry cells, with a lower voltage, as applicable to the filament circuits of a valve set, are obtainable, and a well-known pattern is illustrated in Fig. 8, showing one of the large range made by the Ever-Ready Co. Larger batteries are also procurable specially designed for supplying current for filament-heating purposes with dull emitter valves, as this type of valve works on a voltage of 3 or less, such as the Weconomy valves, which only need 1 volt or thereabouts.

When a large output at a low voltage is needed from a dry cell, it is preferable to

EVER-READY DRY BATTERY

Fig. 8. Low-voltage dry batteries are made specially for wireless requirements. This well-known make is frequently met with on account of its convenient size and voltage

employ one with large and substantial components in preference to using a number of small cells connected in parallel, as when arranged in this way there is a risk of the cells discharging locally to the voltage of the weakest cell in the battery. The electro-motive force of a dry cell is usually taken as $1\frac{1}{2}$ volts, and, therefore, if two cells are connected in series the resulting volts will be 3, and so on; with all of them connected in that way the voltage is always one and a half times the number of cells in a battery when connected in series. Thus, a 44-cell battery will yield a voltage of substantially 66 volts. The amperage will be that of the weakest cell in the battery, and is largely dependent on the size and purity of the components. An old cell which has lost its strength may be greatly improved by punching a hole in the top and pouring in some water which has been saturated with ammonium chloride, that is, sal-ammoniac.—*E. W. Hobbs.*

D.S.C. This is the standard abbreviation for the insulated wire known as double silk covered wire. It is similar in construction to double cotton covered wire, or D.C.C. wire. *See* Double Cotton Covered Wire; Wire.

DUAL AMPLIFICATION, THEORY & CONSTRUCTION

Principles and Practice of Circuits in which One Valve Does the Work of Two

Here is explained clearly the method of using valves for double working and full details are given for the construction of a one-valve set using crystal rectification and high- and low-frequency amplification on one valve. See also Amplifier; Crystal Receiver; High Frequency; Low Frequency; Valve

The term dual amplification is applied to a variety of circuits so arranged that a valve can be made to do the work of two valves, as, for example, employing one valve to amplify the audio- and the radio-frequencies simultaneously. There are certain advantages in doing this, and some disadvantages. The chief feature of interest is that of economy, both in first cost and in the running expense in the replacement of valves and batteries and the re-charging of accumulators.

The range of such a set is considerably greater than an ordinary single-valve set. Alternatively, the volume of sound from the nearest broadcasting station can be considerably increased as compared with the simple receiving sets.

A disadvantage is that, as a rule, these circuits require more critical adjustment and tuning, and a more accurate estimation or calculation of the values of the different components.

When, however, these requirements are met, the dual amplification principle can usefully be employed.

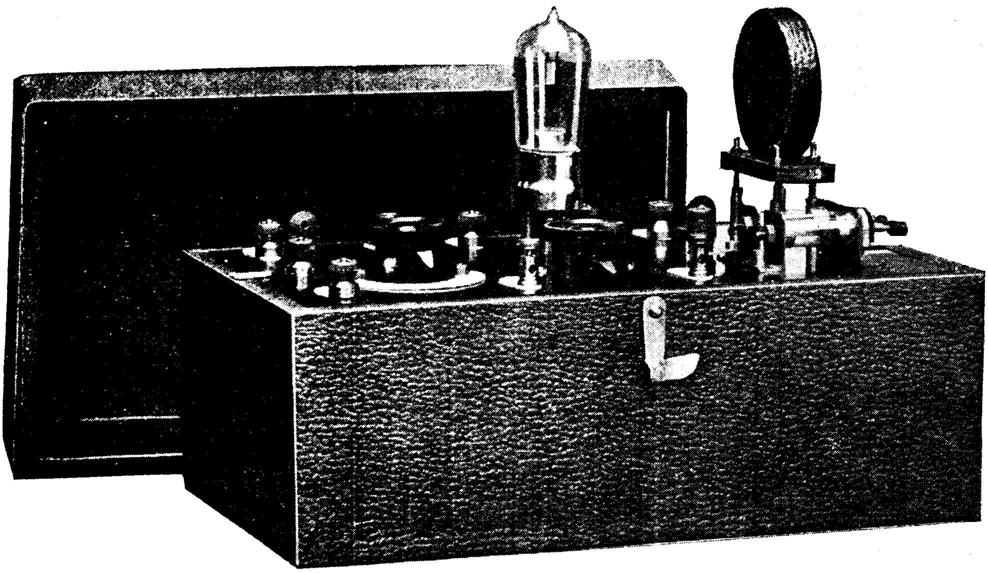
The principle is simple, and consists essentially in applying to the grid of the valve both the high frequency or radio-frequencies and the low-frequency or audio-frequency currents.

There are several ways of doing this, and numerous combinations in detail, but the great point is that the grid of the valve receives the combined effects of the two circuits, and in non-technical language the circuits can be considered as in effect two separate circuits superimposed on each other. The system can be used in conjunction with a crystal or a valve detector.

The set shown in Fig. 1 is a single-valve dual amplification receiver. The valve is used first as a high-frequency amplifier—*i.e.* receiving the signals at radio (not audible) frequency. The signals are then rectified with an ordinary crystal detector and amplified at audible frequency by the valve, one valve thus serving the dual purpose. It will be seen, therefore, that as regards volume and range, the one valve and crystal are at least equal to two valves used in the ordinary way.

Except that a valve used for rectifying in some people's hands in place of a crystal is less trouble, there is little to choose as regards results between crystal and valve for this purpose. A well-made crystal detector should, with ordinary care, be quite easy to keep in adjustment.

If the instructions are followed, there should be little difficulty in making up such a set, and it will give excellent results. Twelve to fifteen miles from a broadcasting station the sound in the headphones is uncomfortably loud, whilst Eiffel Tower concerts may be heard in London comfortably with two pairs of telephones upon the set, on a single-wire aerial, only 18 ft. high one end and about 25 ft. high at the lead-in.



DUAL AMPLIFICATION SET COMPLETE

Fig. 1. In this set only one valve is used and a crystal rectifier. The valve does double duty, detecting radio-frequency currents and amplifying audio-frequency currents. Instructions are given for making the set, and the neat finished appearance can be obtained by covering the cabinet with imitation leather paper or leatherette. It will be noticed that the circular transformer is covered with material to match the cabinet. With careful workmanship and neat and accurate connecting-up this set gives very satisfactory results

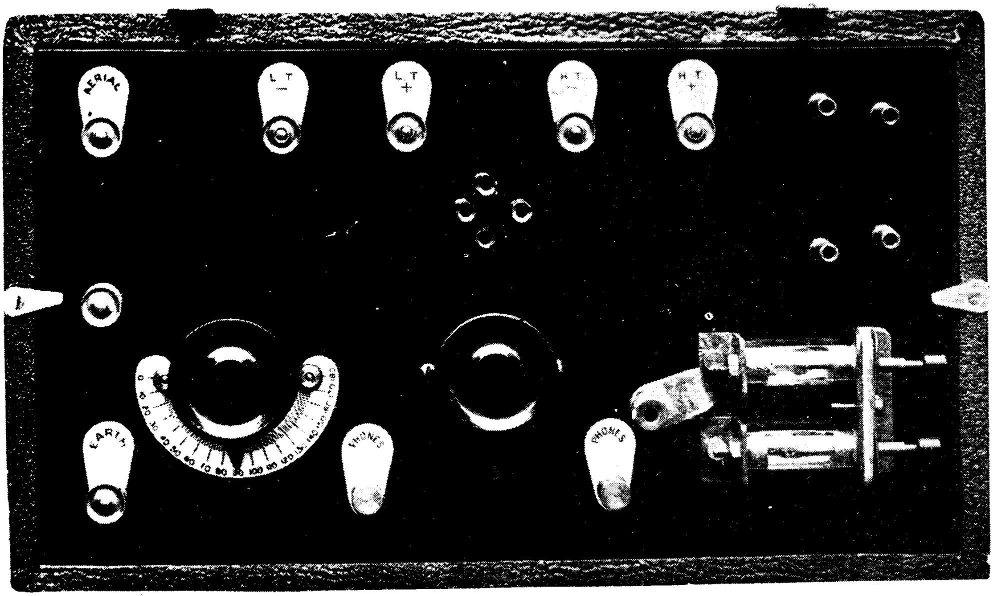
The first step in construction is to procure a panel, 11 in. by $6\frac{1}{4}$ in. This may be ebonite, though three-ply, faced with walnut veneer and polished, will do.

If wood is used, all terminals and fittings should be put in place with a liberal quantity of thick shellac varnish. Referring to the photograph of the panel front, Fig. 2, it will be seen that the valve and filament resistance control occupy the centre of the panel, the knob on the left being the variometer tuner, the double crystal occupying the bottom right-hand corner, whilst four valve sockets are spaced immediately above to accommodate the high-frequency transformer. All the terminals are clearly marked except one, which is for higher wave-length loading coils (as those employed in ship signals or the Eiffel Tower time signals), this terminal being connected to aerial terminal for wave-lengths up to 500 metres, and joined to one end of the loading coil for higher wave-lengths as in Fig. 9.

Fig. 3 gives the lay-out of the panel and dimensions for drilling, and the terminals and transformer plugs should be fitted in place first. In order to get a good fit for the latter, a piece of tin should be cut $1\frac{1}{8}$ in. by $2\frac{1}{2}$ in., and the position spaced out, four small holes being drilled in it. This template can be used later again in order to set out the correct position of the plugs.

We will now consider the variometer tuner. This varies somewhat from the conventional design, and is easier to make. For the stator, a cardboard tube, $2\frac{3}{4}$ in. in diameter by $2\frac{1}{4}$ in. long, is obtained, and well shellacked. Each side of the centre (leaving about $\frac{1}{2}$ in. space) is wound with 13 ft. of 26 or 28 gauge enamelled copper wire. Inside are two basket coils wound on shellacked cardboard formers, each $2\frac{1}{4}$ in. in diameter, with nine slots extending to within $\frac{3}{4}$ in. of the centre. A sketch of the former, Fig. 4, and the method of fastening the basket coils on either side of a little square rod of wood, is shown in Fig. 5, which also indicates the position of the outer tube.

It will be noted that a $1\frac{1}{2}$ in. length of 2 B.A. rod is soldered to a little brass cap, which, in turn, is riveted to the square wooden rod, this accommodating the ebonite knob and pointer upon the panel side. A simple wood screw serves to hold the spindle on the other side of the outer tube. Care should be taken to get a nicely



FRONT PANEL OF DUAL AMPLIFICATION SET

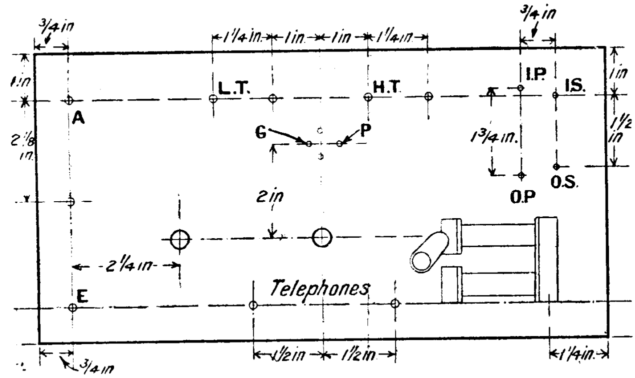
Fig. 2. Attached to each terminal, except one, is a white tab lettered to indicate the purpose of the terminal. This avoids mistakes in connecting up high-tension and low-tension battery leads. The additional terminal permits the inclusion of a loading coil for longer wave-lengths. Sockets for the plug-in transformer are staggered so that primary and secondary windings find their correct connexions; the transformer can only be plugged in the right way

moving arrangement before actually winding the inner baskets, which should then be dismounted and filled with the same gauge wire as before.

To connect up the windings, the commencing end of the outer winding goes to aerial, the end of the first half to the commencement of the second, and the end of the outer winding, with flexible lead, goes to the inside of one basket, the outside of same basket to inside second basket, and the outside of this by flexible lead to earth. Care should be taken to ascertain that the basket windings run the same way when assembling. The variometer is held to the panel, Fig. 6, by two bolts, which also hold the scale outside, and the spindle should be fitted with a spring washer, locking nut, and pointer before fitting the knob.

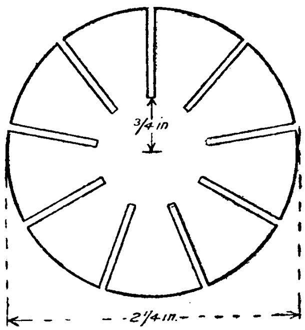
The filament resistance should now be fitted in place, and these, with valve holders, can now be had so cheaply that it is hardly worth while making the resistance and fitting valve sockets.

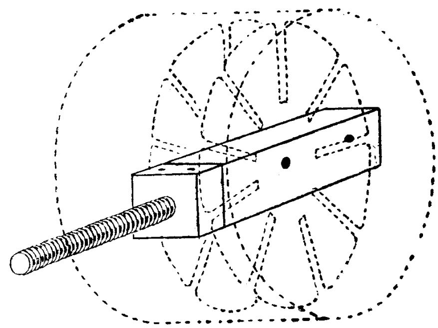
We can now proceed to construct the two fixed condensers, one being required for the telephones and one between the secondary of the transformer, filament negative, and earth. They should be of the value of ·001 mfd., and ·002 mfd. respectively. For the telephone condenser, four pieces of foil (preferably copper), each 3 in. by 1 in., and five pieces of mica, about ·002 in. in thickness and $2\frac{1}{2}$ in. by $1\frac{1}{2}$ in., are required



PLAN AND LAY-OUT OF PANEL

Fig. 3. Particulars of the lay-out required for marking out the panel are given here. The details should be carefully followed, especially with regard to the holes for the transformer, which must be accurate or the transformer will not plug in





BASKET TYPE ROTOR FOR THE VARIOMETER

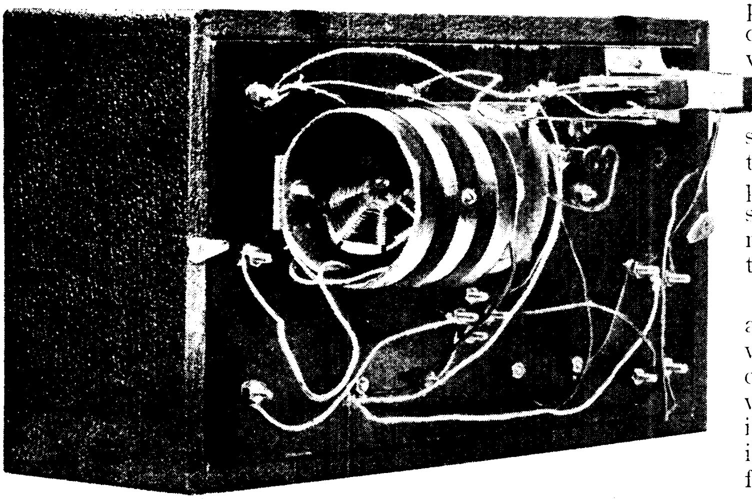
Fig. 4 (left). Two basket coils are made on formers of which the above is a diagram with dimensions. Fig. 5 (right). Having made the two basket coils, they are attached to a square-ended spindle in the manner shown. The whole is mounted within the tubular stator as indicated by the dotted lines. The combination forms the variometer used in the dual amplification set

First take a piece of mica, dab it with shellac varnish, place a piece of foil so that ½ in. overlaps at one end, a little more shellac and another piece of mica, then another foil with an overlap at the opposite end, and so on with the other two. One lead should be soldered to the pair of overlaps, or tabs, at one end, and one lead to the other pair.

The sets of foil at one end must have no metallic connexion with the other set, and there must be a reasonable margin of mica all round the plates. This is allowed for in the above dimensions. The other condenser has eight pieces of foil of the same size as above (four on each side), and nine pieces of mica, also the same size. The task of making these condensers may appear so simple that proper care may not be taken. The experimenter cannot be warned too strongly that a faulty piece of mica or a bad connexion will ruin the condenser.

The most monotonous part of the construction is the winding of the H.F. transformer. This may be seen in position in the photograph of the set, Fig. 1, and a detail photograph is seen in Fig. 7. Prepare three little cardboard basket formers with seven slots, similar to those used for the variometer. They should be 2⅛ in. outside diameter, and the slots cut to within ⅜ in. of the centre. These basket formers should be rubbed down smooth with glass paper and given a coat or two of shellac varnish, rubbed down again and re-varnished, until a smooth finish is obtained. This is important, as a really smoothly finished former is much easier to wind.

Now completely fill all three formers with 42-gauge D.S.C. copper wire. This will take time, and if it is convenient it is better to fill one former, then, allowing a few inches, to fill another former without cutting the wire. The third basket is used separately.



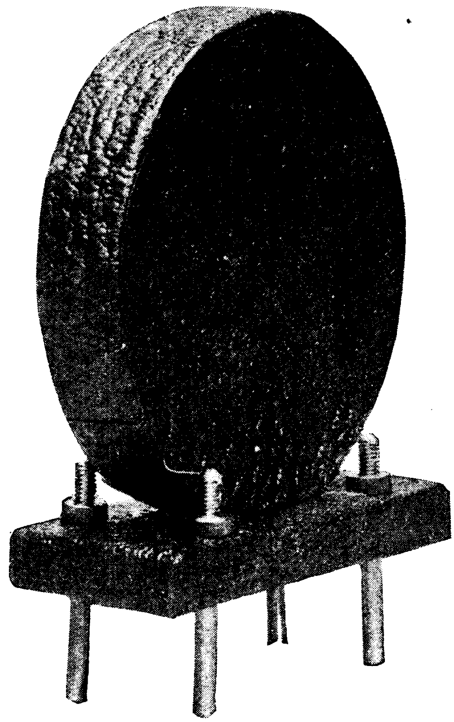
UNDERSIDE OF DUAL AMPLIFIER PANEL

Fig. 6. To show all details the panel of the dual amplification set is seen reversed. In this position the wiring can be seen and the disposition of the variometer and transformer. Inside the stator of the variometer is the basket coil rotor. The staggered legs of the transformer are at the bottom right-hand corner

A little cardboard case is now prepared, $2\frac{3}{4}$ in. in diameter, with a removable lid. The baskets rest in the case. The commencing wire of the two baskets is pushed through a hole on one side and marked I.P., and the finishing end of the pair through another hole on the same side and marked O.P. These are the input and output terminals respectively of the primary coil. The single basket is placed between the other two. Care should be taken that all the windings run the same way, for if they do not the basket coils will counteract one another and no speech or music will be heard in the telephones. The wires are brought out through the lid and marked I.S. and O.S. respectively, *i.e.* the input and output of the secondary coil. The circuits can be tested, if desired, with a pair of telephones and a dry battery, a very decided click being heard when the circuit is completed.

The base of the transformer is a piece of $\frac{1}{4}$ in. wood, $1\frac{1}{8}$ in. by $2\frac{1}{2}$ in., in which four valve pins are screwed. By using the tin template for these positions they may simply be pricked, the holes drilled, and the pins secured. One screw will hold the case to the base, the coils being removed for the purpose without disturbing the leads. The current wires should now be soldered to the top of the pins and the case closed. The covering is better left till after a reception test.

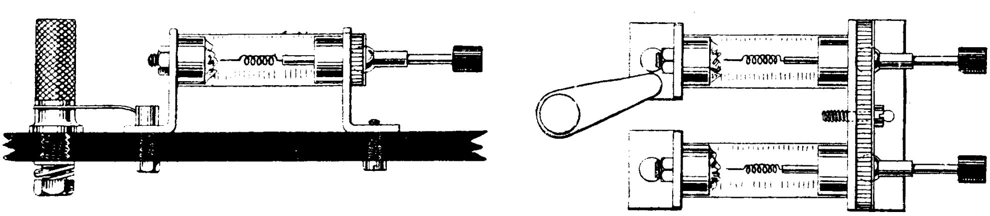
It now only remains to discuss in detail the crystal detector to complete the description of the components. It will be found wise to have two crystals of the super-sensitive galena type for preference, or hertzite, with a change-over switch. This not only gives an opportunity for comparison, but also permits of a progressive setting. If one fails it is the work of a moment to switch in the other. There are numerous crystal detector parts now on the market, and, if the reader prefers, he can fit one or two of these sets, but for the benefit of those who prefer to carry out the simple switching arrangements, the making of one is described.

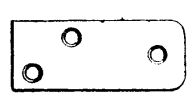


DUAL AMPLIFIER TRANSFORMER

Fig. 7. Mounted on a base with four valve legs for plugging in is the circular type high-frequency transformer used in the dual amplification set

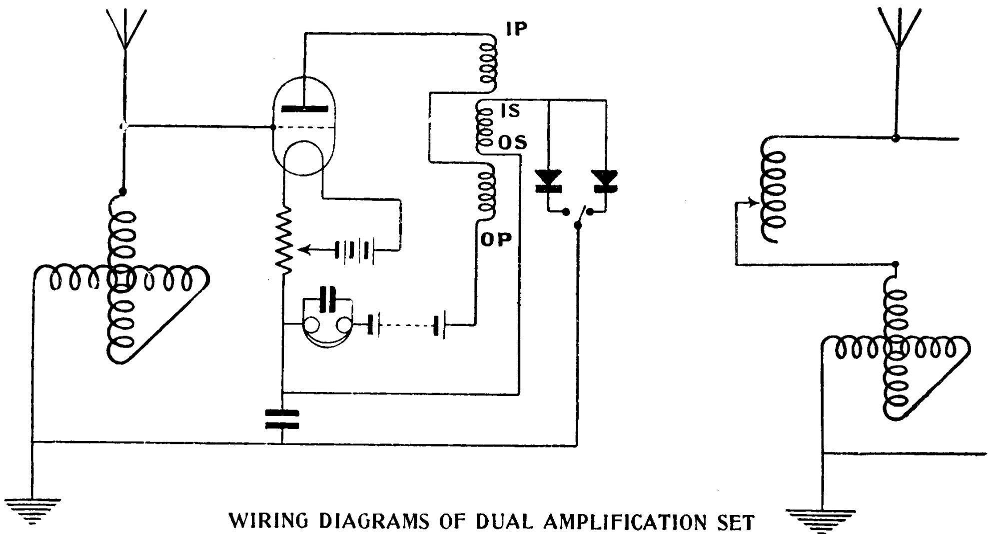
Two separate angle brackets for the crystal ends are prepared from $\frac{1}{16}$ in. brass, $\frac{7}{8}$ in. high, $\frac{1}{2}$ in. base, width $\frac{3}{4}$ in. They are held down to the panel by two contact studs, which act as stops for the switch. The crystals are mounted in little cups with a bolt and loose nut, not screwed into cup, the bolt being held in





DETAILS OF CONSTRUCTION FOR DUAL AMPLIFIER DETECTORS

Fig. 8. Two crystal detectors are included in the dual amplification set, either of which may be employed separately. In the details above will be seen the means of switching over from one detector to the other. A milled turning post and arm act as a switch



WIRING DIAGRAMS OF DUAL AMPLIFICATION SET

Fig. 9. Short wave-lengths are received by bridging the terminals which are used for including the loading coil when long wave-lengths are to be tuned in. On the right the aerial tuning inductance is shown with the loading coil included. In Fig. 2 the loading coil terminal will be seen situated between the aerial and earth terminals, and normally there is a bridging wire joining the two terminals, though this wire is not shown in the photograph

place by the setting of Wood's metal when the crystal is fitted. The double-end bracket is 1¾ in. wide, ⅞ in. high, with ½ in. base; centres between ball joints, 1 in. A nice fit for the ball joints (which should be bought with rod and knob) should be ensured. A piece of thin springy brass, held by one screw, and a piece of thin wood for packing, will serve to keep even pressure on the ball bearings.

Two little pieces of thin brass tube are soldered centrally on the opposite side, and two celluloid tubes, made from spoiled roll-film with gelatine removed, complete the component. The brass tubes and crystal cups are portions of two plated tops from the stoppers of the tiny concentrated perfume bottles. The switch, it will be noticed, simply connects with the feet of the brackets, and is detailed in the drawing of the crystal detector, Fig. 8.

A circuit design is given, Fig. 9, together with a photograph of the back of the panel, Fig. 10. The lower portion of the case is 4¼ in. deep, and there is sufficient room to stow away valve and transformer. The lid is 1½ in. deep inside, and will clear all projections comfortably. It should be noted that the lid lifts right off, two plates being fastened at the back, with one central hole projecting. Two screws are fitted in the lid, and the heads cut off so that, upon the front catch being released, the lid may be entirely removed.

The easiest way to make the case is to prepare a completely enclosed box with ⅜ in. wood, 6 in. deep, 11⅞ in. long, and 7 in. wide. Glue and nail, allow to dry, and smooth off all rough corners. Now cut all round 1¾ in. from the top, when a box with a lid which will fit will be available. The wood may be left quite rough, except the corners, which should be finished with a rasp. The case may be covered with imitation leather paper or leatherette. This method has the advantage that if any slight error arises, packing pieces of cardboard may be glued in place. It will be noted that the panel is held by turn buttons, so as to be easily removable.

The wiring-up can best be done from sketches and photographs of back of panel. Insulated wire should be used, such as cotton-covered bell wire. It is best to solder all connexions to the ends of terminals, but this should not be done till the set is tested out. The connexion to the crystal switch must, however, be soldered, or it will work loose. Note the coil of wire here in order to allow for movement. The set should work right away, but if it does not give really first-class results, make up a few condensers with larger or smaller numbers of foils than those given and try them one at a time.

It does not necessarily follow that under different conditions the same condenser will suit. The difference in insulating properties of good ebonite and a piece of wood may be sufficient to necessitate an alteration. As regards valves, a Dutch valve gives excellent results, and there is little to choose between this and the more expensive English valves. The high-tension battery should be generous, at least 60 volts, but this, again, will depend upon the valve. For the low-tension battery a 6 volt accumulator will serve for the ordinary valve.

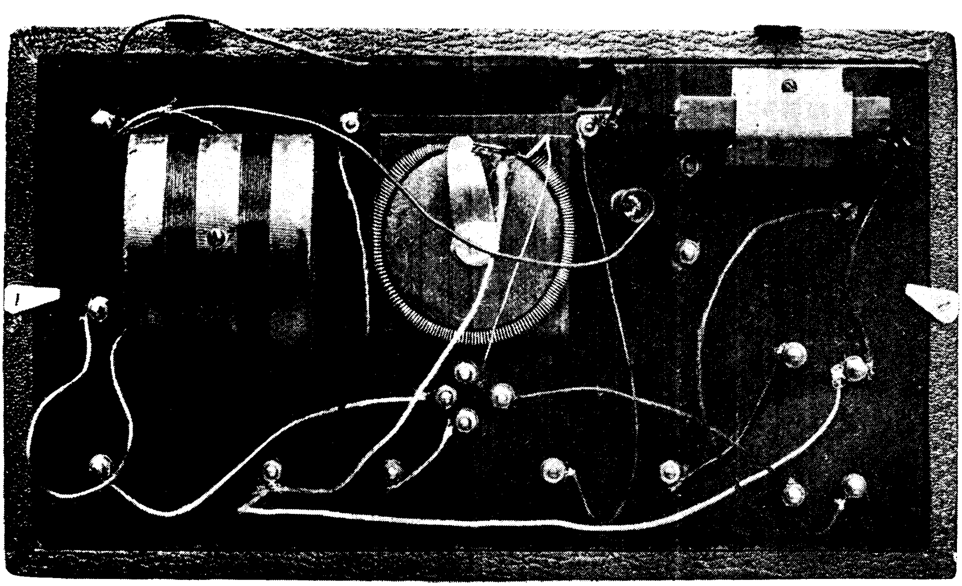
For higher wave-lengths, the terminal not tapped is provided for the insertion of a loading coil. For Eiffel Tower 2,600 metres, and downwards, a 5 in. diameter former, 9 in. long, wound with 28 S.W.G. enamelled copper wire, with slider and no condenser will be required. A set of basket coils could also be used, but in this case a condenser will be required.

When using a loading coil, the aerial wire should be fastened as usual to the aerial terminal, and also a wire from the coil. The other connexion to the loading coil should be made to the untapped terminal. In addition to a loading coil, a larger transformer is required for long waves. A pair of basket coils, 4 in. in diameter, with nine slots cut to within $\frac{3}{4}$ in. of centre, should be filled with 42-gauge double silk-covered copper wire, one to be used as primary and one as secondary. They should be mounted in a cardboard case, $4\frac{1}{4}$ in. inside diameter, the inlets and outlets of primary and secondary being soldered to valve pins exactly as with the short-wave transformer.

Dual Amplification Circuit with Tuned Anode. With some dual amplification circuits the adjustment of two or three fixed condensers to the right value for the particular conditions is sometimes a little troublesome, but in the set shown in Fig. 11 no fixed condensers are necessary, though two, which may vary in capacity within fairly wide limits, may be found desirable in some cases.

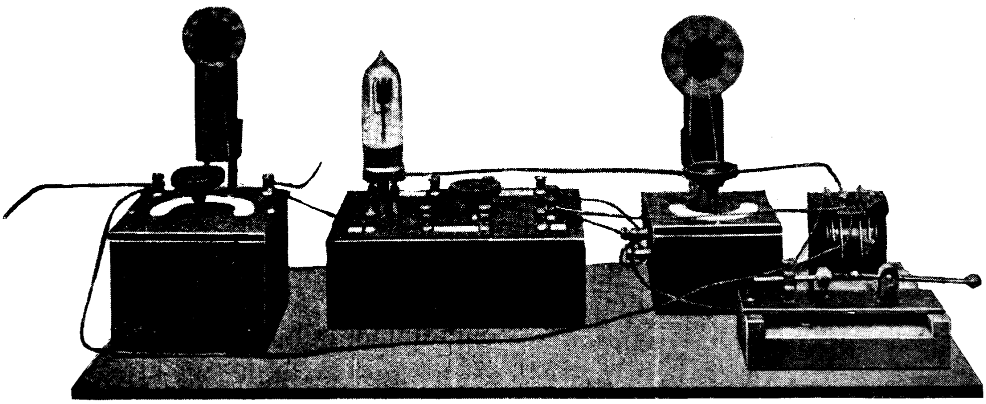
This circuit will be found to be practically nothing more than the addition of a low-frequency transformer to a normal high-frequency valve, tuned anode, and crystal detector, so that a convenient step for improvement over an ordinary crystal receiver would be first to add a high-frequency valve, and then to rearrange the set with the addition of a low-frequency transformer.

It is very convenient in initial experiments with this reflex circuit to use as a starting point an ordinary single-valve panel, which may be bought as a standard



BACK VIEW OF DUAL AMPLIFIER PANEL

Fig. 10. Comparison can be made with this photograph and the diagrams on the opposite page. By so doing the method of wiring can be followed and the position of the components shown in the diagrams can be seen in their actual positions on the panel. The wiring on the actual panel takes the shortest paths. The panel is reversed in its position in the cabinet

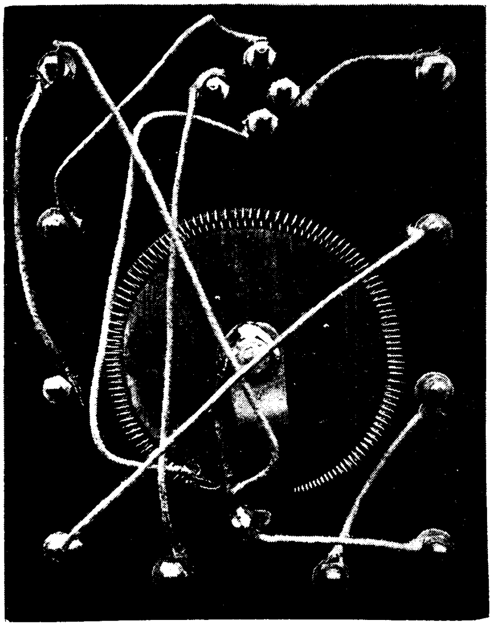


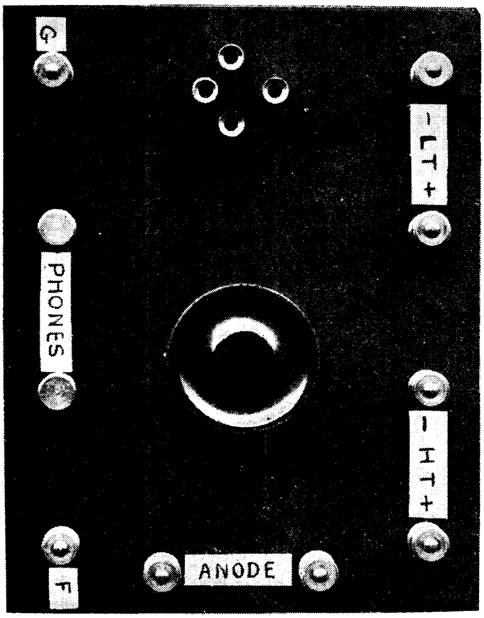
AMATEUR-MADE DUAL AMPLIFIER WITH TUNED ANODE

Fig. 11. No fixed condensers are used in this set. Added to the high-frequency valve, tuned anode and crystal detector is a low-frequency transformer. The above lay-out shows the aerial wire between the valve and aerial tuning inductance, the earth wire is on the extreme left

article in practically the same form. A slight rearrangement of the wiring will be necessary at the back of the panel, and this wiring is clearly shown in Fig. 12, which should also be compared with Fig. 13, showing the front of the panel.

For convenience in laying out the panel the telephone terminals have been rewired, as also have the reaction terminals, now used as the tuned anode pair. It should be noted that in this circuit the terminal marked F need not be used, though the output from the secondary from the low-frequency transformer may be wired to here instead of the low-tension negative terminal as illustrated.





STANDARD VALVE PANEL CONVERTED FOR DUAL AMPLIFICATION

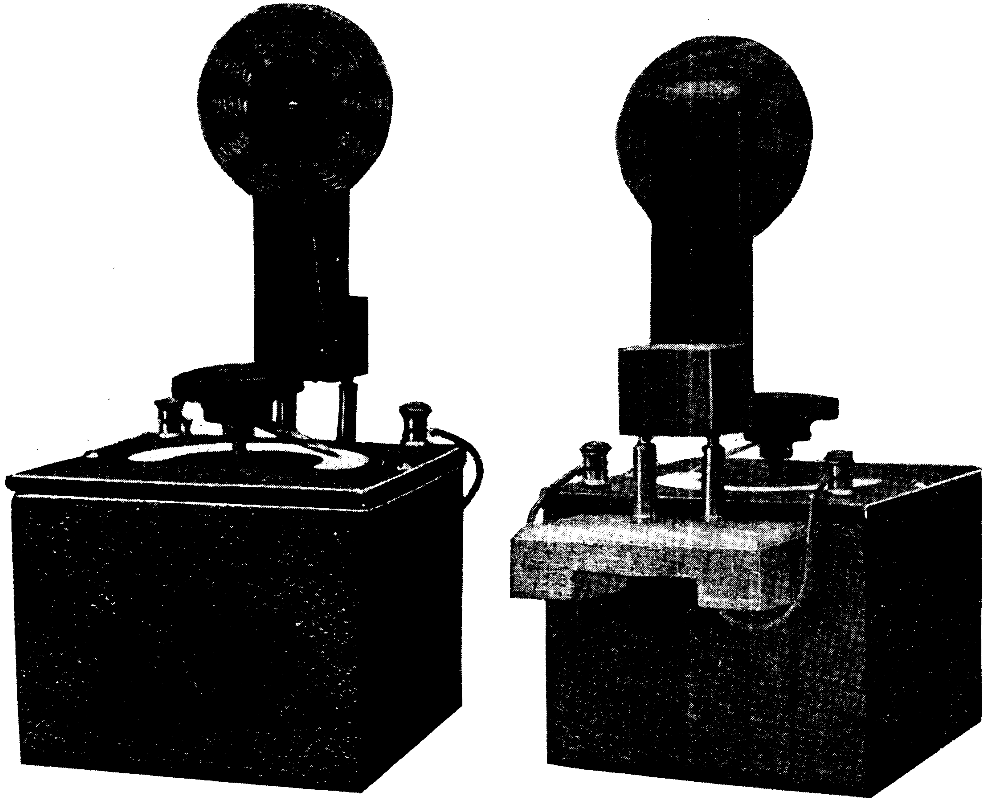
Fig. 12 (left). For the set in Fig. 11 a standard valve panel can be used, but a slight alteration, as here shown, is necessary in the wiring. Fig. 13 (right). When this is done the front of the panel should be marked in this way. It will be noticed that there are two anode terminals. One of these is connected with the valve socket and is used to connect up the cat's-whisker side of the detector, the anode tuning condenser and coil holder. The other anode terminal is connected to the other side of the condenser and coil holder

The aerial tuning inductance is conveniently tuned with a variable condenser of, say, ·001 mfd., though a smaller capacity will do with a sufficient range of tuning coils. The anode may also be tuned with, say, a ·0005 mfd. variable condenser. It will be understood that two slider coils, or any other type of inductance, may be used for aerial and anode tuning, but the method adopted and illustrated in the photographs below will be found very effective and adaptable to other uses as occasion arises.

This consists of mounting a basket or honeycomb coil holder upon the side of the condenser box, taking short leads to the condenser terminals, thus providing a handy tuning unit. In the case of basket coils, a pair of valve sockets mounted upon a piece of mahogany about ¾ in. thick, and screwed to the condenser case from the inside, will be quite efficient (Figs. 14 and 15).

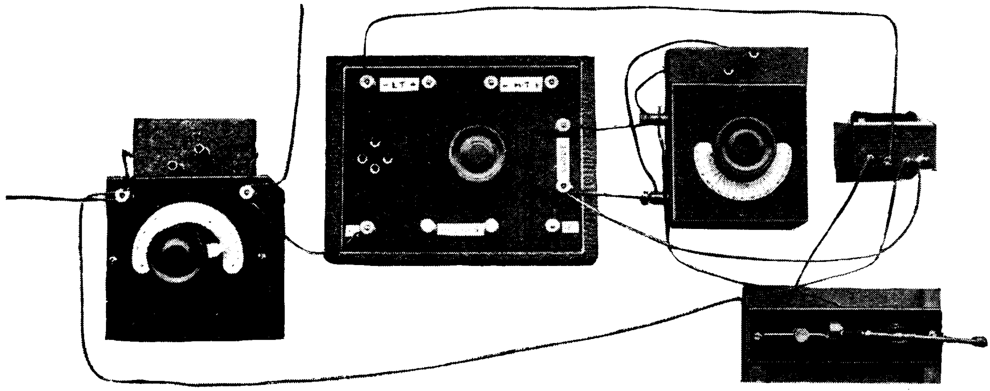
With regard to the wiring, one terminal of the aerial tuning condenser (which adapted as above suggested includes one side of the aerial tuning inductance) is wired to the aerial and also to the grid terminal of the valve panel, the other terminal of the aerial tuning condenser being wired to the input secondary side of the low-frequency transformer and to earth. The output of the secondary of the transformer is wired to the low-tension minus terminal upon the panel.

The anode terminal upon the panel leading direct from the anode valve socket is connected to the cat's-whisker of the crystal detector and to one side of the anode tuning condenser and coil holder. The other anode terminal is connected to the other side of this condenser and remaining point of coil holder. The crystal standard is next connected to the primary input



DUAL AMPLIFICATION ANODE AND AERIAL TUNING COILS

Fig. 14 (left). Front view. Mounted on the condenser box is a basket coil holder plugged into valve sockets mounted upon a piece of mahogany. Fig. 15 (right). In this rear view the method of wiring can be seen. One of the condenser terminals is wired to the aerial, and also to the valve grid. The other terminal is wired to the input secondary terminal of the transformer



LAY-OUT OF COMPONENTS OF DUAL AMPLIFIER

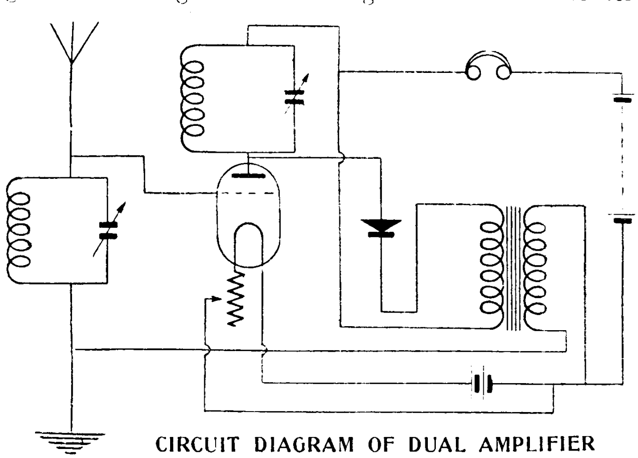
Fig. 16. The connexions are well shown in this lay-out, but they should be compared with Fig. 11 in order to get a clear idea of the association of components. The set has been photographed from above, and the valve and two plug-in coils removed. Note how the coil sockets are staggered. Above the crystal detector on the right is the transformer

side of the transformer, the primary output being brought back to the anode terminal not connected to the crystal.

In operation, the set exhibits no tendency to howl if the components are disposed as illustrated. Fixed condensers may be tried across the secondary of the transformer, a large one across the high-tension battery terminals and across the telephones, but the set will work well without. With regard to crystals, there does not seem to be much difference between any of the well-known varieties commonly used with a cat's-whisker, a common piece of silicon giving results indistinguishable from those obtained with a well-advertised synthetic specimen of galena, although the latter gives considerably better results when used upon a crystal set.

In making a test, the connexions to both the primary and secondary of the low-frequency transformer may be respectively changed over and a comparison made. The crystal connexions should also be tried in their reverse position. On no account should the anode tuning coil be pulled out with filament burning, as a howling will probably result. With regard to the size of the basket coils for broadcast reception, a coil wound upon a former of about $\frac{1}{2}$ in. in diameter, with, say, 30 gauge cotton-covered wire, to an outside diameter of $1\frac{1}{2}$ in. will tune 2 L O with a ·001 mfd. condenser in parallel, whilst a similar coil $2\frac{1}{2}$ in. outside diameter should be found satisfactory for the anode tuning coil, using a much smaller capacity condenser for the purpose of tuning.

The results obtained with this circuit are good. London or any broadcasting station at a distance of about eight miles is sufficiently loud to be heard distinctly six feet from the telephones, with an outdoor aerial 50 ft. long, consisting of a single wire 18 ft. high. With an insulated wire wound, frame-aerial fashion, round the room door in a vertical direction, half a dozen turns spaced about 3 in



CIRCUIT DIAGRAM OF DUAL AMPLIFIER

Fig. 17. From this diagram and the photograph, Fig. 16, the principle of dual amplification is seen. Comparison also shows the method of wiring

apart, a station can be heard with two pairs of headphones eight to ten miles away.

Fig. 17 shows the theoretical circuit diagram.—*F. Huson.*

See Amplifier; Crystal Receiving Sets; High Frequency; Low Frequency; Reflex Circuit; Valve.

DUBILIER, WILLIAM. American wireless expert. Born July 25th, 1888, and educated at the Cooper Technical Institute, New York, he early turned his attention to the study of electricity, and particularly wireless. Dubilier made a special study

WILLIAM DUBILIER

Many wireless improvements and inventions are credited to this American inventor, including the well-known condenser bearing his name

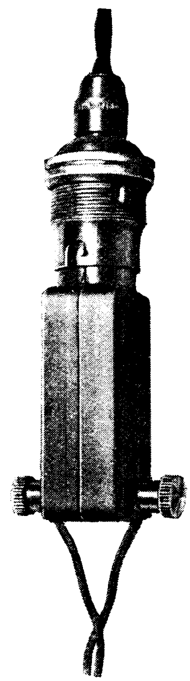
of condensers, and his Ducon mica condenser is well known. He has a number of condenser patents to his credit and is director of the Dubilier Condenser companies of America and England. Dubilier is the author of many patents in wireless, including those for a rotary quenched spark gap, the Dubilier arc oscillation generator, and other forms of arc transmitters.

A diagram of the Dubilier arc appears on page 127. Dubilier's rotary quenched spark gap has a cone-shaped electrode mounted on a spindle and capable of being rotated by an electro-motor at a speed of 1,000 to 2.000 r.p.m. The gap is generally used with an air dielectric, and the lengths of the gap may be varied. The gap was patented by Dubilier in 1910.

Dubilier's quenched arc transmitting and receiving apparatus, which he outlined in 1911, was one of the most compact forms of transmitting and receiving apparatus that has been made. The complete apparatus, as developed, could be placed on a small table, and had a range of 250 miles. The set had an input of 3 kilowatts, and the box containing the discharger was only a little over a foot in height and about the same in length and breadth. A multiple-contact commutator enabled the set to be changed over from transmitting to receiving.

Dubilier is also the author of a large number of papers on wireless subjects and a member of many scientific societies.

DUCON. The Ducon is an attachment to fit into any electric light socket to enable the light conductors to be used as a receiving aerial. In circumstances where an external aerial is impossible or an indoor one inconvenient, it is possible to receive local stations by the use of this fitting.



DUCON ATTACHMENT

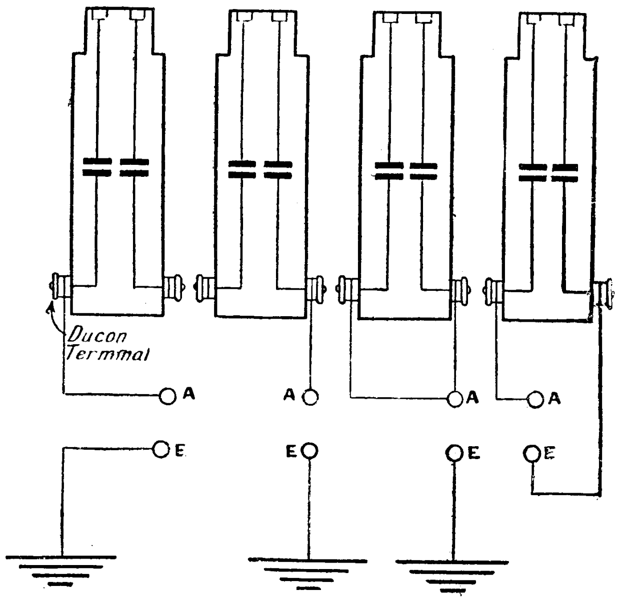
Fig. 1. This attachment enables the electric lighting mains to be used as an aerial without the slightest risk

Radio waves cause feeble electric oscillations to be imposed on any and every metallic object, and even though that object be a conductor already carrying current, the oscillations will be superimposed on that conductor quite independently of the current already there. Therefore if a condenser is placed in a lamp-holder, for instance, in a direct current lighting circuit, the direct current will not pass, but the oscillatory currents will, and therefore, if that condenser is also connected to the aerial terminal of a receiver, signals may be obtained.

There is no risk of shock or damage to the receiver with the Ducon, owing to its extremely high dielectric strength.

The receiving strength obtained when using this device varies greatly with local conditions, and should it be placed in a lighting circuit where the conductors are contained in a steel conduit, it is probable that no signals will be obtained at all, for the conduit itself forms an efficient earthed shield.

The Ducon consists of two fixed condensers of different capacities, insulated from each other and arranged side by side, Fig. 1. One pole of each condenser is brought out to a contact pin arranged in the socket end of the appliance, the other poles being brought to terminals, one on each side. The socket-end contacts are arranged in the same manner as the contacts on a lamp cap. Projecting pins for fitting into the bayonet catches are also fitted. All contacts and screws are completely covered by or countersunk into a moulded insulator compound. In using the Ducon it is essential to see that the light switch be turned to the *on* position.



METHODS OF CONNECTING A DUCON ATTACHMENT

Fig. 2. Four methods of employing a Ducon attachment are illustrated in this diagram. Each of these methods can be tried with the Ducon reversed in position in the lamp holder. Every position should be tried before finally settling the question in order to obtain the maximum efficiency

There are several methods of connecting the appliance to the set, four of which are shown in Fig. 2. Besides these, each individual method should be tried with the Ducon placed in the two possible positions in the lamp socket, thus doubling the possible number of positions. The experimenter should try each position in turn in order to ascertain the most efficient to suit the particular conditions under which it is working.

The makers state that occasionally it will be found to give greater efficiency to a set where an aerial is already in use if the Ducon is used in conjunction with the aerial—*i.e.* by connecting both on to the one terminal of the receiver.

DUDDELL MUSICAL ARC. W. Duddell showed in 1900 that when an arc fed from a source of continuous current through a resistance is shunted by a condenser and inductance in series, it will stimulate an oscillating current in the condenser inductance circuit and emit a musical note to correspond with the frequency of alternation in that circuit, always provided the resistance of the circuit is not too high.

The arc is arranged as in the figure. C is an adjustable condenser of large value, say 3 or 4 microfarads; L is a low-resistance coil having a mean inductance of, say, 5 millihenries; R is a resistance having a value from 30 to 50 ohms; whilst G may be a direct current generator, or a battery giving 50 to 80 volts.

As the condenser C is subjected to high-frequency currents, as well as to voltages which may amount by resonance to several hundred volts, it is well to start with a good mica condenser tested to 1,000 volts.

Dr. J. A. Fleming explains the action of the singing arc in the following manner:—

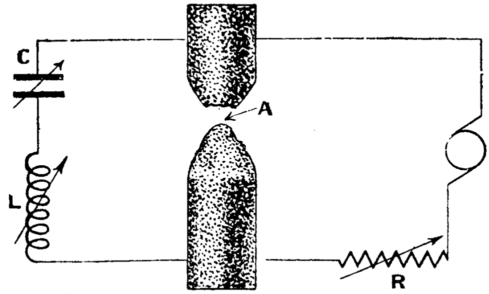
"If a condenser in series with an inductance of low resistance is placed as a shunt across the arc, the first effect is to rob the arc of some current to charge the condenser. This action, however, does not decrease, but increases slightly the potential difference of the carbons. Hence the condenser continues to be charged. When the charge is complete, the current through the arc is again stationary, and the condenser at once begins to discharge back through the arc. This, however, increases the current and decreases the potential of the carbons, hence the action proceeds until the condenser is discharged."

This action goes on very rapidly, but with the values given above will be at an audible frequency. The frequency will be raised, *i.e* the wave-length will be reduced, by reducing the size of the condenser, for a smaller condenser will become charged and discharged in a shorter time than a large one. Also if the inductance of L is increased the wave-length of the circuit will be increased, so that the frequency and note will be reduced.

In the circuit shown in the figure there are really two circuits, one carrying an oscillating current and the other a direct current. The former is the circuit C L A, whilst the latter is the circuit the generator and R A. It will therefore be seen that the arc A, and the carbons between which it is formed, carry at one and the same time both direct current and alternating current of high frequency.

Duddell gives the following as the constants for a circuit which will produce a musical note.

Solid Conradtz carbons, 9 mm. diameter; arc length, 1·5 mm.; arc current, 3·5 amperes; steadying resistance, 42 ohms; shunt inductance, 5·3 mhy.; resistance of the inductance coil and leads, 0·41 ohms; capacity of condenser, 1·1 to 5·4 mfd. R.M.S. current through the condenser, 3 amperes, when using a capacity of 5·4 mfd. Voltage of battery, 50 v.



ARRANGEMENT OF DUDDELL ARC

There are really two circuits in this arrangement, one carrying oscillating, the other direct current. Direct and alternating current are carried at the same time by the arc and the carbons, and all the constants in the circuit being correct the arc A will give a musical note

The actions of the singing arc are explained by Duddell to be dependent upon the fact that the arc itself must be regarded as having a negative resistance. That is to say, that at any moment the instantaneous change in volts divided by the corresponding instantaneous change in amperes in the circuit A C L must be of a greater value than the resistance of the circuit and negative in sign, so that in each cycle the current builds up, whilst the voltage decreases.

DULL EMITTER VALVES & THEIR USES

Characteristics of Current Economy Valves and How to Make a D.E. Receiving Set

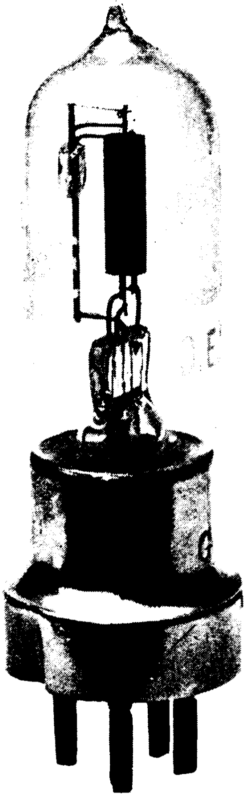
The modern minimum voltage valve is perhaps one of the greatest steps forward in lessening the cost of receiving sets. Here are described several varieties of the valve, and also a two-valve set fully illustrated with a special photogravure plate. See cognate entries such as Detector Panel; Three-valve Set; also the individual valves

A dull emitter valve is a valve used in wireless work that has been specially designed and made to operate on a minimum voltage for the heating of the filament.

The voltage for dull emitter valves varies from ·8 of a volt to 3 volts. The Ediswan type A.R.D.E. valve requires a filament voltage of 1·8 to 2·0, for example, while that of the Mullard Wecovalve is as low as 0.8 to 1·1 volt, so that the filament operates with only one dry cell. This latter type of valve requires an anode voltage of 17 to 22 if used as a detector, and 22 to 45 when used as an amplifier.

The dull emitter valve is really the outcome of the discovery by Wehnelt, in 1903, that a coated filament gave off an electronic emission at a lower temperature than an uncoated filament. This was really due to certain rare earths which were in the coating. The modern filament is a mixture of the rare earth thoria and tungsten, and the thermionic emission at low temperatures is enormously greater than that of the valve which it is now rapidly superseding. With an ordinary dry battery the valve works very successfully, and at a very low cost compared with the accumulator-heated valve filament, which requires anything from 4 to 6 volts to get the best results. There are now over a dozen types of dull emitter valves on the market.

Fig. 1 is an illustration of the D.E.3 Marconi-Osram valve. The voltage for this valve on the filament is 2·4 to 3, and



D.E.3 M.O. VALVE

Fig. 1. It is claimed that this valve can be run for 800 hours off a small dry battery at a cost of about a penny for every eight hours

an ordinary three-cell dry battery should be used with it. The variable filament resistance should have a maximum value of 35 ohms. This three-cell dry battery will last about 800 hours. The D.E.3 valve can be used as a detector, high-frequency amplifier or note magnifier. When used as a detector the anode voltage should be 30–45; as a H.F. amplifier, 45 volts, and as a L.F. amplifier 60–80 volts. The low impedance of the valve renders it particularly suitable as a low-frequency amplifier, and it gives very good results when used in conjunction with a loud speaker. As the thoria on the filaments of all dull emitter valves is liable to deteriorate if the temperature be unduly raised, it is most important never to exceed the voltage stated by the manufacturers.

Dull Emitter Valve Set. In Fig. 2 is shown a two-valve receiving set, complete with batteries and telephone, incorporating the use of dull emitter valves. This set works efficiently on a two-volt accumulator, or if Weconomy, D.E.3, or other minimum-voltage valves are used it works equally well on dry batteries.

The arrangement of this receiving set provides an efficient set in the simplest possible way. The tuner comprises an inductance coil wound on a tubular former having a movable arm running across, by which the value of the inductance is varied. The wave-length range of this inductance covers up to 2,000 metres. The set is wired as a valve rectifier with one stage of high-frequency amplification. The latter is brought about by a plug-in transformer coupling having a novel type of variable condenser across the primary winding. This condenser gives sharper tuning with a corresponding diminution of interference.

This set is one of the series shown in diagram form in the special broadcasting map facing page 282, and has a normal range of 75 miles when well-made and used with an ordinary outdoor P.M.G. aerial. This mileage of reception is more or less approximate, as the care taken in its construction and the efficiency of the aerial to which it is connected are two of the many considerations affecting its range.

The addition of high- and low-frequency amplifying units may be made to the set without any alterations if longer range or increased volume of sound is required. The tuner front consists of a piece of matted ebonite, 5 in. square and $\frac{1}{4}$ in. thick. The base is also of ebonite, cut to the same size as the front. An angle piece of $\frac{1}{2}$ in. brass is used to secure the front to the base. Screw the angle brass flush with the front edge of the base, after cutting away a piece in the centre to clear a brass bush required for the contact arm bearing. A little drilling will be required before assembling the front.

A $\frac{3}{8}$ in. hole for the bearing bush is drilled in the middle of the panel, $\frac{5}{8}$ in. from the bottom edge. At a distance of $2\frac{7}{8}$ in. up from the bottom edge two holes, 4 B.A. clearing size, are drilled, one at each side of the panel and $\frac{1}{4}$ in. from each edge of the panel. These holes should be countersunk.

Two terminals on each side of the panel are required, and may be attached as shown in Fig. 3, which shows the front view of the set. The position of the terminals is not important; but it must be seen that the terminals on the left of the detector part of the set register with those on the right of the tuner. Mount the terminals in position, arranging the holes in them horizontally, in order that a horizontal bar may connect them to the valve unit. The appearance of the tuner is improved if a scale similar to the one shown in Fig. 3 is engraved or ruled on with a ruling pen, or preferably incised and filled. A radius of 2 in., with the bush hole as centre, will be found suitable.

A brass bush $\frac{3}{8}$ in. in diameter and $\frac{5}{8}$ in. long, having a flange at one end and a central hole of $\frac{3}{16}$ in., is pushed into the

$\frac{3}{8}$ in. hole at the base, so that the flange rests against the inside of the panel. The panel front may now be screwed to the angle brass of the base with three 4 B.A. by $\frac{3}{8}$ in. screws. In mounting the inductance coil, two valve sockets are used. It will be found that the part into which the valve leg normally fits will tap out 4 B.A. very conveniently. When this is done, the legs may be screwed to the inside of the panel with 4 B.A. by $\frac{5}{8}$ in. screws in the holes previously drilled to receive them. The tuner will now appear as in Fig. 4.

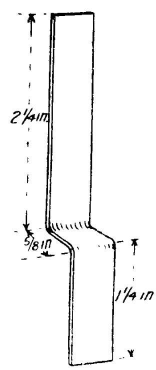


Fig. 14. Brass strip is used for the contact arm, cut and bent to dimensions here given

The inductance is wound on an ebonite former 4 in. in diameter and 5 in. in length. No. 24 gauge enamelled wire is used, starting and finishing $\frac{1}{2}$ in. from each end. A good method of anchoring the wire ends securely is to drill two small holes about $\frac{1}{4}$ in. apart and $\frac{1}{2}$ in. from each edge. The beginning of the wire is threaded through one pair of holes several times, the bends formed being pressed at right angles.

Considerable care must be taken in winding to keep the wire free from kinks, spaces, and any tendency to slackness. If possible, wind the inductance in a lathe to get an even result. The method for winding a coil on a lathe is given on page 457. Two holes of 4 B.A. clearing size are drilled, one at each end of the inductance. These holes must correspond with the two drilled holes at the side of the panel. The inductance is mounted on the front by means of two valve-holder sockets, but this operation is better left until the brass pieces of the contact arm are made and assembled.

Fig. 5 shows the complete set of contact arm parts ready for assembly. A 4 in. length of $\frac{1}{2}$ in. by $\frac{1}{16}$ in. brass strip is bent as shown in Fig. 14. The longer length of the straight portion is bent back to a blunt-ended V shape to permit a smooth contact over the wires, and a slot is cut at the top end of the arm on each side to clear the coil supports, thus making contact to the ends of the coil. A brass bush, identical with the one inserted into the front of tuner, is sweated on at the other end. The bush hole is now continued right through the brass flange. The holes are drilled and tapped 5 B.A. in the side of the bush, enabling two set-screws to lock the contact arm to the spindle.

The spindle is a rod of $\frac{3}{16}$ in. diameter brass, 4 in. in length. One end is drilled to run in a centre bearing; and $2\frac{1}{4}$ in. from this end a flat is filed for a length of 1 in. in order to prevent the contact arm from moving on the spindle when strain is put upon the latter. The set-screws on the contact-arm bush must register with this flat when the whole is assembled.

A brass bracket to hold the centre for the spindle bearing is made from $\frac{1}{2}$ in. by $\frac{1}{8}$ in. brass strip, and is $1\frac{1}{8}$ in. in length. It is now bent in the middle to form a right angle. In order to prevent the strip from breaking, it may be bent hot. A 4 B.A. clearing hole is drilled in one side for securing to the base, and a 2 B.A. hole drilled and tapped at a distance of $\frac{3}{8}$ in. up when the bracket rests on the base. This bracket is shown in side elevation in Fig. 15.

A $1\frac{1}{2}$ in. length of 2 B.A. screwed rod is filed or ground to a point at one end, and a slot cut in the other end for adjustment with a screwdriver. The bracket is fastened down to the base at a distance of 4 in. from the bush in the tuner front and in line with it. Screw in the centre bearing roughly in position with a locking nut added on the pointed side. The spindle is now pushed through the bush in the panel, centre side first. Before the spindle reaches the point centre the contact arm is put on and locked into position. The point centre is then screwed up and locked, when a smooth, easy motion is found on moving the contact arm. This operation is shown in Fig. 6, on the special plate facing page 762, the left hand holding the contact arm in position while the right hand, holding a screwdriver, approaches the centre to the spindle end. Fig. 6 shows the assembly at this stage.

A short length of flexible insulated wire is soldered to the bush of the contact arm and connexions taken to the two lower terminals on either side of the panel. These terminals are the earth terminals. Another wire joins the top terminals together, and to one of these is afterwards attached the left-hand side of the inductance winding viewed from the front of

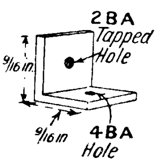


Fig. 15. Right-angle brass strip for spindle bearing is bent and drilled

the instrument. The inductance coil is mounted in the valve legs by the holes drilled in the former, and locked with nuts on the valve stem. The pressure of the contact arm may be adjusted by careful handling.

A method of correcting inaccuracies in construction is to insert a washer or two on the valve legs if the contact arm is found to press more on one side of the coil than on the other. A slight swivelling of the centre bearing bracket will have the same effect.

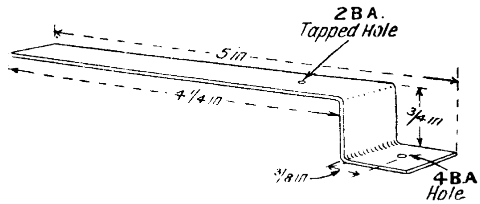
A piece of emery paper is slipped over the contact arm where it touches the coil and the insulation removed by sliding the arm over its path of the inductance coil. A handle is now required to operate the arm from the outside of the panel, and is shown in Fig. 5, to the left of the set of contact arm parts. A small brass collar is made with a centre hole of $\frac{3}{16}$ in. in diameter into which a set screw is arranged to grip a flat on the spindle end when the collar is in position. A handle of $\frac{3}{32}$ in. diameter brass, about $5\frac{1}{2}$ in. long, is now screwed into the collar. An ebonite knob or handle is screwed to the opposite end of the rod. A double bend in the rod will be found necessary in order to clear the terminals when it is moved from side to side. The handle must be kept in line with the contact arm behind the panel.

The tuner is now finished, and any dirt or soldering paste should be removed with a piece of clean rag. A stick of wood will be found useful in pushing the rag into otherwise inaccessible places. The completed tuner is shown in Fig. 7 on the plate.

For the valve part of the set, a panel 7 in. long and 5 in. high is attached to a base 7 in. by 5 in. in a similar manner to the tuner front and base. Before this operation, however, the front is drilled out according to the lay-out shown in Fig. 8. Two terminals are arranged on either side of the panel to correspond with the terminals on the right of the tuner. The $\frac{3}{8}$ in. holes towards the bottom of the panel take the filament resistance bushes. These resistances may be fixed in position by 6 B.A. by $\frac{3}{8}$ in. countersunk screws from the inside of the panel. Their position is clearly shown in Figs. 12 and 13. An ebonite holder of any suitable type for H.F. transformer is mounted where shown dotted in Fig. 8 on the top left-hand side. Either four peep-holes, as in Fig. 8, or five, as in Figs. 3 and 9, may be drilled, according to the size of the valve, to permit of inspection.

A novel type of variable condenser for tuning the primary of the transformer is arranged with the plates between the resistances. The condenser plates are both the same size, and are cut from 18 gauge sheet brass, $2\frac{1}{8}$ in. by $1\frac{3}{8}$ in. A 4 B.A. nut is sweated to the back plate at a distance of $\frac{3}{8}$ in. from the shorter side and in the centre of it. The plate is now drilled out through the nut and tapped 4 B.A. The hole previously drilled 4 B.A. in the centre of the ebonite front is countersunk to take a 4 B.A. by $\frac{3}{4}$ in. screw. Two nuts are added, after which the back condenser plate is screwed on with the nut against the inner side of the panel. One nut is used to lock the screw in position and the other to lock the fixed plate.

The method of clamping these nuts is shown in Fig. 11. The moving plate is supported by a long brass arm extending to one corner of the panel, to which it is bolted securely. A little way from the end the arm is drilled and tapped 2 B.A. Details for the construction of this arm are given fully in Fig. 16. It is made from $\frac{1}{2}$ in. by $\frac{1}{16}$ in. brass strip and the bends may be made cold. At a distance of $\frac{3}{4}$ in. from the bend, along the long side of the strip, a 2 B.A. tapping hole is drilled and tapped. The $\frac{3}{8}$ in. hole to the top right-hand side of the panel is fitted with a brass bush identical with the two used in the tuner. This is pushed in with the flange to the inside.



DIMENSIONS FOR CONDENSER ARM

Fig. 16. Details of the moving plate condenser arm for the dull emitter set are here given. This is made of $\frac{1}{16}$ in. brass strip, $\frac{1}{2}$ in. wide

An ebonite knob is attached to a 2 in. length of screwed rod and then pushed through the bush from the outside. A 2 B.A. spring washer is slipped on the rod, followed by two lock nuts. The hole in the arm is now engaged in the screwed rod, which is rotated until the end of the arm rests flush on the panel. The long side of the arm should be parallel with the panel, with the farthermost end on the condenser plate already assembled. The panel is drilled to take a 4 B.A. screw and nut for bolting the arm securely to the panel. Fig. 9 indicates the assembly at the present stage.

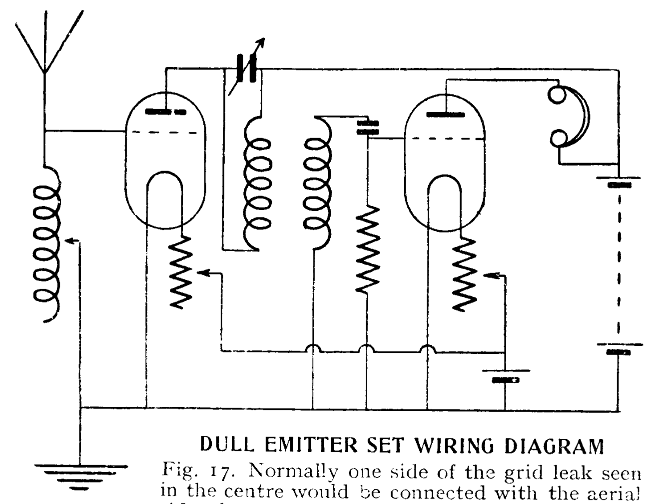
A piece of flat mica, overlapping the fixed plate by $\frac{1}{8}$ in. all round, is fitted on to the screw projection of the fixed plate. The method of fixing the mica is to shellac one side thoroughly, and when nearly dry press against the condenser plate so that the screw end forces its way through the mica. The shellac will prevent any sideway movement of the mica. The moving plate is drilled to clear the screw projection, as in Fig. 10.

When the moving plate is correctly set over the fixed plate, the former may be soldered to the arm. As the arm is attached to the 2 B.A. screwed rod, the rotation of the latter will cause the arm to move nearer to or farther from the fixed plate, thus varying the capacity of the condenser. A small $\frac{1}{8}$ in. condenser washer is slipped on the end of the screwed rod, and two more lock nuts tightened against each other form stops to prevent the arm from being screwed back too much. The two condenser plates are now connected to the transformer primary winding by a wire soldered to the back plate and the grid leg of the valve holder on the panel. The anode valve leg is joined to the movable plate and high-tension positive.

On the base are mounted two flange-type valve holders and the grid leak and condenser. The terminals for connexion to high- and low-tension batteries are also conveniently mounted on the base at the back. The valve holders are placed in the centre behind each other, as shown in Fig. 10. In mounting the valve holders, the legs are cut off flush with the bottom of the valve holder flange and soldered wire connexions are made to each leg before the holder is screwed into position.

A channel will be found in the moulded base appropriate to each leg through which to carry the wires. Looking from the back of the set, the grid leak and condenser are mounted to the base on the right of the valve holders. A convenient position is shown in Figs. 12 and 13. The grid condenser is of fixed value, ·0003 mfd. being chosen in conjunction with a 2 megohm leak.

It will be seen from the wiring diagram in Fig. 17 that the leak is not placed straight across the condenser. The side of the grid leak normally connected with the aerial, or aerial side of the rectifier, is insulated from the condenser on this side by wrapping the metal cap in a strip of thin mica before replacing in its clip. This end of the grid leak has a lead connected to it going to earth or H.T. negative. The other end of the condenser and leak are metallically connected and are led straight to the grid of the rectifying valve.



DULL EMITTER SET WIRING DIAGRAM

Fig. 17. Normally one side of the grid leak seen in the centre would be connected with the aerial side of the rectifier. In this case that end of the leak is insulated from the condenser and a lead is taken to earth and the negative side of both batteries and the filament of the rectifying valve. Thus the ordinary combined condenser and grid leak can be used

The wiring, which is carried out with No. 22 gauge tinned wire covered with 2 mm. insulated sleeving, may now be finished off, and three terminals, high-tension positive, a common terminal for high-tension negative and low-tension negative, and low-tension positive terminal, conveniently set in this order from right to left. It is important to mark these terminals, as a mistake in connecting-up the batteries would probably result in burning out the valves. The experimenter may choose his own method of doing this. A simple, yet very effective method of engraving the lettering is explained under Crystal Sets, where a low-frequency amplifier was fitted into the telephone recess of a commercially made crystal set (page 609). This engraving is shown in Figs. 12 and 13.

The complete set is now cleaned free from dust and dirt and connected up to the tuner by two brass connecting strips. The valves are put in their sockets and low-tension terminals correctly connected up. Having ascertained that the valves light when the filament resistance is turned, the high-tension battery is also connected to its respective terminals. The plug-in transformer must be purchased to suit the wave-length it is desired to receive. For British broadcasting a 400-metre transformer is suitable. A distinct click will be heard when the telephones are connected to their terminals at the right of the set. Aerial and earth wires are connected to the left of the tuner.

On the average aerial broadcasting will be found to come in with the contact arm about three-quarters of an inch from the left of the inductance. A slight tap on the valves should produce a ringing noise in the telephones, which indicates that the valves are oscillating correctly. Failure to hear this ringing noise usually indicates a broken high-tension circuit, which should be checked over again. The high-tension connexions may be temporarily plugged into the sockets in the battery by two or three bends in the wire. When the correct voltage has been found, the wires may be soldered in their places, or if wander plugs are used, strict care must be taken to ensure perfect electrical contact, as failure in this respect occasions loud noises or disturbing "frying" sounds in the telephones.—*W. W. Whiffen.*

DUMB ANTENNA or DUMB AERIAL. Name given to an artificial, non-radiative circuit used in transmission as a supplement to the radiating aerial circuit. It has the same frequency as the latter, and is used to steady the load on an oscillation generator in order to facilitate the necessary "spacing" when transmitting by the Morse code. Dots and dashes in the code are formed by splitting up, by means of the transmitting key, the energy supplied by the oscillation generator to the aerial circuit.

For the "spaces" a change-over from the aerial to the dumb aerial is made by a special key, which is actuated electromagnetically from the hand key. A circuit of this description is sometimes used in the transmission of continuous waves by means of an arc generator, and is known as a back-shunt circuit.

DUO-LATERAL COILS. Name applied to a particular type of inductance coil extensively used in wireless work and characterized by the method of winding. These coils are very similar to the honeycomb coils, and the methods of winding and making them are dealt with under that heading.

In the duo-lateral winding the wires are so arranged that the turns of each successive layer do not come radially above each other as in the honeycomb coils. The first layer is wound in a criss-cross manner, and the second layer arranged so that the turns of the wire are spaced midway between the turns of the first, and successive layers are wound on in the same manner.

This arrangement provides an increased spacing between the layers, as, the second layer being staggered, there is more space between the alternate turns than is the case when the wire is wound so that the turns come immediately above each other.

Such a method is sometimes known as a lattice winding, and the method is capable of development in various ways, as, for example, in the winding of a variometer. *See* Basket Coil; Coil; Coil Winder; Honeycomb Coil.

DUO TERMINAL. Terminal which has an arrangement for the clamping of two wires simultaneously. Duo terminals may take the form of either the binding post or telephone type.

The former has the usual circular base with the vertical screw projecting from it. Between this and the milled edge clamping nut generally fitted there is another, thinner, circular lock nut. This is also provided with a milled edge, and is usually of larger diameter than the top nut, to facilitate handling.

One wire is clamped between the base and the lock nut, the second wire being placed on top of the lock nut and finally being clamped down tightly by the top nut. This type of terminal is frequently fitted to laboratory instruments.

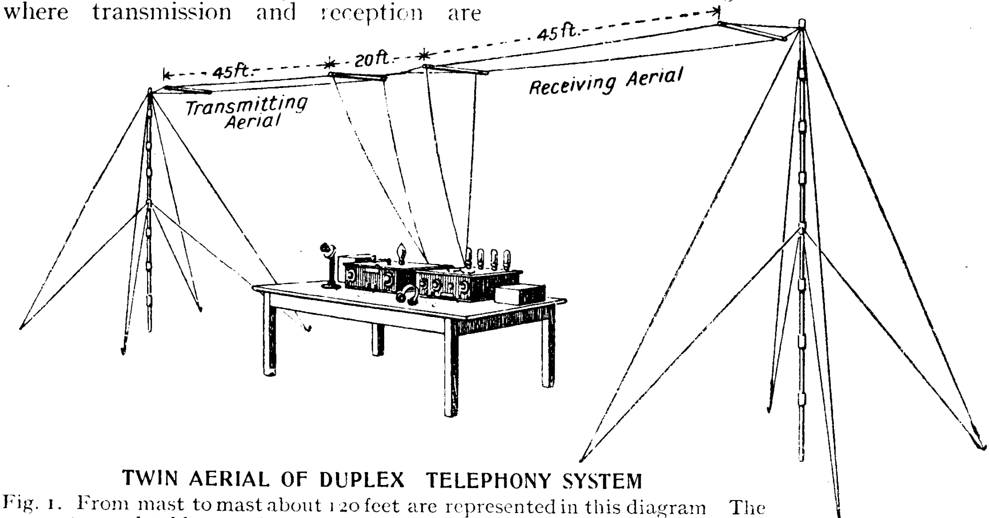
Telephone-type duo terminals have two holes drilled transversely through the post, a clamping screw being fitted to each. These have necessarily to be fitted through the side of the post, instead of through the top as in the case of the single-hole type.

The fitting is greatly facilitated by using this type of terminal.

DUPLEX TELEPHONY. The term duplex as applied to wireless telephony refers to systems whereby transmission and reception may be carried on simultaneously, the transmission not affecting the reception. For instance, in a telephone set working on the duplex system it is possible to interrupt a conversation in precisely the same manner as with the ordinary land-line telephony, the listener becoming transmitter at will. In the ordinary, or simplex system, a station where transmission and reception are carried on uses the same aerial for both purposes, and when the operator wishes to receive he switches off the transmitter by means of a change-over switch.

It will be readily understood that a real conversation cannot be carried on under such conditions. Consider two stations, A and B, working on the simplex system. Should B be transmitting to A, it is possible that A will not understand or agree with whatever B is saying. A's only method of informing B of this is to wait until B has finished his transmission and then change over and ask B to repeat his statement. The unavoidable delay caused by this method is obvious.

The fundamental difference between simplex and duplex working is that, while with the former type only one aerial is used and the transmitter is dormant while reception is in progress, with the latter system two aerials are used, and the transmitter is always sending out a carrier wave. The general arrangement of the twin aerial system is shown in Fig. 1. While this shows an ideal arrangement as regards relative disposition, exigencies of space and the proximity of buildings, trees, etc., may necessitate a small deviation from the ideal. In erecting the aerials, however, it is advisable to follow the plan shown in Fig. 1 as closely as possible to obtain the best results.



TWIN AERIAL OF DUPLEX TELEPHONY SYSTEM

Fig. 1. From mast to mast about 120 feet are represented in this diagram The apparatus and table are shown large for illustrating the two systems. On the left is the transmitting gear, and on the right the receiver. The transmitter is always sending out a carrier wave. In duplex telephony a fixed wave-length for both stations is essential, and reception and transmission can be carried out simultaneously

Fixed wave-lengths for both stations are an essential in duplex working, and for purposes of explanation let us assume that wave-lengths of 350 and 400 metres are to be used. Each station has a transmitter and receiver which controls their respective wave-lengths. This switch has two positions, one being marked "stand-by wave," and the other "call wave." The arrangement of this switch is such that if it sets the transmitter to 400 metres, the receiver is automatically set to 350, and vice versa.

Let us imagine now that A wishes to call up B. Normally, both stations will leave their switches in the stand-by position, but as A wishes to start the conversation, he throws his switch into the call position. This will set his transmitter to the 400-metre wave-length. B's set is meanwhile sending out a carrier wave of a frequency corresponding to 350 metres, for his switch is in the stand-by position. It will therefore be seen that not only is B's receiving aerial being impressed with A's wave, the frequency of which corresponds to 400 metres, but he is also receiving his own carrier wave of frequencies corresponding to 350 metres. These two frequencies combine and form a third series of oscillations of a frequency corresponding to a wave-length of 2,800 metres. This is due to the well-known phenomena of the heterodyne, or beat principle.

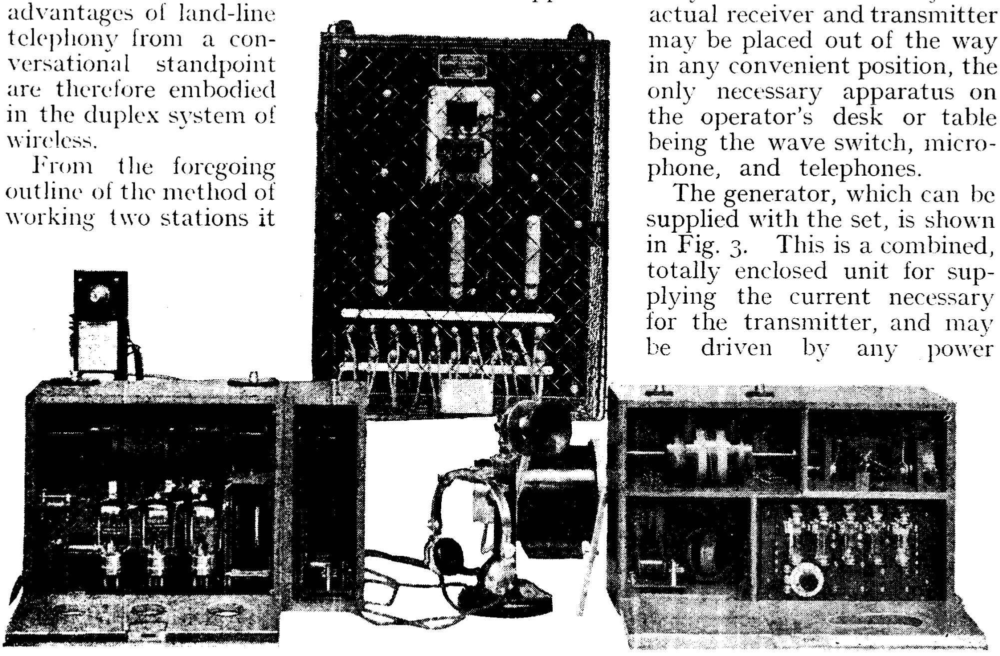
This third frequency is rectified by B's receiver, and the speech or whatever is passing is reproduced in his telephones. A similar sequence of events is meanwhile taking place in A's apparatus, the only difference being that his receiving aerial is impressed with a 400-metre wave from his own transmitter and a 350 one from B's. It will thus be seen that A and B may talk separately or together at will without either station actually receiving his own voice, even though his own receiving aerial is being impressed with his own modulated transmitted wave. All the advantages of land-line telephony from a conversational standpoint are therefore embodied in the duplex system of wireless.

From the foregoing outline of the method of working two stations it will be apparent that the system is readily adaptable to multiple stations working on the party line principle. The same procedure is followed as with two stations, namely, the station wishing to call throws his switch to the call position and indicates then with which other station he wishes to converse. The conversation may then be carried out without further switching.

A typical commercial duplex set, illustrated in Figs. 2 to 9, is the Marconi Duplex set. This set, by reason of its extreme simplicity of operation, is called the subscriber's set. The general arrangement of the complete apparatus will be seen by reference to Fig. 2. The transmitter is seen on the left of the picture, the receiver, with amplifiers, on the right. The generator unit and switchboard are in the centre, behind the very orthodox-looking microphone fitted with its radio-type head gear receivers.

While the whole apparatus is here shown all closely assembled, it is by no means essential for this to be the case in actual practice. Special remote control appliances may be fitted whereby the actual receiver and transmitter may be placed out of the way in any convenient position, the only necessary apparatus on the operator's desk or table being the wave switch, microphone, and telephones.

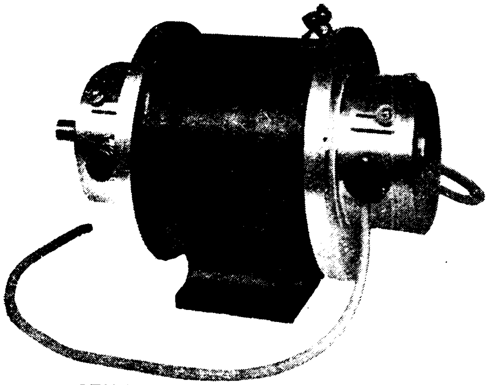
The generator, which can be supplied with the set, is shown in Fig. 3. This is a combined, totally enclosed unit for supplying the current necessary for the transmitter, and may be driven by any power



SUBSCRIBER'S DUPLEX TELEPHONY SET, TYPE XA2

Fig. 2. A simple wireless set of this kind enables two people to communicate with one another in exactly the same way as though they were speaking on ordinary land lines. The microphone and ear pieces are similar to the universal style of office table telephone combination, except that a pair of earpieces and headband are substituted for the usual single earpiece. The apparatus is shown closely assembled, but in actual practice may be placed in any convenient position

Courtesy Marconi's Wireless Telegraph Co., Ltd.



GENERATOR FOR DUPLEX SET

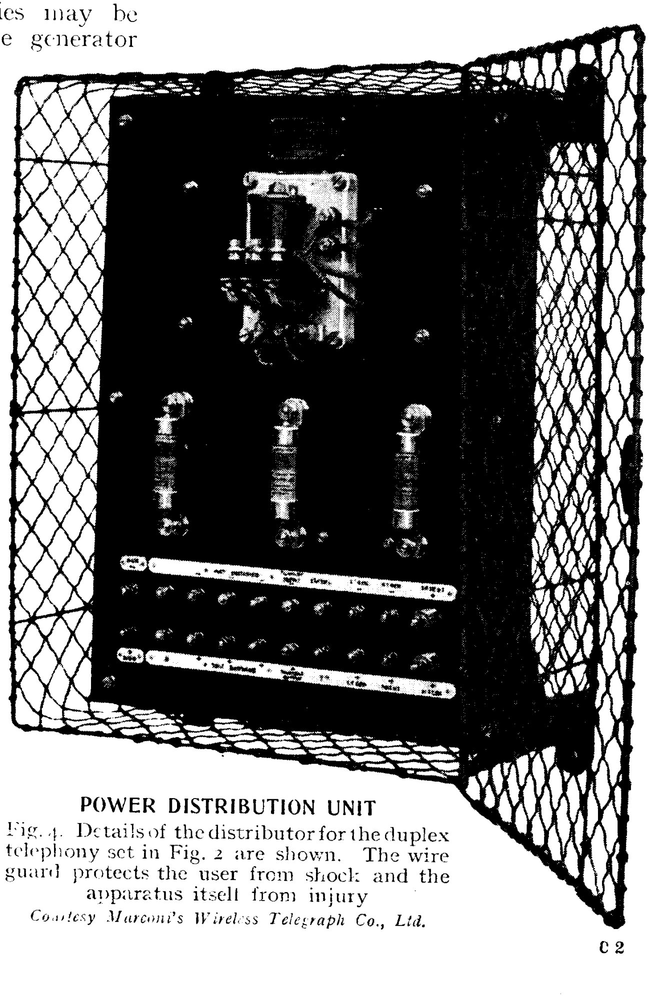
Fig. 3. Any power available may be used with the duplex telephony set, and a generator of the kind here shown may be used for supplying current to the transmitter. This is a totally enclosed generator, and is used in conjunction with a distribution board which brings all the necessary connexions to convenient terminals

Courtesy Marconi's Wireless Telegraph Co., Ltd.

supply available. Should this not be convenient, however, batteries may be used. The current from the generator is conducted to the distribution board Fig. 4. This board brings all the necessary connexions out to convenient terminals for connexion to the various components of the set. An auto cut-out and fuses are provided, and all terminals, etc., are plainly marked for their respective purposes. The user and the board are protected, the former from shock and the latter from mechanical injury, by a strong wire mesh cage with a hinged door.

Fig. 5 is an interior view of the transmitter, looking from the front. The transmitting and modulator valves may be seen, with the chokes, condensers, etc., in position. At the top of the cabinet, above the valves, is the tuner, which provides just sufficient adjustment of wave-length to allow of varying aerial sizes. When once set it need never be altered. A view of the same instrument, but from the back, is shown in Fig. 6. This shows the tuner and the other components more clearly. The short, straight bus-bar connecting wires may be noted, as well as the heavy insulation around the aerial and earth connexions, which may be clearly seen at the top of the cabinet.

The receiver unit is illustrated in Figs. 7 and 8. Fig. 7 is a view of the front of the instrument. The receiver comprises three high-frequency valves, a rectifier, and one low-frequency. V24 valves are used throughout. The tuning arrangements can be seen on the left-hand side of the cabinet. Like the transmitter, they only require an initial adjustment. The handles shown in the top right-hand compartment are the vernier condenser controls. Fig. 8 is a rear view of the same instrument showing the various coils and the connexions. A close-up view of the interior of the bottom left-hand compartment shown in Fig. 8 is given in Fig. 9. This is the rear of the valve panel. The



POWER DISTRIBUTION UNIT

Fig. 4. Details of the distributor for the duplex telephony set in Fig. 2 are shown. The wire guard protects the user from shock and the apparatus itself from injury

Courtesy Marconi's Wireless Telegraph Co., Ltd.

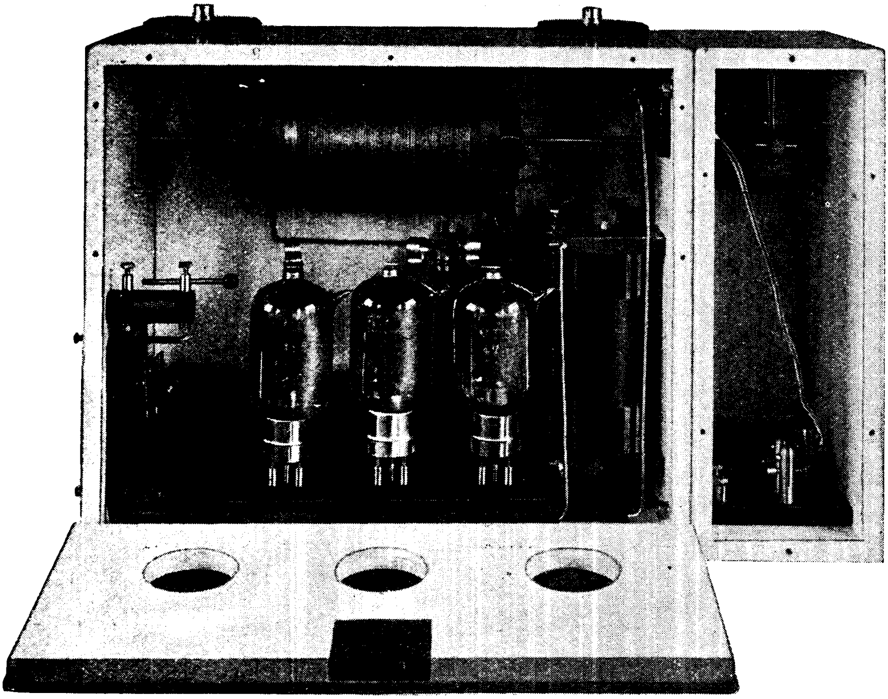


Fig. 5. Chokes, condensers, valves, and tuning coil are seen in this view of the interior of the transmitter, seen from the front. Sufficient adjustment can be made with the tuner to allow of different aerial sizes

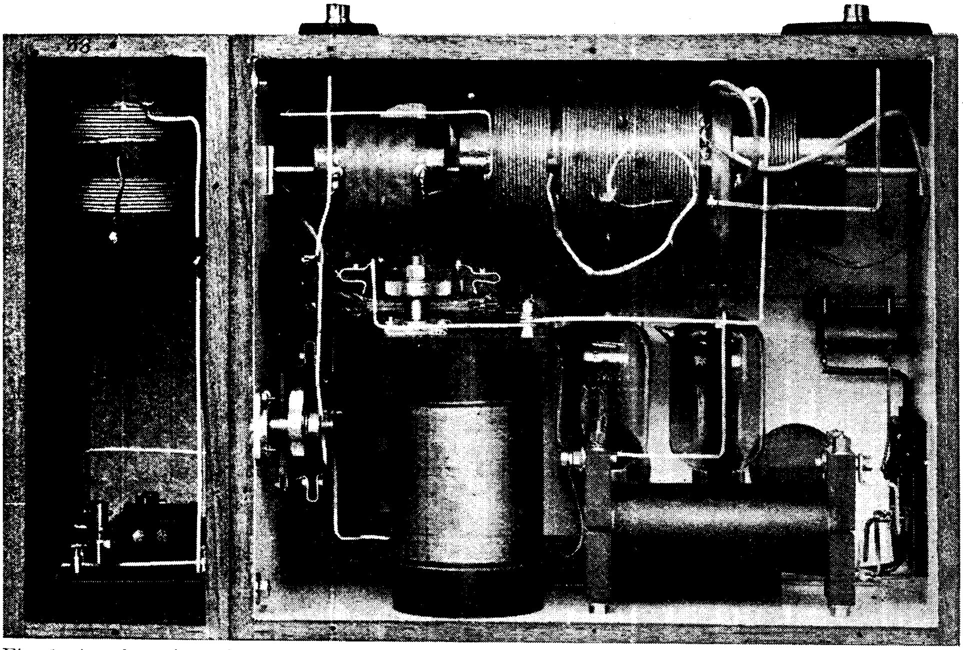


Fig. 6. Another view of the interior is taken from the back. It will be noticed that short straight connexions are used whenever possible, and the aerial and earth connexions are heavily insulated

Courtesy Marconi's Wireless Telegraph Co., Ltd.

INTERIOR AND REAR VIEWS OF DUPLEX SET TRANSMITTER

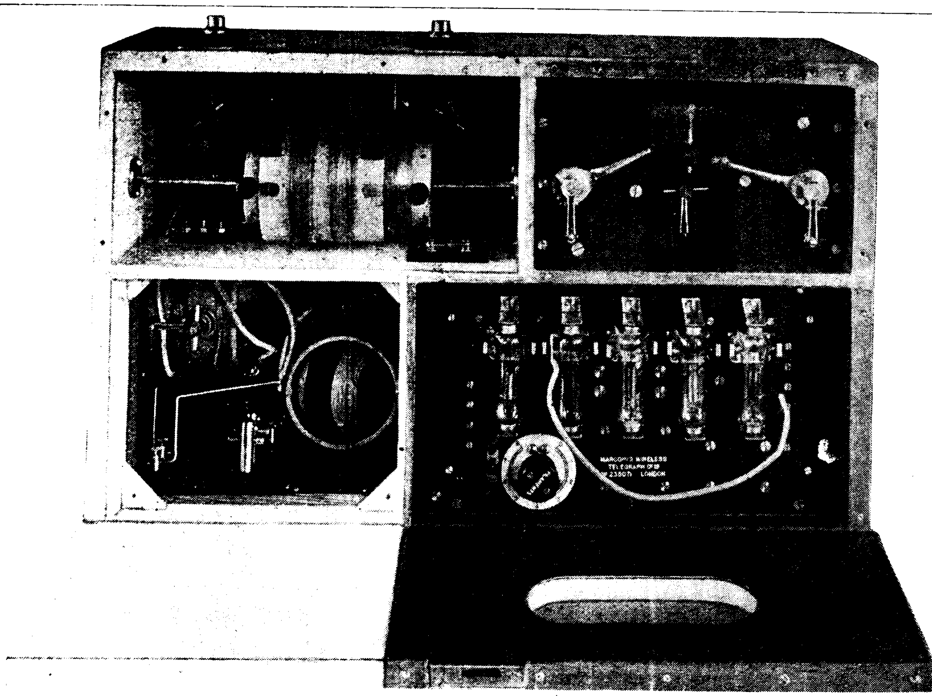


Fig. 7. Five V24 valves are mounted on the panel with one filament control switch. Three of these are high-frequency, one is rectifying, and the fifth low-frequency. This is a front view of the interior. In the right-hand top corner will be seen the two handles for operating the vernier condensers

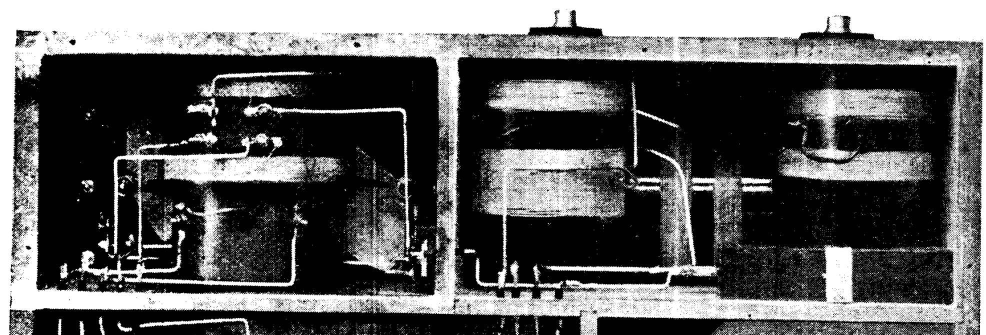


Fig. 8. On the reverse side the interior shows the various coils and connexions. The connecting wires are as short as possible. In the bottom left-hand compartment the rear of the valve panel cannot be actually seen, as the baseboard through which the leads are taken intervenes. A photograph of the contents of this compartment is given in Fig. 9

Courtesy Marconi's Wireless Telegraph Co., Ltd.

RECEIVING UNIT OF THE DUPLEX TELEPHONY SET

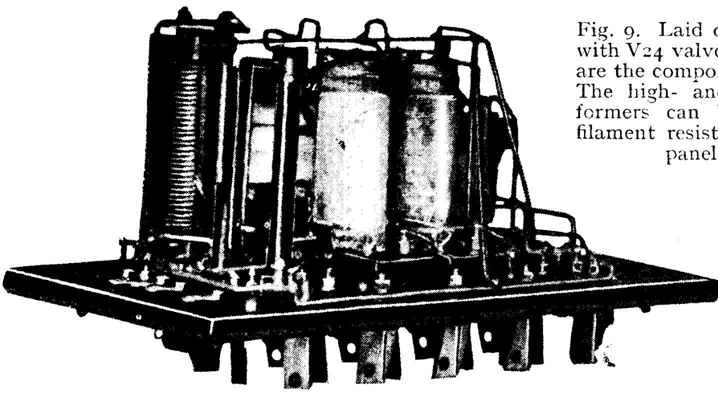


Fig. 9. Laid on its face is the panel, with V24 valve holders, and uppermost are the components behind the valves. The high- and low-frequency transformers can be seen and the heavy filament resistance. The front of the panel is seen in Fig. 7

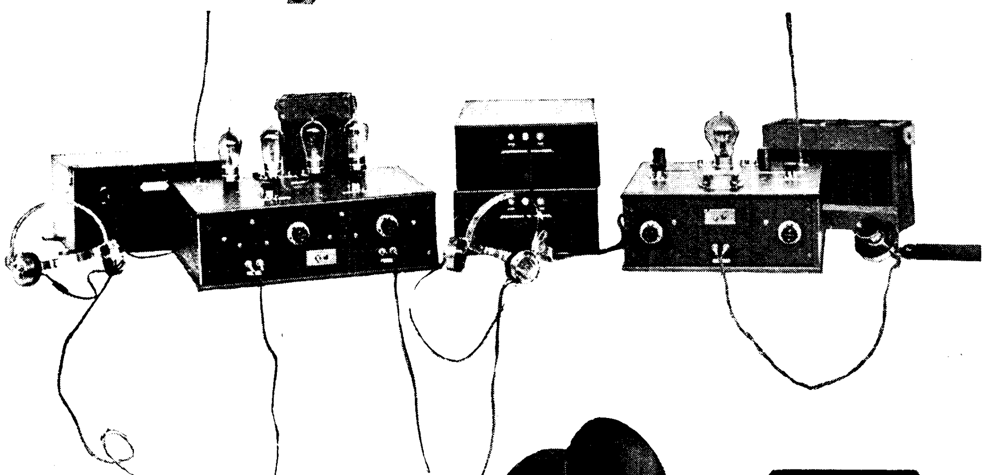


Fig. 10. Known as the XPI set, the complete duplex telephony apparatus is here seen with its various units assembled. A hand microphone is attached in this case, but a table combination receiving and sending set as in Fig. 10 may be used

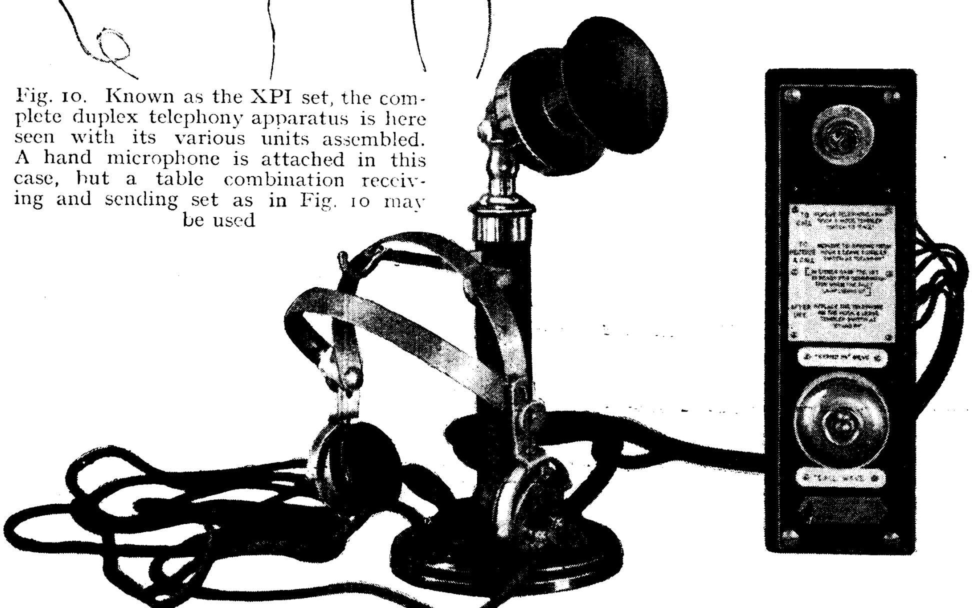
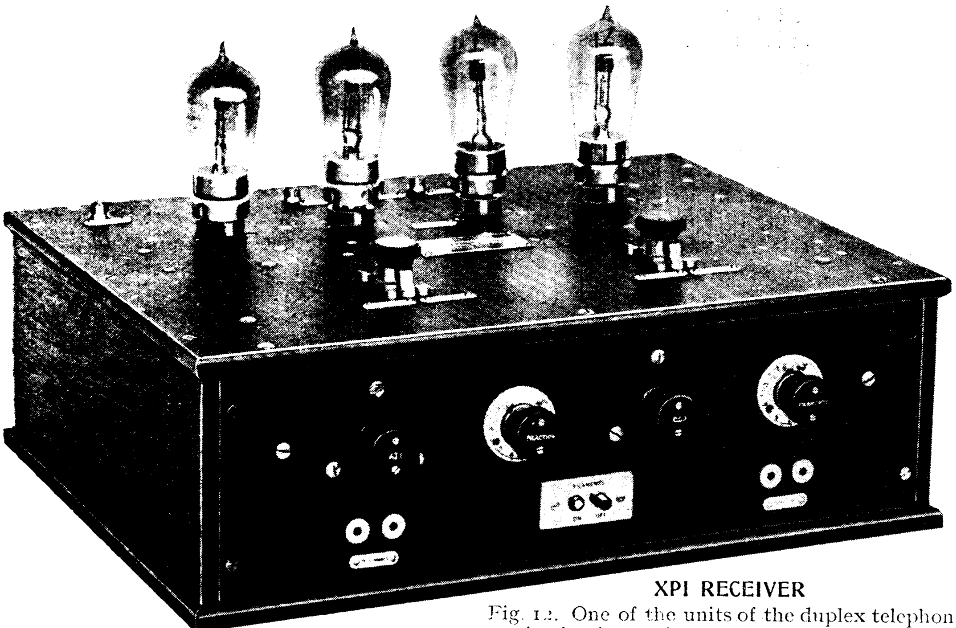


Fig. 11. Both reception and transmission are possible with the duplex telephony set, and a table microphone with lift-off double earpieces can be used for conversation two ways. Once the apparatus is tuned-in all that is required of the operator is to switch on and lift off the receivers

DUPLEX TELEPHONY SET COMPLETE AND DETAILS

Courtesy Marconi's Wireless Telegraph Co., Ltd.

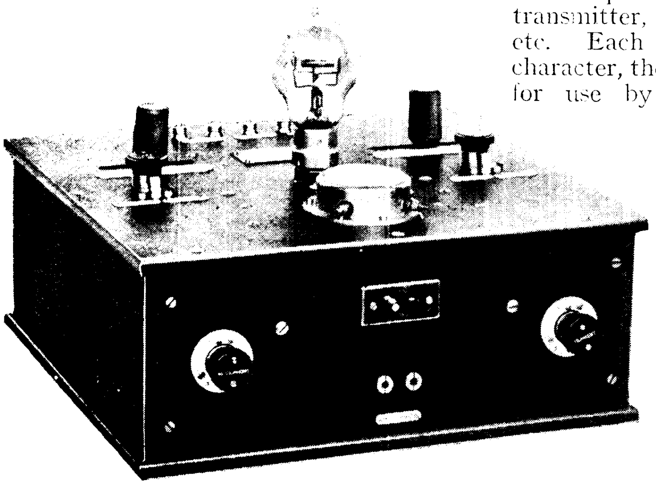


XPI RECEIVER

Fig. 12. One of the units of the duplex telephony set is the four-valve receiver. This is designed to work on wave-lengths of 190 to 260 metres

Courtesy Marconi's Wireless Telegraph Co., Ltd.

high-frequency and low-frequency transformers are clearly shown. Note the heavy filament resistance, which controls the filament temperature of all the valves. Finally, Fig. 10 is a photograph of the only apparatus which the operator has to handle. A clear exposition of the switch control is given on the right. The simplicity of working of the whole apparatus may be gathered from this picture.



DUPLEX TELEPHONY TRANSMITTER

Fig. 13. Wireless knowledge is not necessary in order to make use of this apparatus. The transmitter of the complete set shown in Fig. 11 is shown here, and is of very simple design. The microphone plug is inserted in the sockets in the front centre at the bottom

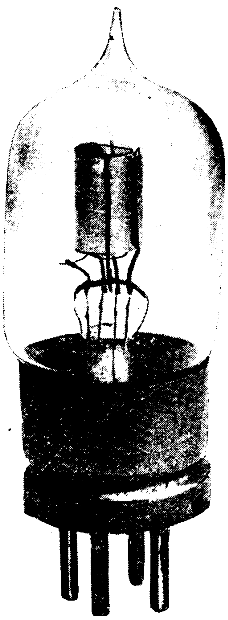
Courtesy Marconi's Wireless Telegraph Co., Ltd.

The set just described, given a good aerial, has a normal dependable range of 45 miles. A simpler and less costly set, which can be obtained to work on either the simplex or duplex system, is illustrated in Figs. 10, 12, and 13. The complete apparatus is shown in Fig. 10. In this picture will be seen the receiver, transmitter, battery boxes, accumulator, etc. Each unit is of the very simplest character, the whole station being designed for use by people having no wireless knowledge. Separate illustrations of the receiver and transmitter are given in Figs. 12 and 13 respectively. The set is designed to utilize wave-lengths of 190 to 260 metres when arranged to work on the duplex system. *See* Transmission. —*R. B. Hurton.*

DUTCH METAL. An alloy of copper and zinc, technically forming one of the brasses. The proportion of copper is high, ranging from 77·75 to 84·5 per cent, and the colour of the alloy varies from pale to dark yellow according to the proportions of copper used.

It is much used as a substitute for gold leaf, and its only use in wireless is for ornamental purposes.

DUTCH VALVE. Name given to a type of soft rectifying valve. The Dutch valve is very similar in appearance to the Mullard "Ora" and the Ediswan A. R. valve, but shorter in length and larger in diameter than these two valves. A feature of this valve is its low vacuum, which makes it specially suitable for rectification purposes, but of little use for either high- or low-frequency amplification.



DUTCH VALVE

Soft Dutch valves of this type are specially suitable for rectification purposes

DWYER'S ARC. Form of arc oscillation generator due to H. P. Dwyer, and patented by him in the United States of America in 1912. The Dwyer arc was tested in America in 1910. The tests were carried out between San Francisco and Los Angeles, a distance of nearly 500 miles, and gave excellent telephonic results. A copper positive electrode and an aluminium negative electrode are used. Both are cooled by the circulation of liquid through them at a low temperature. The complete apparatus is immersed in alcohol to keep the temperature within reasonable limits. A stream of alcohol is forced through the hollow copper electrode into the arc space in a manner similar to that used in the Moretti arc (*q.v.*). The Dwyer method, however, gives stronger and steadier oscillations than the Moretti arc.

DYKE AND FLEMING BRIDGE. A variation of the Wien capacity bridge due to G. B. Dyke and J. A. Fleming. By means of the bridge the capacity of a condenser may be calculated when such a condenser is being used in wireless circuits. The figure shows the form of the bridge. C_2 and C_3 are two air condensers variable in capacity, whose conductance may be neglected. C_4 is another variable air condenser connected to a non-inductive resistance, R, and C_1 is a fixed condenser connected across a grid leak, S, of known resistance. The bridge circuit is joined across through a telephone The ends of the bridge arms C_3 and C_4R are connected to a source of alternating current.

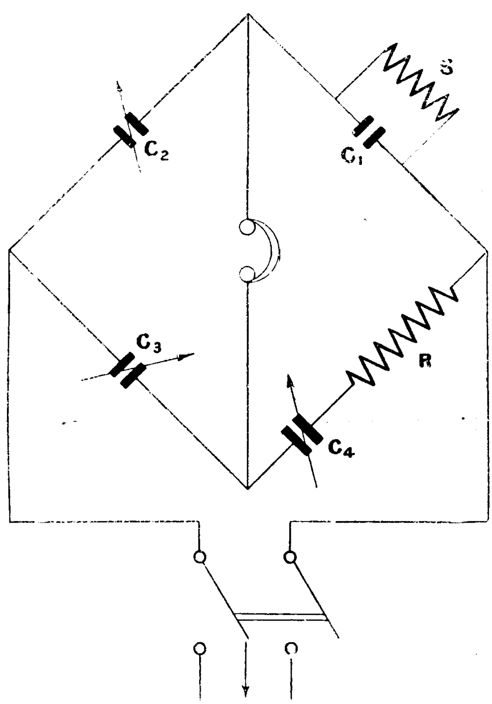
When the impedances of the four arms of the bridge are in proportion there will be no sound in the telephones. The equations determining this condition are:

$$S/C_1 p = p C_4 R$$

$$\text{and } C_2/C_3 = C_1/C_4 + RS$$

where $p = 2\pi$ times the frequency of the alternating current. The solution of these equations gives the separate values of S and C_1 in terms of C_2, C_3, C_4 and R when p is known.

DYNAMIC EQUATOR. Name given to an irregular curve drawn through the point of each magnetic meridian on the earth's surface where the magnetic intensity is the least. *See* Magnetism.



DYKE AND FLEMING CAPACITY BRIDGE

Condensers used in wireless circuits may have their capacity calculated by a variation of the Wien capacity bridge. A theoretical circuit diagram is given of this bridge, which is due to Dyke and Fleming

THE DYNAMO: HOW IT IS MADE & HOW IT WORKS

Details of the Standard Types of Dynamo, Fully Illustrated

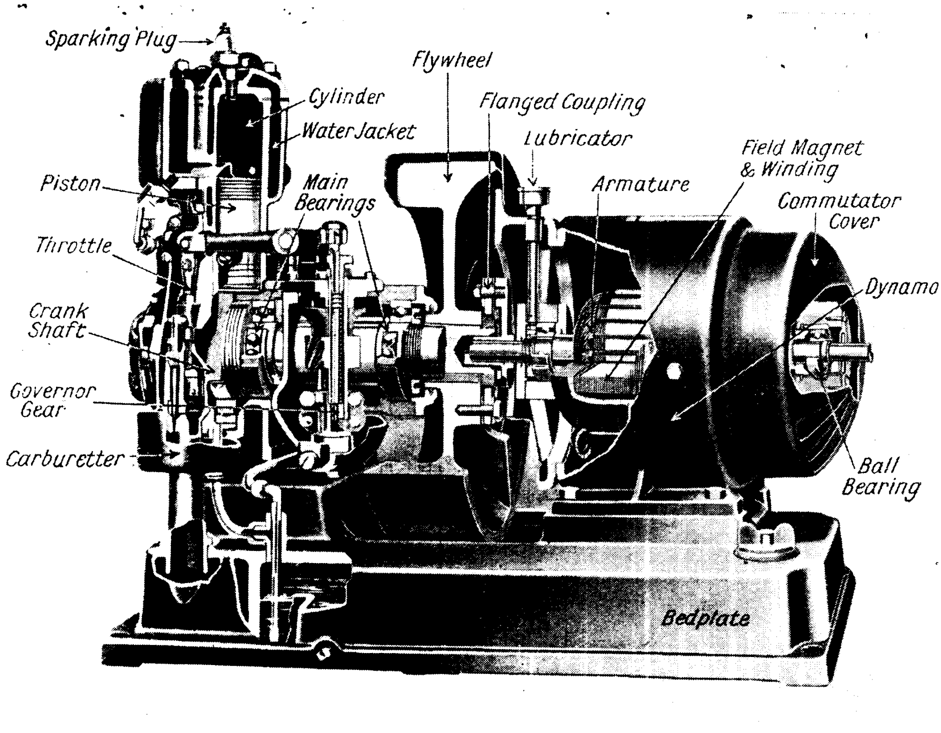
In this section a complete description is given of the way a dynamo, one of the most useful electrical machines, works, with practical hints on its handling and care. The article should be read in conjunction with such articles as Generator, and cognate articles, as Electricity, Flux, Magnetism, should be consulted. See also Influence Machine; Frequency Changer

A dynamo is a machine for converting mechanical into electrical energy by electro-magnetic induction. All dynamo-electric machines are commercial applications of Faraday's discovery of induced currents in 1831, however disguised they may be in external form. Dynamos may be divided broadly into two classes, alternating and direct current machines.

The former are more often known as generators, and both types are employed in wireless. The direct current dynamo is the most common method of charging accumulators, and it is in this connexion that the dynamo is largely used by the experimenter. Methods of charging accumulators by means of a dynamo, together with circuit diagrams, are given under the heading Accumulator in this Encyclopedia.

The alternating current machine is extensively used in transmitting stations for generation of high-frequency currents, and may also be used when necessary for charging accumulators or other purpose where a unidirectional current is required, provided a Noden valve or other type of rectifier is included in the circuit. Charging from an alternating current supply, using various types of rectifier, is described on page 16.

The main essentials of a dynamo are the armature (*q.v.*), with commutator and field magnets, and a means of rotating the armature relative to the field magnets.



SECTIONAL DIAGRAM OF A LALLEY LIGHT DIRECT-COUPLED DYNAMO

Fig. 1. Direct current dynamos are frequently used for charging accumulators. This is a Lalley 500/750 watt direct current dynamo, directly coupled to a single cylinder two-stroke engine on the left. A section of the flywheel appears between. All parts are shown in section

Courtesy Studebaker, Ltd.

These are shown clearly in Fig. 1, from which a comprehension of the relative location of these parts may be obtained.

The figure shows a sectional illustration of the Lalley light generating set. This consists of a single cylinder two-stroke petrol engine seen on the left of the illustration and directly coupled to a 500-750 watt direct current dynamo. Between them is seen a section of the flywheel.

The engine, which is of the water-cooled pattern, is a unit in itself, and is bolted securely to a large cast-iron bed, a part of which acts as an oil reservoir. Lubrication of the moving parts is effected by means of a mechanically actuated pump. The engine shaft, mounted on ball bearings, has an oil-retaining device, consisting of a drum having a series of grooves around its circumference. This is essential to prevent oil from reaching the wires of the dynamo, where its presence would cause deterioration of the insulation. The engine is governor-controlled, and this feature, combined with a massive flywheel, gives the set a very even speed. On the side of the flywheel nearer the dynamo is fitted a series of vanes arranged to form a fan for cooling the dynamo. The dynamo shaft is also mounted on ball bearings, and is connected to the engine shaft by means of a flange keyed to the end of the armature shaft and then bolted to a flange on the flywheel.

Home Charging and Lighting Set

The commutator, which is hidden in the illustration by the casing of the machine, is mounted on the armature shaft on the right of Fig. 1. The armature is of the drum-wound type, having a retaining band across the wires to prevent them from flying out by centrifugal force.

An installation of this type is very suitable for house lighting and charging purposes. It is essential that the form of power used for driving the dynamo should be capable of attaining the revolutions the latter requires, and a convenient method of transmitting power running at a lower speed than the required dynamo speed is to use a belt transmission with a larger pulley on the engine shaft than the dynamo pulley.

Thus for a dynamo to function, the armature must be revolved rapidly between the poles of the field magnets. The nature of the current generated will depend largely on the system upon which the machine is wired. There are three methods adopted in wiring direct current dynamos, known as series, shunt, and compound winding.

In series winding the armature, field magnets, and the external circuit are all in series, which arrangement is suitable where the speed of the dynamo and the loading or resistance of the external circuit is constant. Where these factors vary the shunt or compound-wound machines are more suited to the work.

The field magnets of the former are wound with many turns of finer wire, giving them a higher resistance than the field magnets of the series type. This comparatively high resistance of the fields enables them to be shunted across the armature windings. The external circuit is also shunted across the armature. Shunt-wound dynamos are by far the most suitable for accumulator charging, as in the event of the dynamo failing to excite the polarity of the field magnets is not reversed.

How the Compound-Wound Dynamo is Built

The compound-wound dynamo is a combination of both series and shunt types, and is most often found in large machines.

The practical direct current generator consists essentially of two main parts, the field magnets and the armature. In the majority of machines, such as the Crypto (seen in Fig. 2), the field magnets are stationary and provide a magnetic flux in which the armature revolves. Two or more poles are provided for the field magnets, which are arranged alternately north and south. In practical work four or more poles are usual, made of soft iron. They are either cast integral with the dynamo yoke or body, or cast in special iron and bolted on afterwards. The body has a triple purpose—one, to support the poles, two, to support the armature bearings, and three, to provide a path of low reluctance for the magnetic circuit.

The armature bearings carry a rigid shaft, to which is clamped a cylindrical mass of soft iron composed of laminae and known as armature stampings (*q.v.*), in which a series of longitudinal slots are arranged. Insulated copper wires are laid inside these slots, and are connected to a commutator placed on one end of the shaft. Suitable collecting gear is attached to the body on this side, and usually consists of carbon or copper gauze brushes as described under the heading Brushes and Brush Holders.

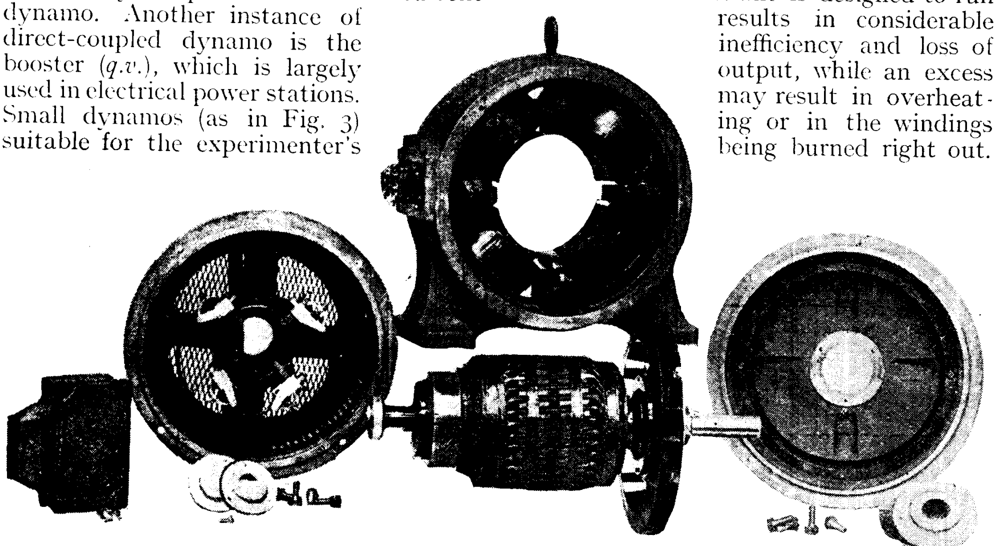
When the armature is revolved by external means a feeble current is generated in it owing to a certain amount of residual magnetism in the field magnets. This current is built up by further increases of magnetic flux until the maximum lines of force for the particular speed at which the machine is running are reached. In the case of the series machine no excitation occurs until the external circuit has been completed.

For accumulator charging a dynamo should be chosen having at least six, or preferably eight, commutator segments, as the fewer the segments the more pulsating will be the resulting current, and an accumulator will not be properly charged if the current is seriously intermittent.

Many methods are adopted for driving dynamos, which largely depend on the size of the machine and the purpose for which it is required. Where current is generated in large quantities, it is usual to couple the generator direct to a triple-expansion steam engine or oil engine. Direct coupling is also used to convert one form of electrical energy to another, and in this case an alternating motor may be directly coupled to a direct current dynamo. Another instance of direct-coupled dynamo is the booster (*q.v.*), which is largely used in electrical power stations. Small dynamos (as in Fig. 3) suitable for the experimenter's use can conveniently be driven by a small gas, steam or oil engine, the power being transmitted by means of a flat belt. If the dynamo is to be used for lighting purposes, care should be taken to use a form of power having an even torque, otherwise a "jerky" motion will be transmitted to the lamps, resulting in a fluctuating light. This may be avoided if accumulators are used and the power used for charging them up.

The dynamo should be securely bolted down to a concrete bed and care taken to line it up correctly to the form of power used. Where shafting is already in use for driving machinery, the dynamo is readily driven by a belt from a flat pulley on the shaft, which will be found to be the best and cheapest method of driving it. It is inadvisable to use a short belt, neither is it good practice to run the belt in a vertical position. An uphill drive at an angle of about 45° is best.

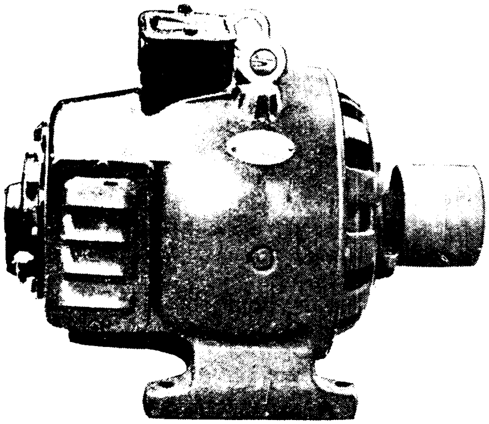
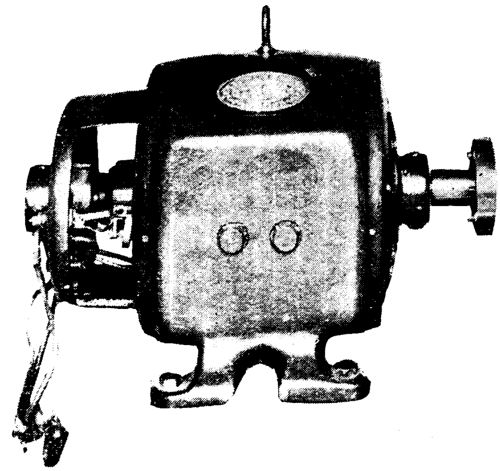
The speed at which a dynamo is driven is an important factor on which the efficiency and safety of the machine largely depends. The table on the following page will be found of use in ascertaining the correct speed at which a machine should be run. Failure to reach the speed for which the machine is designed to run results in considerable inefficiency and loss of output, while an excess may result in overheating or in the windings being burned right out.



5 KW. DIRECT CURRENT GENERATOR WITH INTERPOLES

Fig. 2. Dissembled and arranged for inspection are the parts which make up a 5 kw. generator. This is a Crypto direct current generator. The armature, complete with cooling fan, is seen in the centre of the foreground, with the yoke, containing poles and interpoles, immediately behind. To the left is one bearing support, with brush rocker attached. On the extreme left is the terminal box, and on the right the other end plate

Courtesy Crypto Electrical Co., Ltd.

EXAMPLES OF DYNAMOS FOR AMATEUR WIRELESS STATIONS

Fig. 3 (left). For experimental purposes a dynamo of this kind may be used. This consists of a semi-enclosed machine, with terminal box mounted on top. A slightly crowned pulley is used in conjunction with a flat belt for transmission of power. Fig. 4 (right). A bipolar dynamo for house lighting and battery charging is illustrated. The output at 750 r.p.m. is 750 watts

Courtesy General Electric Co., Ltd.

CORRECT DYNAMO SPEEDS.

Diameter of Armature in inches.	Speed Revolution per minute.
1	4,000
$1\frac{1}{4}$	3,800
$1\frac{1}{2}$	3,300
$1\frac{3}{4}$	3,000
2	2,800
$2\frac{1}{4}$	2,700
$2\frac{1}{2}$	2,600
$2\frac{3}{4}$	2,500
3	2,400
$3\frac{1}{2}$	2,250
4	2,150
5	1,900
6	1,650

After the dynamo has been running for a period of fifteen minutes it should be stopped and the hand placed on the windings to ascertain that it has not been overheating.

A trouble prevalent with dynamos, unless periodic attention is given, is sparking at the collecting brushes. Sparking usually takes one or two forms. A small white spark or series of sparks usually indicates that the commutator requires cleaning. This spark is not serious, and will probably disappear when the commutator has been cleaned.

A more serious kind of sparking is shown by a vivid green arcing at the brushes. When this occurs the dynamo should be stopped at once. The greenness of the spark indicates that the copper segments of the commutator are being burned, and if this is allowed to continue considerable damage may be done. Green sparking is sometimes caused by frayed edges to the gauze brushes, by uneven wear to the brushes or their incorrect adjustment.

The most convenient way to clean a commutator is to procure a flat stick of dry hardwood and wrap a piece of soft rag round one end. A piece of F.F. emery paper is wrapped over the rag, the whole being bound to the stick with a piece of string. The stick is now rested against the dynamo in a convenient position so that the rounded edge of the emery paper touches the commutator. The stick is held towards the direction of rotation of the commutator while the machine is being rotated.

If the emery paper is not sufficiently wide to cover the width of the commutator it should be carefully moved along, taking care not to make a groove. Should the commutator squeak when running, the smallest trace of lubricating oil may be applied when cleaning. This trouble may be obviated by decreasing the pressure on the brushes or on any particular brush with too much tension.

If cleaning the commutator fails to check the sparking, the collecting brushes should be taken out for inspection. It sometimes happens, especially with carbon brushes, that a glazed surface occurs on the side of contact with the commutator. This may be removed by putting the brush in a vice and removing the glazed portion with a piece of emery paper. Care should be taken not to rub the brush out of shape or another cause of sparking will result; or the emery paper can be placed face up on the commutator beneath the brush and the commutator rocked to and fro.

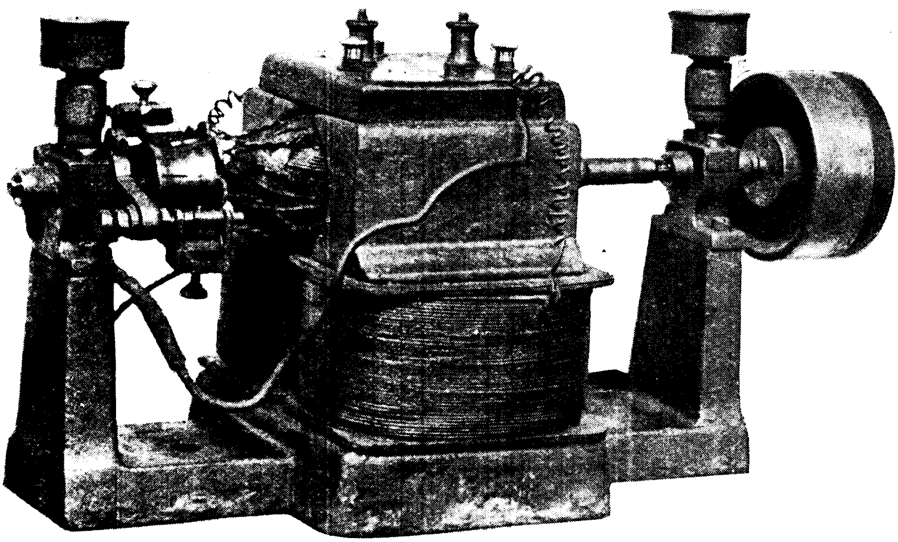
With dynamos the correct tension of the brushes is a matter of importance. A good method of securing this tension in small machines is to insert a voltmeter in the external circuit. The tension of the brushes may now be varied, with the object of securing the least pressure consistent with the maintenance of voltage and freedom from sparking.

A commutator in good condition should be flat throughout its length, but in time it will be found to wear hollow in the centre. Providing it has not worn unevenly, this does not matter much if the brushes are also worn to fit. With a commutator worn in this way, sparking will occur if the armature sways from side to side. This usually indicates a slack belt. If the belt is taken up a little, trouble from this cause will disappear.

Many types of dynamos have ring-oiler lubrication, and when oiling up it should be noted that the oil overflow pipe is free from obstruction.

In Figs. 3 and 4 are seen two commercial types of dynamo suitable for house lighting and battery charging. Both machines are made by the General Electric Company. The dynamo illustrated in Fig. 3 is a $1\frac{1}{2}$ kilowatt generator supplying a voltage of 25 at 750 revolutions per minute, requiring about 3 horse-power.

Fig. 4 illustrates a $\frac{3}{4}$ kilowatt machine, driven also at 750 revolutions per minute. This machine is bi-polar, and is shown with one brush removed. A flange on the free end of the armature spindle is used for direct coupling to a petrol engine or similar form of high-speed engine.



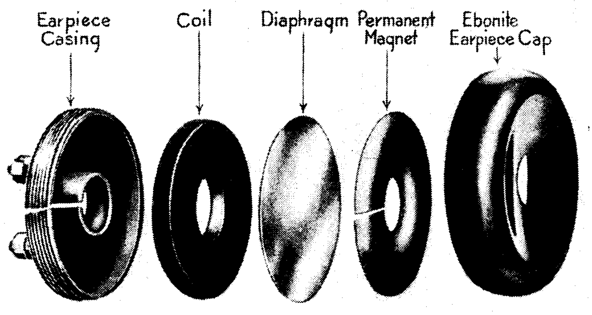
OVERTYPE CHARGING MACHINE WITH EIGHT-POLE ARMATURE

Fig. 5. Without seriously heating, this dynamo will deliver 5 to 6 amperes for fairly long periods. The machine is shunt-wound and designed to give 25 volts at 1,500 r.p.m. Fields are brought to the two terminals seen toward the front of the terminal board, so that a field rheostat can be conveniently connected in this way

The dynamo illustrated in Fig. 5 is an "overtype" charging machine with an eight-pole armature. The machine is shunt-wound, the fields being brought to two terminals so that they may be conveniently connected to a field rheostat. The field terminals are seen towards the front of the terminal board.

The dynamo is designed to give 25 volts at 1,500 revolutions per minute, and will deliver 5 to 6 amperes for fairly long periods without serious overheating. Copper gauze brushes on an adjustable rocker are fitted. In order to prevent undue wear on the commutator, the shaft is allowed about $\frac{1}{2}$ in. end play in the bearings. This allows it to move about longitudinally (which it does do if a fairly long belt is used for driving), and thus distributes the brush wear on the commutator.

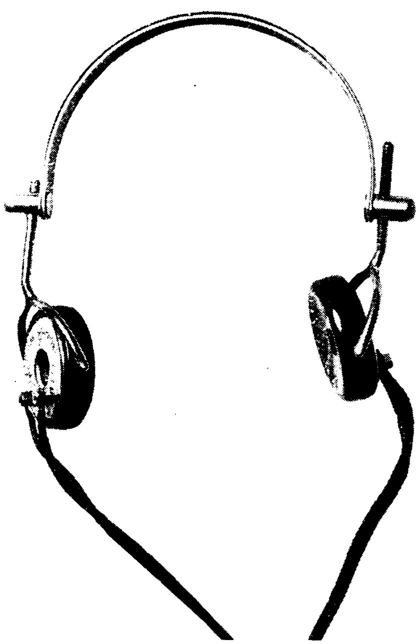
It is often desired to know the horse-power required to drive a dynamo of a given size, and this may be ascertained in the following manner. The voltage and amperage of the machine in question are multiplied together and the product divided by 746, which number of watts is taken as the standard of electrical horse-power. A small margin of 5 to 10 per cent may be added for mechanical losses and electrical inefficiency. Large dynamos are found to be rather more efficient than smaller ones, and will often return as much as 95 to 98 per cent in electrical power of the mechanical energy expended on them. *See* Generator.



DYNAPHONE COMPONENTS

Fig. 2. Parts of a dynaphone arranged in the order in which they are assembled. Both permanent magnet and windings are of a special type, and the receiver works on electro-dynamic principles instead of electro-magnetic

Courtesy Radio Communication Co., Ltd.



EXTERNAL VIEW OF DYNAPHONE

Fig. 1. Outwardly the appearance of the dynaphone is very much the same as ordinary telephones. The chief difference is the hole in the back, which corresponds with that in the ebonite ear-cap, the purpose of which is to reduce the air-cushioning effects on the diaphragm

Courtesy Radio Communication Co., Ltd.

DYNAMOMETER. Device for measuring force or power. The term is extensively used for many different kinds of measuring instruments, but it is better confined to those instruments used for measuring the horse-power of engines. In electrical work the electro-dynamometer is another term for a wattmeter. *See* Electro-dynamometer; Wattmeter.

DYNAPHONE. The dynaphone is a type of telephone receiver in which radical departures from standard practice have been made. An external view of the dynaphone double headgear receiver is given in Fig. 1. Externally the dynaphone differs from the ordinary telephone in that there is a hole in the rear of the receiver case. This hole is of the same diameter as that in the ebonite ear-cap. The headband used is made of aluminium throughout and is very light in weight. Adjustment for different-sized heads is provided by sliding the tailpiece of the fork which holds the earpiece through a hole. A knurled screw is fitted for clamping the tailpiece in position, when final adjustment has been made.

Fig. 2 shows the five components of the dynaphone dis-assembled, but in their correct relative disposition. It will be noted that the earpiece casing is split through one side; and an annular groove is made all round inside, to take the receiver coil. This coil, which is of circular formation wound upon a former, is, for a telephone winding, of very large dimensions. Owing to this large diameter a heavier gauge wire for the same resistance may be used. Furthermore, ample space for impregnating the coil is automatically provided. The Radio Communication Co., Ltd., who are the manufacturers, claim that owing to this construction there is very little likelihood of the individual turns short-circuiting, or the insulation burning out under heavy work on high voltages. The diaphragm is quite a normal component, being made of a special grade of iron for the purpose.

The magnet, which is clamped between the diaphragm and the ebonite casing, is of the same size as the coil and practically the same shape. This also is split through one side in the manner indicated in the photograph. A screwed ebonite cap is used to clamp the five components together and to form the earpiece.

From the construction embodied in this receiver it will be apparent that an electro-dynamic effect is produced. The name of the instrument is, of course, derived from this effect. In reality the whole receiver becomes a transformer, wherein the winding forms the primary, and the diaphragm itself the secondary. The eddy currents which are produced in the diaphragm, and which are a replica of the current in the windings, are unaffected by any magnetic circuit, for this is practically non-existent, due to the fact that the magnet is not in itself a closed circuit. Again due to the slotted magnet, no eddy currents of any consequence form therein, their flow being prevented.

The vibration of the diaphragm is produced by the magnetic flux from the permanent magnet reacting with the currents in the diaphragm. The magnetic pull is distributed evenly over an area of about one-third of the diaphragm's diameter, which is claimed to be an advantage over the comparatively small area pull of the usual pole-pieces of the more orthodox telephone receiver. Air-cushioning effect on the diaphragm is reduced by having an open air-space on both sides of it.

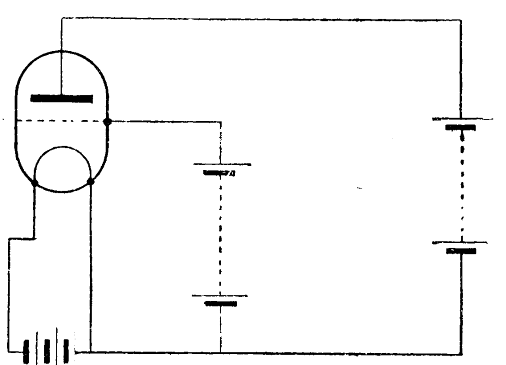
DYNATRON. A thermionic device, similar in construction to an ordinary valve, but possessing a negative resistance which enables it to produce continuous oscillations such as are required for C.W. transmission.

The dynatron consists of three electrodes enclosed in an evacuated globe, the first being a filament, usually a spiral of fine tungsten wire. The second electrode—the anode—may also be a spiral of thicker wire, or a perforated metal cylinder. The third electrode, known as the plate or "target," is a plain metal cylinder, containing in its internal circuit a condenser and an inductance which determine the frequency of the oscillations generated.

A low-tension battery heats the filament, another battery applying a high positive potential to the spiral forming the anode. Now, if a conductor be placed in close proximity to a filament emitting a stream of electrons under these conditions, electrons striking the surface of the conductor mix with the electrons of the latter, and, if the conductor is maintained at a steady potential with respect to the filament, there will be a flow of current along the external circuit. But it is necessary to impart to the primary electrons—those emanating from the filament—sufficient velocity to enable them by their impact to knock secondary electrons off the surface of the conductor, in this case the third electrode, the plate or "target."

The plate receives its potential either from a third battery or from a tapping off that supplying the anode. In Fig. 1 the three electrodes of the dynatron and their sources of potential supply are shown.

The electrons are, in the first instance, sucked from the filament by the anode, and some pass along the anode circuit; others through the spiral or perforations of the anode to the plate, whence they pass along the plate circuit. But secondary emission, or the knocking off of secondary



DYNATRON CIRCUIT

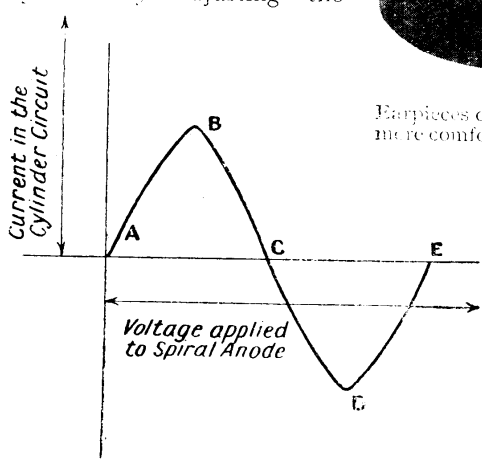
Fig. 1. Sources of potential supply and the three electrodes are shown in this diagram. There is no grid The three electrodes consist of filament, spiral or cylindrical anode and a cylindrical "target" or plate. The plate receives its potental from a separate battery

electrons from the plate, does not occur until the voltage of the plate has been raised sufficiently to give the impinging primary electrons the requisite velocity. It is now the turn of the anode to attract the secondary electrons, with the result that the second current thus formed in the plate circuit is in the opposite direction to that of the original flow of primary electrons.

A characteristic curve for the dynatron is shown in Fig. 2. The part A B of the curve is explained by D. Alcase as representing the increasing current in the plate circuit. From B to C shows a lessening of current, until at C as many secondary electrons are released as there are primary electrons received, and there is zero current in the plate circuit.

The portion C to D shows the increase in the number of secondary electrons knocked off the plate, and the growing value of the reverse current. At the point D, however, the potential of the plate has so closely approached that of the anode that the latter begins to lose its power of attraction for the secondary electrons. At the point E the number of secondary electrons which have left the plate never to return has again become equal to the number of primary electrons received, and the net current is again zero.

Continuous oscillations are set up in the plate circuit by suitably adjusting the initial voltage applied to the plate. These oscillations, after their frequency has been adjusted by means of a condenser and inductance in the external plate circuit, can be transferred inductively to a transmitting aerial in the ordinary way. The dynatron may also be used as a detector, or as a current or voltage amplifier, but its value in this connexion is not sufficiently marked to indicate any likelihood of its general use. *See* Magnetron.



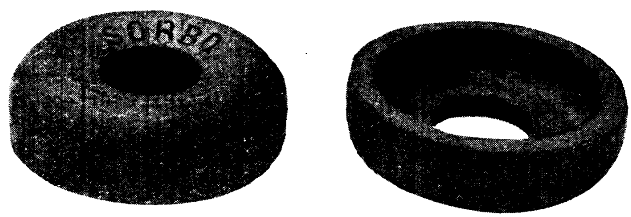
CHARACTERISTIC CURVE OF DYNATRON

Fig. 2. Increasing current is represented by the portion A B, and from B to C a lessening. C D shows the growing value of reverse current. At the point D the anode begins to lose its power of attraction for secondary electrons

DYNE. Unit of force, which, applied to a mass of one gramme, produces an acceleration of one centimetre per second every second. It is the unit of force in the C.G.S. system. The dyne is very nearly equal to the force with which the earth attracts a weight of one milligramme at sea level. *See* Erg; Joule; Units.

E

EAR PADS. Name given to a flexible device adapted to be placed on a telephone receiver to relieve the pressure on the ears of a listener. A well-known example is illustrated and shows the characteristic appearance of a type made in moulded and vulcanized rubber. In use ear pads improve the acoustic qualities and are very comfortable, especially when the instrument is in use for lengthy periods. For hygienic reasons they should be cleansed occasionally by washing in warm water.



SORBO EAR PADS

Earpieces of the headphones of a wireless receiver may be made more comfortable by the addition of these flexible devices, which relieve the pressure upon the ears

EARTH. Expression used to refer to the actual earth itself, and in an electrical sense to that side of a circuit which is connected to the earth. The expression is also sometimes used in electrical work to describe an absolute short circuit.

The earth plays a very important part in wireless work. It is conveniently considered as the return side of a circuit which commences at the generator of a transmitting station, continues through the apparatus, thence through the ether, and is intercepted by the aerial of the receiving set. The current flows through the receiving set and thence to earth, and so back to the station from which it started. While this is not a technically accurate or complete explanation, it serves to emphasize the fact that to the experimenter the earth, and the connexions therewith, are as important as the aerial. It must also be remembered that water acts as a conductor and therefore is a good earth, and in the case of a ship the earth return is made through the sea water. There are in practice two classes of earth: first, those that make actual contact with the ground or water, and secondly, those which are deliberately insulated from it, as in the case of a counterpoise earth (*q.v.*).

The Standard Water-Pipe Earth

The former are by far the most numerous and in general the type adopted in amateur sets. Fortunately, a perfectly good earth is made by means of the domestic water pipes. This is because the pipes are made of metal which is a conductor of electricity, and the water in the pipes is likewise a fair conductor.

When there is any choice in the matter it is best to connect the wire from the receiving set to a water pipe buried in the earth and directly connected to the water mains. This is because the numerous joints in the pipes that are fitted in the house may be poor conductors, due to the use of paint to make them watertight or to the natural oxidation between the surfaces of the joints. Such bad places would seriously interfere with the passage of the high-frequency currents, and the resistance of the earth connexions would be high.

With such a standard arrangement the receiving set becomes, as it were, the dielectric of a huge condenser, the aerial acting as one plate and the earth as the other.

A good connexion to earth is obviously vital. In large transmitting stations the earth arrangements call for great care, and are often effected with a number of earth plates (*q.v.*), disposed in a large circle measuring many hundreds of feet in diameter, and interconnected with the earth lead by wires of appropriate size. In smaller amateur stations the efficiency of the earth is just as important, and may be accomplished on similar lines or by the use of iron pipes driven into the ground, by burying metallic receptacles, such as a large cistern, and filling it with broken coke, cinders, charcoal, or similar material.

Qualities that should be sought for in the design of an earth are to reduce the dielectric losses, and to reduce the resistance to a minimum. To reduce resistance losses the whole of the earth wires must be adequate in size, and as a rough practical guide it is safe to make the area of the earth leads twice the area of the aerial. For example, if a single wire aerial made with 7/22 stranded wire is employed, the earth leads should be the equivalent of two wires each of 7/22 strands. If a single wire is used the earth leads should not be less than No. 16 gauge, and two such wires are preferable.

The length of the earth lead should be as short as possible, to reduce the ohmic resistance, and as high-frequency currents are being dealt with, the use of stranded wire is preferable, as this offers less impedance to their passage. It is also desirable to have several such leads in parallel, as this tends to a more uniform distribution of the current. Another reason for a short earth lead is that by this the receiving or transmitting set is brought as near to the antinode of current in the circuit as is possible.

Importance of Short Earth Lead

For amateur purposes a short lead may be taken as one that is not over 9 feet in length, measured from the receiving set to the point of contact with the earth. It has been observed in a particular receiving set that the signal strength is greatly diminished when the set is removed from the vicinity of a window adjacent to the aerial and earth leads, to the opposite side of a room. This loss is largely attributable to the dielectric losses set up in the neighbourhood of the earth wires by the presence of the walls, with a consequent loss of signal strength.

These losses are best eliminated by keeping the earth lead as short as possible, always well insulating it, and as far as possible isolating it from the surface of walls and the like.

The reduction of resistance losses between the actual earth plates and the soil is an important matter, and is largely affected by local surroundings. When the plates are embedded in a moist soil the electrical connexion between the plate and the ground is generally effective, but in dry locations it is often a good plan to embed the earth plate in a cavity dug in the ground and filled with broken coke, cinders, charcoal, and any materials that keep damp or naturally attract dampness.

Another plan is to embed two or three long stranded copper wires in shallow trenches dug just below the surface of the earth parallel to and as nearly beneath the aerial as is possible, terminating each wire at a galvanized iron or zinc plate, set vertically in a hole filled with damp-attracting material. It is partly for these reasons that the water-pipe system of the dwelling house becomes effective as an earth.

Gas pipes ought not to be used as an earth, as it is contrary to the requirements of various fire insurance interests. From the electrical point of view there is little in favour of the gas pipes as an earth, as by the methods of jointing in practice the joints are almost insulated, and the resistance is therefore likely to be very high. The other important item to be considered in arranging the earth is to reduce the dielectric losses, and this may be attained when the dielectric is as nearly perfect as possible.

Substitutes for the Standard Earth

To obtain this result an ideal dielectric would transmit all the electro-magnetic strains without occasioning any loss in the process. In this respect a counterpoise earth would appear to offer great possibilities, especially in view of the results achieved some years ago by the Lodge-Muirhead system.

When a good buried earth is not feasible a fairly efficient substitute is to lay a roll of galvanized iron wire netting on the surface of the ground beneath the aerial and peg it to the ground or otherwise secure it in place. The earth wire is bolted or preferably soldered to it in several places. Whatever the arrangement of the buried earth, it is desirable to keep the earth lead short, as if it is long it may have a natural oscillation frequency approximating to the wave-length of the aerial, and thereby act as a type of rejector circuit or loop and offer a high impedance to the current flowing in the aerial circuit.

When an outdoor aerial is possible and the earth connexions appear to offer difficulties, the trouble can be overcome in some cases by the use of a Ducon adaptor plugged into an electric light circuit. This results in a form of capacity earth, but is not suitable for transmitting purposes, as trouble may occur in the lighting circuit due to the high-frequency currents employed. When this type of earth is used a separate earth will have to be provided to enable the aerial to be earthed during a thunderstorm.

The expression earth in regard to a loop or frame aerial is more a matter of convenience than a statement of fact. Such aerials virtually combine the functions of the aerial and the earth, the receiving set being placed between them, as the two ends of the windings are customarily connected to the aerial and earth terminals of the set respectively.

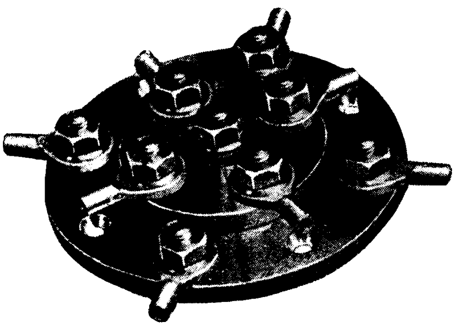
How Transformers Should Be Earthed

The earthing of parts of a receiving or transmitting set, as well as in some forms of wireless apparatus, is a convenient means of relieving local potential differences in that circuit. For example, in a transformer the secondary windings are frequently earthed at the centre because the core and the case are generally earthed, and should an earth leakage occur in the windings the centre part of the secondary windings would be excessively strained. Normally, they are subjected to one-half the maximum voltage above and below earth potential or zero. Should a partial breakdown occur this proportion would be altered, and the terminal on the leaking side of the transformer would be automatically fixed at earth potential, and the other terminal and the windings be subjected to the full maximum pressure alternations above and below zero potential. This is obviated by earthing the centre of the windings.

The metallic parts of wireless apparatus are often earthed to provide a path of low resistance for stray and eddy currents set up within them when their presence is undesirable.—*E. W. Hobbs.*

EARTH ARRESTER. An earth arrester may be defined as an automatic change-over switch. Its use has been confined principally to spark transmitter-receiver stations, both for land and marine work.

Fig. 1 shows a typical Marconi earth arrester. It consists essentially of two metal plates, separated by a piece of



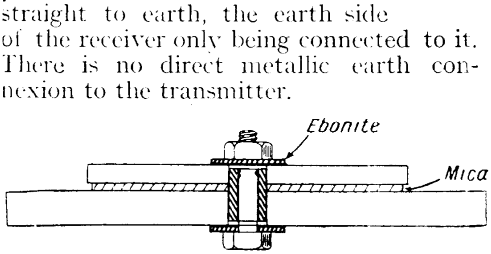
EXAMPLE OF EARTH ARRESTER

Fig. 1. This form of earth arrester consists essentially of two metal plates separated by mica, and is used chiefly for spark transmission and reception

Courtesy Marconi's Wireless Telegraph Co., Ltd.

mica about ·01 in. in thickness. As will be seen from the illustration, the top plate is much smaller than the lower one. The mica separator is slightly smaller than the top plate; this is shown in the sectional drawing in Fig. 2. The nut and screw shown in the centre hold all three components together, but are insulated from both electrodes by a heavy ebonite bushing. The methods of attaching the wires to the plates is by terminal tags, this being clearly shown in the photograph.

Fig. 3 is a circuit diagram showing the application of the arrester in a spark station. Only the connexions necessary are shown, the others being omitted for the sake of clearness. It will be seen that the top plate is common to the aerial side of both the transmitter and the receiver; in fact, with this arrangement the transmitter tuner forms part of the receiver tuner. The bottom plate of the arrester is connected straight to earth, the earth side of the receiver only being connected to it. There is no direct metallic earth connexion to the transmitter.



SECTIONAL DIAGRAM OF EARTH ARRESTER

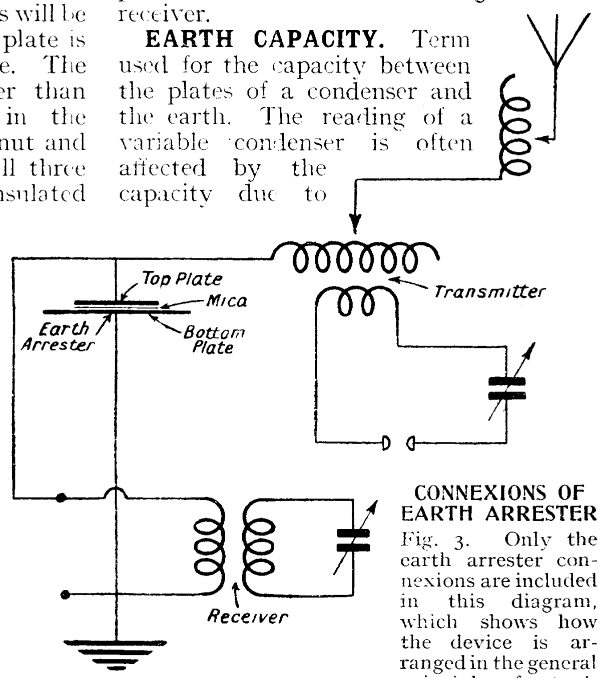
Fig. 2. All three components are held together by the nut and bolt in the centre. Heavy ebonite bushing insulates these from the two electrodes

Courtesy Marconi's Wireless Telegraph Co., Ltd.

The receiver then is quite normally connected, it having the aerial and earth directly connected to it. The high-tension current of the transmitter is easily able to jump the one-hundredth of an inch between the two plates of the arrester. This current jump takes the form of a spark over the edge of the top plate, and in this manner the transmitter current runs to earth without any serious losses being incurred.

It will be gathered, therefore, that by the use of this device no other change-over switch is necessary, for both instruments are always connected to the aerial, and an efficient method of allowing the transmitter currents to reach earth is provided without it interfering with the receiver.

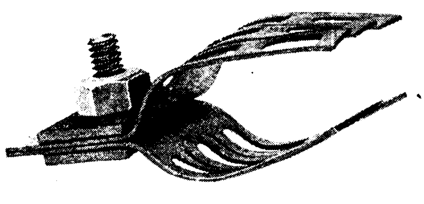
EARTH CAPACITY. Term used for the capacity between the plates of a condenser and the earth. The reading of a variable condenser is often affected by the capacity due to the earth or surrounding objects. All variable condensers, especially in any case those of small capacity, should be enclosed in order to obtain accurate results. *See* Capacity; Condenser.



CONNEXIONS OF EARTH ARRESTER

Fig. 3. Only the earth arrester connexions are included in this diagram, which shows how the device is arranged in the general principles of a typical spark station

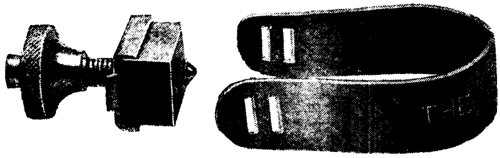
EARTH CLIP. Name used to describe a large number of variously shaped fittings adapted for use as a means of connecting the earth wire from a circuit to some metallic object used as an earth. In this connexion most of the fittings suitable for amateur use are adapted to clamp on to a water pipe. The type shown in Fig. 1 comprises two prong-like plates bolted together with a single bolt and nut. In



PRONG-TYPE EARTH CLIP

Fig. 1. In this form of earth clip two prong-like plates are bolted together to clip round a water pipe. The connecting wire is fastened under the nut

use they are placed around a water pipe and the nut is then tightened. The wire is placed under the nut and the whole makes a perfect connexion.



COPPER STRAP EARTH CLIP

Fig. 2. Both ends of a copper strap are pierced to fit on to the ears of a brass block. By tightening the screw passing through the block the strap can be tightened round a water pipe

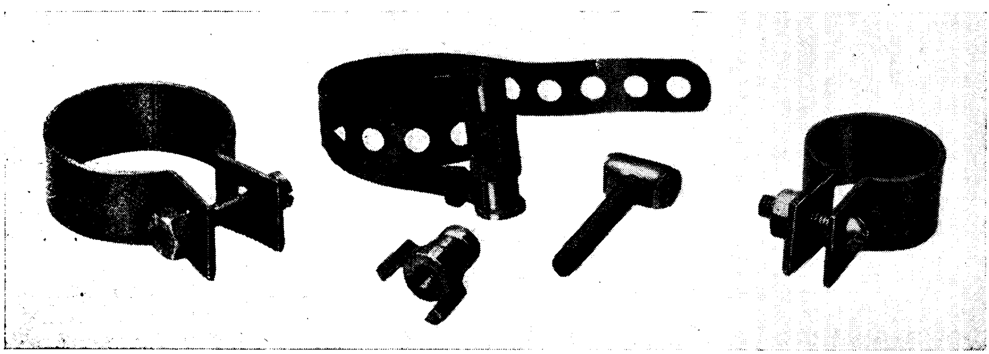
Courtesy Economic Electric Co.

Another pattern, illustrated in Fig. 2, consists of a copper strap pierced at its end and adapted to encircle the pipe. A block of brass is provided with a set-screw which, when tightened, draws the strap closely into contact with the water pipe. This is carried out by slipping the ears on the metal block into the slot in the end of the strap and then tightening the set-screw with a screwdriver. Connexion is afterwards made by tightening the knurled nut on to the wire.

A more elaborate arrangement is illustrated in Fig. 3, and consists of a pierced metal strap, which is passed twice around the water pipe and tightened by means of the small flynut and T-headed bolt. To the right and left of this fitting, shown in Fig. 3, are two plain copper earth clips which simply bolt on to the pipe and have the earth connexion soldered to them. It is important with all this class of clip to be sure that the pipe is filed or sandpapered to reveal a bare metallic surface, and that the clip itself be perfectly clean when it is fixed in its place.

EARTH CONNEXION. Expression used to describe a variety of points of contact made between the conductor forming part of the aerial circuit of a receiving set and some metallic object suitably in contact with the earth itself. The amateur will find that for all ordinary purposes a water pipe forms an excellent means of connexion between the set and earth, and may be used successfully, especially in cases where the pipes are located below the level of the receiving set.

A most important item in any earth connexion is that the wire conductor shall make a good metallic connexion with the pipe or earth plate (*q.v.*) to which it is attached. Probably the simplest method is that illustrated in Fig 1, where the conducting wire is twisted several times



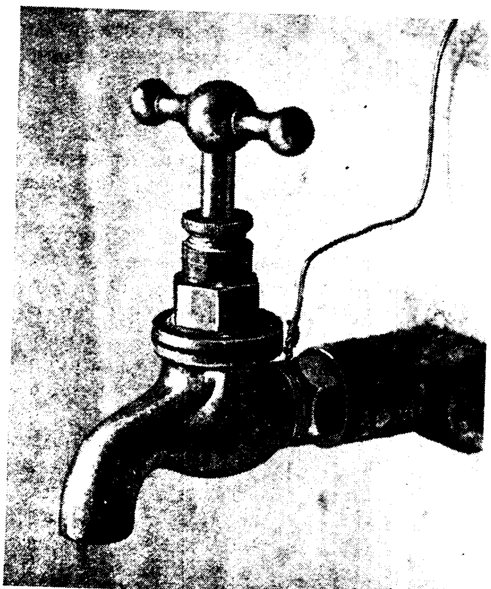
THREE CLIPS FOR MAKING EARTH CONNEXIONS

Fig. 3. To the left and right are plain copper earth clips which bolt on to a pipe and have the connexions soldered to them. In the centre a pierced metal strap is passed twice round a pipe and tightened by a small flynut and T-headed bolt

Courtesy Will Day, Ltd.

around a brass water-tap and soldered thereto. The object in connecting it to the brass tap is that the brass can generally be cleaned easily, and the soldering is facilitated. Moreover, it is the best point of connexion, as the local resistance is far less than would be the case if the wire were directly attached to the iron pipe. It is imperative that the wire be soldered in place.

When it is not feasible to attach the wire to a tap in this manner, the method illustrated in Fig. 2 can be adopted, and a simple way of effecting a good connexion

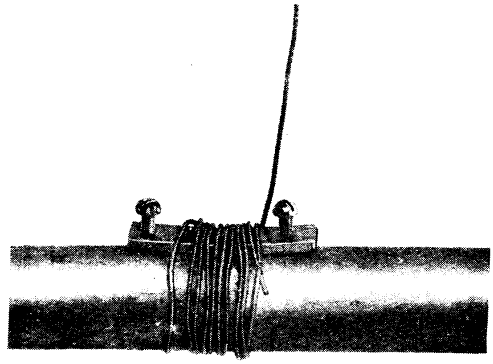


EARTH CONNEXION TO TAP

Fig. 1. Connexion can be made to a brass water tap in this way. It is important that the tap should be cleaned where the contact is made and the connexion soldered. This is one of the simplest forms of earth connexion

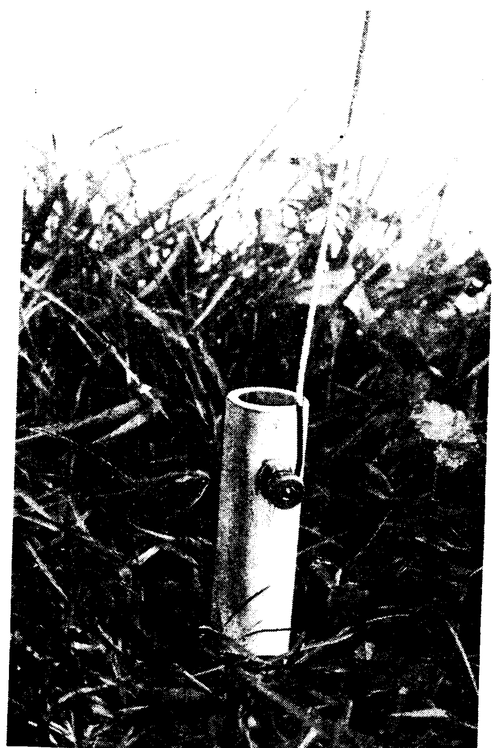
is to use a piece of brass strip about 2 in. in length, ½ in. in breadth, and ⅛ in. in thickness. Two holes are drilled and tapped at the end of this strip and provided with set-screws. The conducting wire is then bent tightly around the water pipe and the plate in the manner illustrated, and afterwards the screws are tightened up, thereby bringing the wire into firm contact with the pipe.

This method can be used when for any reason it is impracticable to solder the wire to the pipe itself, as, for instance, when only a temporary attachment is to be made, but in all cases it is necessary that the wire and the pipe be scraped



PIPE AS EARTH CONNEXION

Fig. 2. Bound round the pipe is the earth lead from the wireless set. A piece of brass strip, drilled and tapped at both ends, is laid between the pipe and the turns of wire. Set-screws are then inserted in the holes and screwed up, bringing the wire in tight contact with the pipe



BURIED TUBE EARTH CONNEXION

Fig. 3. Almost buried is a length of galvanized iron pipe. A terminal is attached to a screw, which is passed through the pipe, and the earth wire is attached or detached as required. This is a simple means of making contact when water pipes are not available

clean and bright so that a proper metallic connexion is made. Should the pipe be dirty or rusty it acts as a partial insulator.

When there are no water pipes available a practicable plan is to take a good length of large diameter galvanized iron pipe, bore a hole in the ground with the aid of a crowbar or pitch-bar, and drive the pipe well down into it, leaving a small part projecting at the top, as shown in Fig. 3. To ensure a good connexion a brass screw can be passed right through the pipe and should screw into a tapped hole and be locked in place with a lock nut. Connexion is then effected by twisting the earth wire around the screw, securing it with a terminal nut and making a perfect connexion by soldering it.

EARTH CURRENT. As its name implies, an earth current is a current of electricity present in the earth. The earth may be regarded electrically as one large conductor of very low resistance. While the resistance of a small portion of the earth's crust may be of a high order, the resistance of the whole is so low that for most electrical purposes it is negligible. The only resistance likely to be felt is in actually making contact with the earth.

From the point of view of the wireless worker it is unfortunate that all electrical plant and machinery must necessarily be earthed. The Board of Trade specifies that all electrical apparatus such as conduits, motors, dynamos, and the like, must be earthed by a stout copper wire. The reason for this is that it is essential to prevent shock and fire. If the insulation of the windings of a motor were faulty its potential might easily be raised to the potential of the mains. It would, therefore, follow that if that motor body was not earthed, a heavy shock would be caused to anyone touching it. The earthing of the motor body causes the potential to fall to that of the earth itself, and as no potential difference would then exist between the machine and earth, no shock could occur. One kind of earth current is therefore caused by this protective earthing system.

Electric tramways and railways very often have one side of their power supply earthed, the overhead wire or centre rail being one side of the circuit and the running rails the other. This, again, is another cause of earth current.

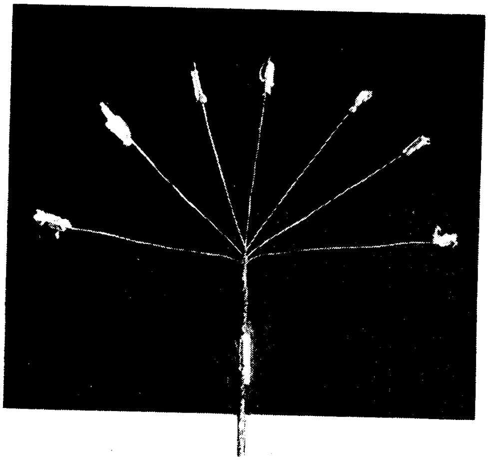
The presence of these currents may easily be detected in the following manner: Sink two earthed plates as far apart as is conveniently possible. Connect them in series with a pair of high-resistance telephones. Immediately on completing the circuit a click will be heard, followed by continuous rumblings and crackling noises. Should the person trying this experiment live near a railway or tramway system, it is often the case that he can detect the movement of these vehicles by the intensity of the clicks at different periods of time.

It frequently happens that when using a wireless receiver, loud rumbles, clicks, etc., can be heard in the telephones. These noises are very often put down to bad connexions, faulty insulation, or H.T. supply; but they will often be found to cease when the earth wire is disconnected. In large factory areas these currents are a great nuisance to the listener-in, especially during the daytime. Moreover, it is a nuisance which is very difficult, and frequently impossible, to cure. Occasionally it will be found that using an earth in a different location will partially relieve the interruptions, for different earths appear to lend themselves particularly to certain local currents.

EARTH PLATE. Flat metallic conductor of relatively large area embedded in the earth to act as the terminal of the earth system of a wireless set. In large installations earth plates are very important, and call for considerable care in design. As the amateur is called upon to deal with small currents, it is very important that the earth plates be of adequate size and properly placed, relative to the set and to the geographical surroundings.

The illustration Fig. 1 shows a rectangular plate of copper and a seven-strand copper conductor leading to it. To ensure perfect metallic connexion, the last 6 in. or so of the conductor are untwisted and spread out fan-wise. Each end is soldered securely to the copper plate, as is the stranded conductor itself.

The size of the plate will be governed by various conditions, and the larger the apparatus the more important becomes the size of the earth plate. But for the experimenter a commercial-sized sheet of copper, which measures about 3 ft. by 2 ft. and about No. 16 gauge, should answer all requirements. Such a plate must be buried in the earth in a vertical position



EARTH WIRE AND EARTH PLATE

Fig. 1. Attached to a rectangular copper plate by means of solder are the seven separated strands of a stranded copper wire. The wire is untwisted at a point about the middle of the plate

and preferably 3 ft. to 4 ft. deep, somewhat in the manner illustrated in Fig. 2, which shows a copper plate embedded in a hole in the earth and the stranded conductor leading away from it.

It is desirable to select a damp place in which to embed the plate. In ground that is naturally dry several plates may be necessary; and it is often desirable to embed the plates in mould, sand, or other soft material which has a natural tendency to retain moisture. Various proprietary devices are made and adapted to retain a quantity of moist earth. In one example such a container is conical in shape and has the earth lead attached to the apex of the cone on the inside and the whole embedded in moist material. A good, damp and efficient earth greatly assists the efficiency of a receiving set.

In general, the resistance of an earth contact is largely dependent on the surface area. Consequently, it is best to err on the side of using large plates. A regular arrangement of large commercial stations consists of a number of rectangular zinc plates embedded vertically in the ground and connected to the earth side of the apparatus by large stranded conductors.

The earth end of this is connected by radial wires to the zinc plates. The plates are arranged in the form of a circle, and from them other wires extend outwards under the ground, sometimes to several hundreds of feet in length.

Another extensively used method is to drive a number of pipes into the ground, arranging them in a large circle and connecting by radial wires. *See* Aerial.

EARTH RETURN. Earth return is the name given to the method adopted in all branches of electrical engineering of using the earth itself as the connexion to one pole of any source of supply of electricity. It is frequently inconvenient and more costly to have to have two or more wires running from the source of supply to the apparatus for which that supply is intended.

Taking an extreme case, consider the Atlantic cable. If an earth return was not used in this instance, over three thousand more miles of cable than are at present necessary would have to be put into service; and the risk of failure, either through fracture of the conductor itself or of insulation breakdown, would be doubled.

The resistance of the line would also be tremendously increased, for three thousand miles of the earth's surface is of far less electrical resistance than a similar distance of the comparatively minute cross-sectional area of copper in the cable.

BURIED EARTH PLATE

Fig. 2. About 3 ft. by 2 ft. of copper sheet, with the earth wire soldered to it, is placed in a hole at a depth of about 3 ft. or 4 ft. from the ground surface

Again, the construction of various electrical plant and appliances frequently necessitates an earth return. In the case of electric railways, for instance, where either a third rail or an overhead wire is used, the running track forms the return conductor to the power station. This system, then, is an earth return, for no attempt is made, or indeed necessary, to insulate the running track from the earth.

The whole of the land-line telephone system is provided with an earth return to every instrument. The wires leading from the telephones to the earths may always be seen. They are invariably of base copper, the earth connexion itself being usually made to the nearest main water pipe.

In wireless work, although reception and transmission may be effected without the use of an earth connexion, the latter is undoubtedly a great help to efficiency. By the aid of a good earth connexion or return, reception over considerably greater distances may be obtained than without. This means economy in power input in the form of amplifiers.

EARTH SWITCH. Name of a switch adapted for or employed in the aerial circuit, and generally to connect the aerial lead-in wire to the earth lead when the set is not in use, and to connect the earth lead to the earth side of the receiving set when it is in operation.

Numerous proprietary makes of earth switch are available, varying in size and design of some specific points. The experimenter using a small set with the ordinary type of P.M.G. aerial can readily construct an efficient device from odd material. The useful pattern illustrated in Fig. 1 consists of an ebonite base, 3 in. in length, 2 in. in width, and ¼ in. or more in thickness. At one end of this is fitted a terminal to support and act as a pivot for the metallic contact arm. The latter has at its outer end an ebonite insulating handle.

Two other terminals are fitted to the opposite end of the base, and to them are attached copper contact plates, with one or other of which contact may be made by moving the lever from one side to the other. The components of this switch are shown separately in Fig. 3, which shows, on the left, two of the terminals, in the centre the ebonite base and the two copper contact plates, and on the right the contact arm and the third terminal.

The first step is to cut the ebonite base to the shape, true it up and drill five holes, and tap them with the same size threads as those on the terminals, which may be ordinary standard pattern. The contact arm is simply a piece of brass or copper strip ¼ in. wide, $\frac{1}{16}$ in. thick, and 3 in. in length. One end is rounded off, and a hole drilled through it so that it can turn easily on the terminal screw. The other end is tapered.

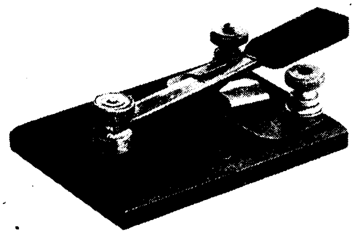
A block of ebonite is then sawn to shape and neatly filed up to act as a handle, and may measure 1 in. in length and ½ in. in breadth. Two small holes are then drilled in the smaller end, and the tapered end of the brass strip is warmed in the flame of a blow-lamp, or otherwise. The ebonite handle is held in a horizontal position in a vice and the heated end of the contact arm pressed well into it. The arm should be grasped with a pair of strong pliers or a small hand vice.

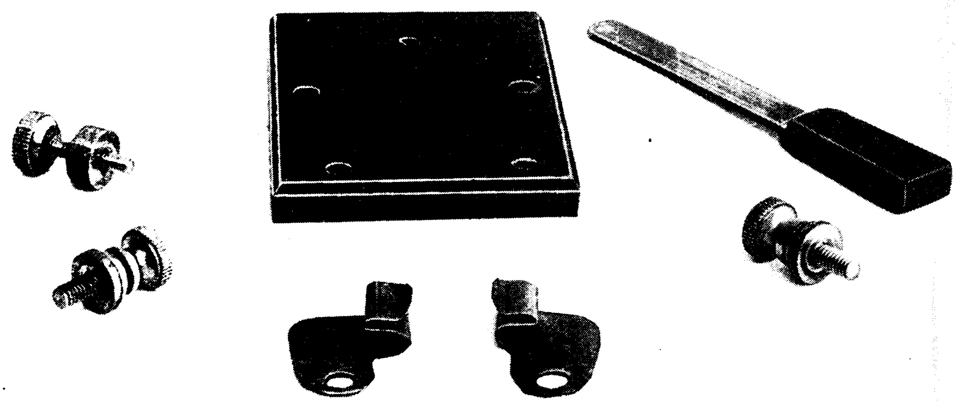
It may be necessary to reheat the arm once or twice to enable it to be forced well into the ebonite, and when it is sufficiently embedded it should be left free to cool off, when the ebonite will contract, and the whole will form a neat and effective joint. The ebonite may finally be polished and the contact arm cleaned up with very fine emery paper.

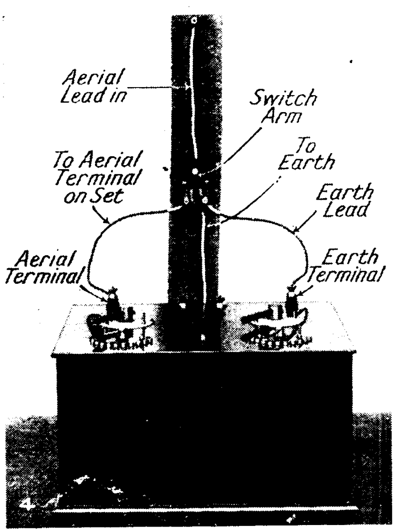
How the Switch is Used

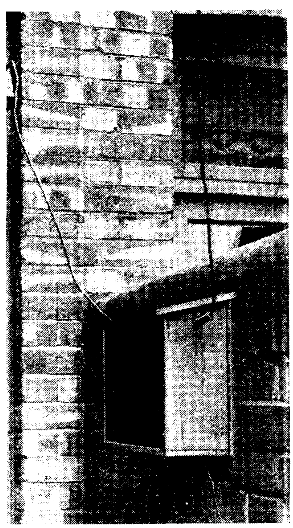
The contact plates are made from sheet copper, about No. 20 gauge, and are first cut to the shape of the letter L. The arm is drilled to receive the terminal screws, and the other end is folded over, as shown in the illustrations, to form a spring contact. They are then mounted in position on the base in the manner shown in Fig. 2, and secured in position by tightening the terminal nuts. The lever is placed over the remaining contact screw, and when moved from side to side should slip easily and freely between the spring jaws of the contact.

One way in which this switch can be used is clearly illustrated in Fig. 4, which shows the aerial wire leading from the terminal on the lead-in tube to the underside of the contact arm terminal. One well-insulated wire is taken from one of the terminals on the contact plates to the aerial terminal on the tuner or receiving set. From the other contact terminal one wire goes direct to earth and the other to the earth terminal of the set.









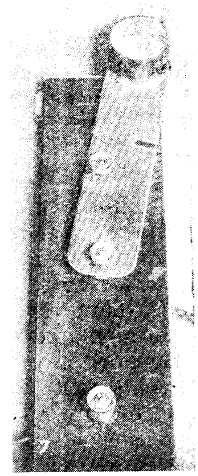


Fig. 1. A type of earth switch which the amateur may readily make with simple tools and material is here illustrated. Fig. 2. Terminals and contact plates are mounted together, the legs of the terminals piercing the plates. When the nuts on the underside of the terminals are tightened the plates are secure. Fig. 3. Components of the switch in Fig. 1 laid out to show the parts that are required. Note the shape of the contact strips, giving a firm, springy contact. The base is of ebonite. Fig. 4. In this photograph will be seen the position in relation to a receiving set which the earth switch occupies. Fig. 5. Alternatively, the earth switch may be housed outside, as shown here. Fig. 6. How the blade is slotted. Fig. 7. Another form of earth switch consists of a blade and boss on an ebonite base with terminals

AMATEUR-MADE EARTH SWITCHES AND HOW TO USE THEM

When the switch is placed in the left-hand position the current flows through the aerial to the receiving set, and thence to the other terminal on the contact plate, and so to earth. When the switch is moved to the right, any current set up in the aerial flows from the aerial direct to earth, and it is in this position that the switch should be placed whenever the receiving set is not in use.

Fig. 7 shows a simple form of earth switch for external use which is quickly made by the amateur and which will prove very efficient in practice.

A piece of ebonite, not less than $\frac{1}{4}$ in. thick, by $2\frac{1}{2}$ in. wide, is prepared. This may be seen in Fig. 6. In the centre is fitted a large telephone terminal. On the centre line and $2\frac{1}{4}$ in. to the left of the centre terminal is fitted another terminal. The third terminal shown in Fig. 7 is 3 in. to the right of the centre terminal.

A piece of stout paper is cut about 1 in. in width, and in one end of it a hole is made of sufficient diameter to be an easy fit upon the central terminal screw. This strip is temporarily fitted in place, and is then swung round to the left and right and notched so that it will slip over each of the side terminals in turn. This acts as a template for the cutting of the copper switch arm shown in Fig. 6. The notches are purposely made so that they do not come opposite one another and thereby weaken the arm. A small circular wooden handle may be screwed to one end of this arm or, preferably, an ebonite knob is fitted.

The switch is conveniently mounted out of doors in an open-fronted box, as shown in Fig. 5. The various leads are clearly shown. The aerial lead comes in through a tube on the near side and the wire to the set in the house through another insulated tube on the opposite side of the box. The earth lead comes out through a hole in the bottom without being insulated. The insulating tubes may be of ebonite, glass or porcelain, or brown paper. In the latter case the paper should be wound round a pencil till the walls are at least an eighth of an inch thick, bound with cotton, and boiled in paraffin wax.

The wiring is as follows: The aerial is fastened to the centre terminal, the left-hand terminal to the receiving set, and the right-hand terminal to the earth. A separate earth is connected to the receiving set. The lead to the earth, shown in Fig. 5, should be as short as possible, and should be at least as heavy gauge wire as the combined aerial wires.

EBONITE: HOW TO WORK & USE IT

Practical Information on a Material Essential in Wireless Work, Fully Illustrated

Here the characteristics of one of the most important materials used in wireless construction are described and all the methods of working it, cutting, drilling, turning, filing, etc., demonstrated with action photographs. See also such articles as Drills and Drilling; Filing; Lathe, etc.

A form of vulcanite, composed largely of rubber and sulphur, thoroughly mixed and vulcanized at a temperature of some 150° C. for several hours. It is black in colour, hard, and makes a most useful insulating material for wireless purposes.

There are several grades of ebonite, and the composition also varies. That most suited to wireless work is even in texture, homogeneous, and free from any trace of metallic particles and foreign matters that have a tendency to reduce the insulation value.

The specific inductive capacity of ebonite varies from 2·2 to 3·15, according to the nature of the material under test.

Ebonite is capable of taking a high polish when required, but this is not a desirable feature for any wireless work where high-frequency currents have to be dealt with, as there is a surface leakage, which is prevented or minimized by matting or very slightly roughening the surface.

Ebonite is capable of being readily moulded in course of manufacture, as it can be worked in a plastic state and compressed into moulds prior to vulcanization, and afterwards the material is found to be solid and durable. If made in metal moulds of appropriate design and having a sufficiently smooth surface, the resulting article will be smooth enough to be serviceable without any subsequent machining. Consequently a great number of components are made in this way for wireless purposes—the rotor and stator of a variometer are examples, as are the bases of some small condensers and the bases of many switches. In the common use of the word, ebonite includes many inferior mixtures, some with a considerable admixture of mineral matter. Generally they are marketed under a trade name, but are often spoken of as ebonite.

The experimenter will mostly be concerned with ebonite in the manufactured state, as it is not practicable for the home constructor to mix the ingredients and vulcanize them, as it necessitates a considerable plant to do the work properly.

The only possible plan is to use the so-called dental ebonite or vulcanite, obtainable in the plastic state and known as dental rubber. This can be pressed into plaster of paris moulds, placed in a flask or metal container, and vulcanized in a small dental vulcanizer. With small objects this is possible, but costly. The time required for vulcanization varies, but as a basis an article taking about 3 oz. of rubber would require vulcanizing for an hour or thereabouts. The method might be useful under some circumstances, such as arise when the experimenter has to make a special part for a new set.

In the commercial state ebonite is obtainable in the form of sheets ranging from $\frac{1}{16}$ in. thick upwards, and also in the form of rods and strips of various shapes. The round rods and rectangular strips are the most serviceable, as well as the tubes, which are made from about $\frac{1}{4}$ in. diameter upwards.

Hints for Working Ebonite

The sheets are employed extensively for the panels of wireless sets and for all manner of small parts used in the construction of components. The tubes are useful as insulation for lead-in wires, and as bushes for other conductors. The larger sizes of tube are extensively employed as formers for winding inductance coils.

The methods of machining ebonite vary somewhat according to the nature of the sample being worked on at the time, but assuming a good specimen, the following notes will serve as a basis.

The important fact with ebonite to remember is that it is manufactured by a heat treatment and at a low temperature, consequently whatever the process of working, it must take this into account. When the work is to be carried out with turning or other tools, it is important to avoid overheating, or the sulphur will be released and the surface badly pitted as a consequence. On the other hand, much can be done by the application of heat. For example, a sheet of ebonite, if well heated over the escaping steam from a kettle, will speedily become pliable and can then be bent to simple curved shapes.

One use for this treatment is in the construction of a tube for a former. This can be made in emergency from a thin sheet of the material, cut to slightly over the correct length and wide enough to bend to the desired diameter circle. The sheet is simply heated in steam or boiling water and bent around a pre-heated wood former, the whole rapidly wound with tape and allowed to remain in the heat for a minute or two to relieve all internal stresses, and then permitted to cool off slowly. When cold the tube will be stiff and rigid, and only require smoothing with a file or sand-paper.

How to Mark and Drill Holes

Ebonite is a peculiar material in that it is easily worked and is capable of taking a high polish, at the same time it is difficult to finish in a clean and workmanlike manner unless due regard be paid to the nature of the material. To obtain a good finish it is generally necessary to have a high cutting speed and a slow feed. The latter is especially important, as if the tool is used too rapidly the material will heat and the cutting edge be blunted.

Probably the first operation to be undertaken by the experimenter is the drilling of holes in ebonite. To do this effectively it is first necessary to mark the centre for the hole and make a small depression with a centre-punch exactly at that centre. This is accomplished by holding the punch upright, with the pointed end pressed firmly on the centre and striking a blow with a light hammer fair and square on the top of the punch. Too much force must not be exerted or the ebonite will be cracked. Only sufficient pressure is needed to make a shallow depression in the surface.

The point of the drill is started in the centre pop, as this depression is called, and provided a suitable drill be employed and the drill stock be held upright, a perfect hole should result. It is impossible to drive a screw into ebonite successfully without first drilling a hole, nor is it practical to attempt to make holes without a drill and a hand drill stock or machine of some sort. The drills may be the ordinary twist and straight-fluted varieties sold for engineers' use, but they must be perfectly sharp and well ground, with accurately formed cutting edges and angles.

The drill should be run at as fast a speed as possible, and only very lightly fed into the work. The use of a drilling machine or a lathe is a distinct advantage, especially for such purposes as the construction of small bushes, which can be made from ebonite rod chucked in the lathe by a three-jawed chuck, as shown in Fig. 1, and the drill held in a drill chuck held in the tail stock. Here, again, a high speed for the work and a slow, regular feed for the drill is an essential. The drill can be lubricated with turpentine should it exhibit any tendency to overheat.

Cutting Large Holes In Ebonite

Large holes can be cut in ebonite with the aid of an expansion bit, as illustrated in Fig. 3. This bit comprises a centre which is virtually a small twist drill, and upon it is located an adjustable cutter, which is locked in any position by means of a thumb-screw. The cutter should be adjusted so that it describes a circle of the desired size. The piece of ebonite to be drilled is then held in the vice or supported on blocks on the bench, or in any firm and convenient manner, and the centre of the hole marked with a centre-punch and the drill rotated steadily and evenly. When the cutter has drilled its way through about half the thickness of the ebonite, the material should be turned over and the hole completed by working from the other side.

When a larger diameter hole is required, beyond the capacity of the expansion bit, a convenient method is to mount the plate of ebonite on the face plate of a lathe by first fixing to the face plate a block of wood, planed up true and flat on both surfaces and of a uniform thickness. The ebonite is screwed to the face of this block with three or four screws passed through the waste material. The top side of the slide rest is then set over, and the parting tool used in the manner illustrated in Fig. 2.

The lathe is then set in motion and the tool gradually fed into the cut, when it will speedily remove the centre portion. The latter may be used as the top of a condenser, a rheostat graduated dial, or turned to some other useful purpose. The same method, it is clear, may be adopted for producing disks as for producing holes of a large diameter.

The most convenient way of cutting up ebonite is with the aid of a band saw or a small circular saw, driven either by power or treadle. Several small lathes are made with a circular saw attachment, such as that illustrated (Fig. 5), and in practice a small slitting saw with fine teeth, or adapted for wood cutting, will cut through ebonite at a good speed. The saw should be rotated towards the operator, and the feeding up of the ebonite regulated according to the cut. This can be judged by noting the performance of the saw. If the saw has a tendency to jam and stick, the ebonite is being pressed forwards too vigorously. When operated properly the saw should cut with a clean, ripping sound and the chips be passed freely from it.

A powerful fretsaw is another useful tool for cutting ebonite sheet, especially in curved shapes, such, for example, as the end plate of a variable condenser, seen in Fig. 4. In this case the tool is manipulated exactly as for cutting wood, except that the work cannot be pressed quite so vigorously. The saw must be kept at its greatest tension, and the pressure exerted according to the style of chips produced. When the saw cuts properly, all is well and the work may progress, but when the blade shows a tendency to stick it may be over-heated, the teeth may be worn, or, more probably, the ebonite is being twisted or pressed sideways, thus jamming the blade.

The Best Method for Sheet Cutting

By far the bulk of the cutting of ebonite sheets for experimental purposes and amateur use is in the nature of straight cuts, and this can most conveniently be effected with the aid of the ordinary hack-saw. The work is grasped firmly in the vice, interposing soft lead clamps or pieces of leather between the jaws of the vice and the ebonite, so that the latter is not scratched or damaged. A good clear line should be scratched on the ebonite, and, if desired, may be filled with chalk to act as a guide during the cutting operation. This is clearly shown in Fig. 6.

In cases where the depth of the cut is greater than the space between the saw

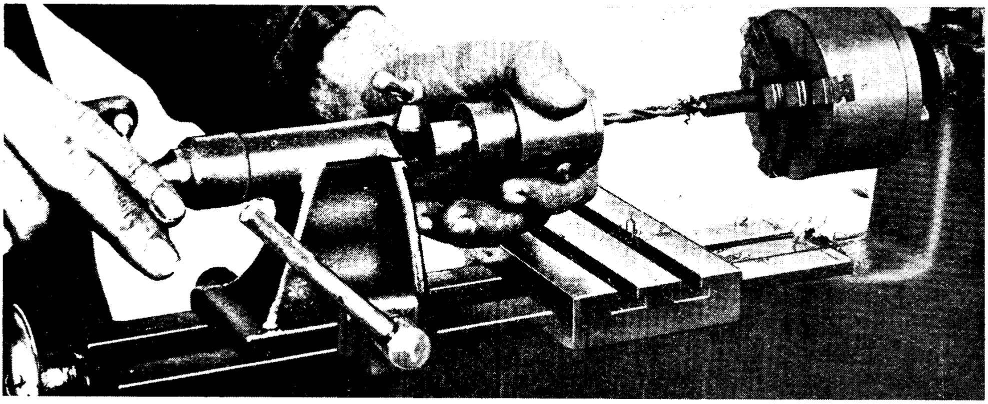


Fig. 1. Ebonite rod in the chuck on the head stock of a lathe, the chuck on the tail stock holding a drill. By this means an ebonite bush is made to any dimension desired. The drill should be driven at high speed and fed slowly into the work

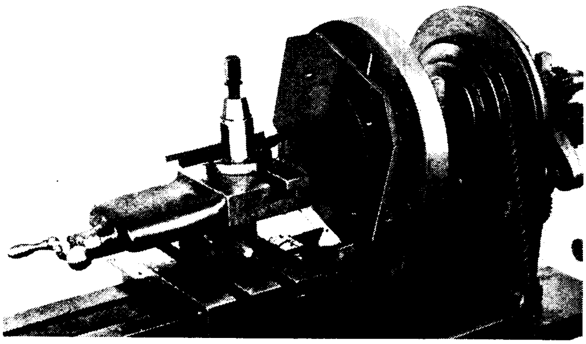


Fig. 2. Mounted on the face plate of the lathe is a sheet of ebonite, and the centre is being cut out to make a disk

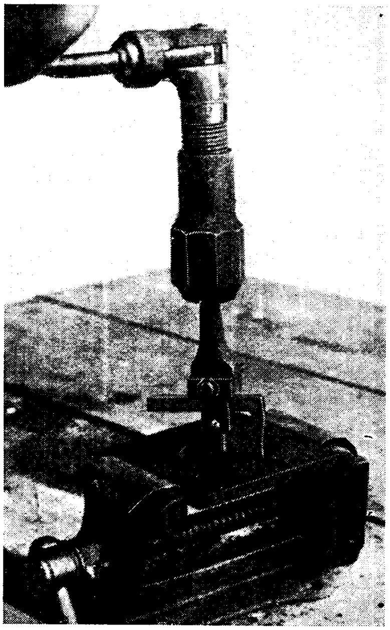


Fig. 3. Large holes are made in ebonite by using an expansion bit in this manner. Note how the work is held in the vice with lead clamps to prevent injury

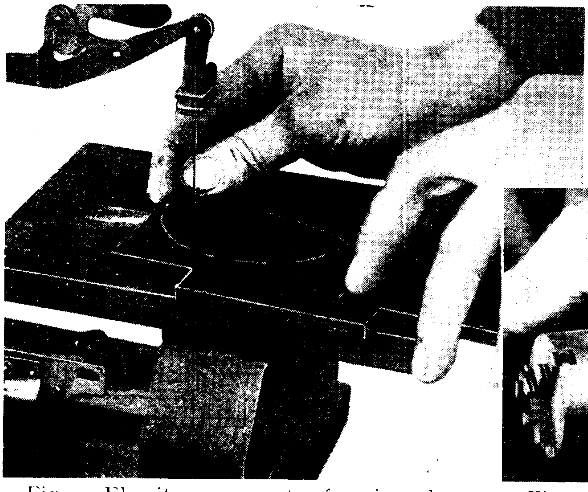


Fig. 4. Ebonite components of various shapes and sizes can be cut to shape with a hand or mechanical fret-saw

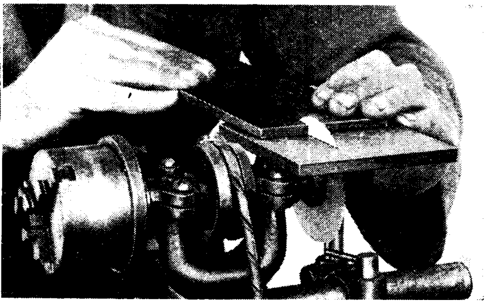


Fig. 5. Sheets of ebonite can be rapidly sawn to the desired lengths by means of a small circular saw

THE BEST METHODS FOR DRILLING, SAWING AND TURNING EBONITE

blade and the back of the frame, the saw is set over at right angles to the frame and manipulated at right angles to the blade instead of vertically. It is desirable to use a fine-toothed saw and to keep it well tensioned. When the teeth are blunted, substitute a new one, as a sharp-toothed saw is essential for cutting ebonite rapidly. The blunt blades should be preserved and used for cutting iron and steel, when they will be found in excellent condition for that work.

In some types of condenser and other apparatus used in wireless, lines are required on an ebonite plate, and these also may be produced with a hacksaw, by manipulating it in the manner illustrated in Fig. 8. In such work it is necessary first to start the cut by holding a batten or straight edge as a guide to the saw blade. This may be secured to the bench with two small clamps, or in any convenient manner, according to the nature of the work. The saw is then worked to and fro, using only a very short stroke of, say, an inch or so in length, keeping the blade perfectly flat on the work, by maintaining an even pressure at each end of the frame. When cutting a tube it is best to support it with a wooden liner or former, as shown in Fig. 7, as this prevents the tube breaking, and enables it to be held in the vice without difficulty.

Files to Use on Ebonite

After a sheet has been cut to shape the edges will be rough and exhibit the saw cuts. These will have to be removed with a file (*q.v.*) and the surface worked up true. The files used may be those employed for metal work, and should preferably have a fairly coarse cut, such as a rough file for the commencement, and a smooth or second cut for the finishing work. A cabinet rasp is also useful as a quick and effective remover of material.

All files should be grasped by the finger and thumb of the left hand near to the tip of the file, the right hand being employed in grasping the handle, the general position being as shown in Fig. 9, where a light cut is being taken across the top edge of a panel.

When any heavy filing is to be done, the work should be backed up with a piece of wood grasped in the vice and held at the back of the panel or other object, to enable it to withstand the action of the file and obviate the risk of the ebonite cracking or breaking.

To ensure a smooth and true surface the edge ought to be tested with a steel or other straight edge, and the filing governed accordingly, removing the high parts and avoiding the low ones until the whole is straight and true. A fine finish is imparted by manipulation of an engineer's steel scraper, as shown in Fig. 10. The tool is used with a scraping action by drawing it along on the surface of the work with the blade inclined at a small angle to it, thus removing a very small shaving and enabling a perfect fit to be made, as one piece can be scraped away until it fits accurately to another.

How to Shape Curved Surfaces

The scraper is particularly valuable for the shaping of curved surfaces on moulded work, and also on sheet work. In this case the filing is accomplished with a half-round file or with a round file, according to the sharpness of the curves. The file is used in the same way, but with a sweeping motion, so that the file passes at an angle across the edge being filed, as shown in Fig. 11. The use of a little French chalk is sometimes an advantage if the file appears to be clogging. Another lubricant that can be used for fine work is turpentine.

For wireless work the surface of ebonite should be well matted, as the glossy skin is very often hygroscopic, which would result in considerable surface leakages. Very often during the manufacture of ebonite minute particles of tinfoil or other metallic substances are left on the surface of the material, and these may cause leakage of high-frequency currents.

If possible, the ebonite should be bought already matted, and the slight increase in cost is usually well worth while, as the professional methods of sand-blasting give a very pleasing effect. Ebonite may best be matted by fastening the sheet rigidly so that both hands are free, as in Fig. 12, to apply the pressure required. If the sheet is small it may be clamped in the jaws of a vice, care being taken to insert a piece of rag or cardboard over the vice jaws to prevent the edges from damage. A sheet too large to go in a vice may be held on a flat bench between two shallow strips of wood nailed down at either end, so that the ebonite is a tight push-in fit.

A pad of fairly fine emery paper is now rubbed over the surface of the panel in one direction only. The direction of

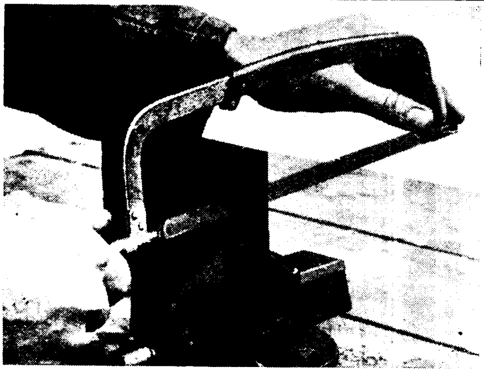


Fig. 6. Ebonite panels may be cut to size with a hack-saw. A line is cut and filled with chalk as a guide, the panel being held vertically in a vice

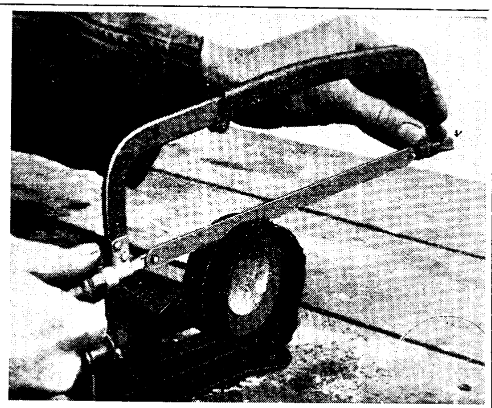


Fig. 7. Tubes are best cut with a hack-saw, using a wooden liner as a support for the tube. Care must be taken to fill the inside of the tube completely and not to screw up the vice too tightly

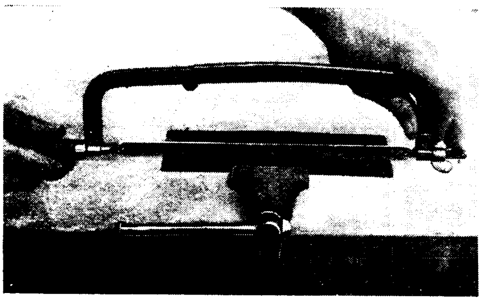


Fig. 8. Laid flat on the bench is the ebonite plate, and the operator is cutting a long groove as a guide

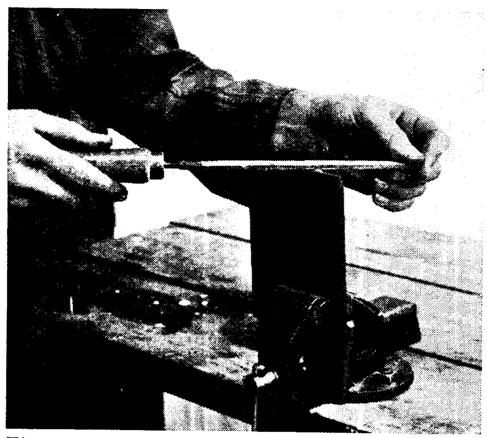


Fig. 9. Edges of the ebonite panel are filed after cutting to make them flat and true. Note how the file is held. Too great a pressure should not be applied, and the accuracy of the filing should be checked with a set square

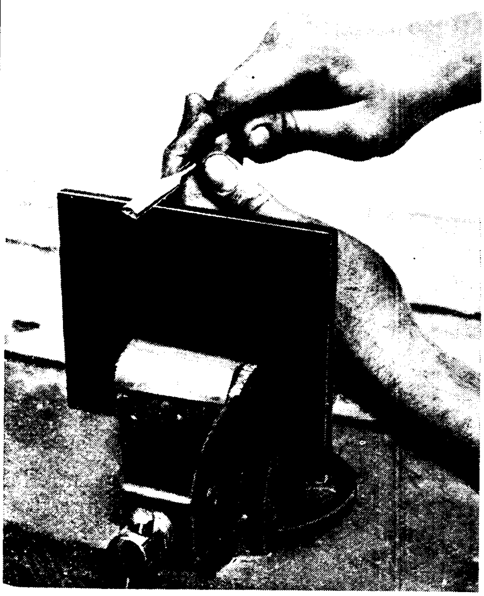


Fig. 10. An engineer's steel scraper may be used for making the edges smooth and true instead of a file. Note how the scraper is held

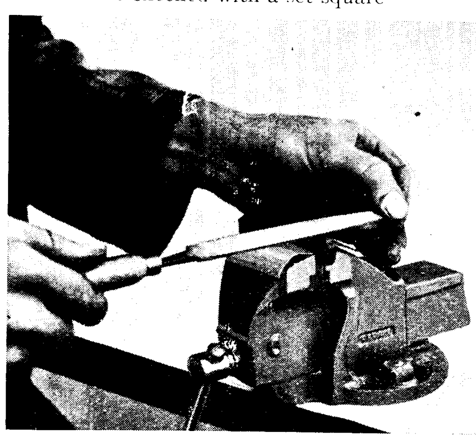


Fig. 11. Curved shapes may be made by using a half-round file. French chalk is used to prevent the file from becoming clogged

HOW EBONITE PLATE AND TUBES ARE CUT AND FILED

rubbing should correspond with the normal horizontal attitude of the ebonite when in the position it will occupy in the set. In the case of a panel lying horizontally on the top of a cabinet the rubbing should be done in a direction parallel with the front of the table where the set is placed. The rubbing, which should be done with fairly slow, heavy strokes to get a maximum effect with a minimum of effort, should be continued until all the glossiness has disappeared.

A finer grade of paper, preferably a nearly worn-out piece of FF paper, is now rubbed over the surface in the same direction as before. This will obliterate the scratches of the coarser paper. If a superfine finish is required the panel may be treated with brickdust or similar fine abrasive powder. Fig. 13 shows the method of rubbing down a small panel of ebonite held on the bench with one hand. This method may be used where the panel is small. For large work it is an advantage to wrap the emery paper round a wood or cork block.

A pleasing effect is obtained by darkening the ebonite with lubricating oil, but if this is adopted, care should be taken to rub off all traces afterwards, as the slightly sticky surface will attract dust, to the detriment of the efficiency of the set.

Ebonite Engraving for the Amateur

The appearance of a set is considerably improved by the addition of engraving when carefully done. A suitable tool, known as a graver or burin, may be bought or made from a small piece of steel filed to a fine V-shape at one end. The point of this instrument is pressed into the ebonite, and should follow the course desired, previously marked out with a scriber. Fig. 14 shows this operation. The method of operating this tool is to rock it slightly from side to side, using a scraper effect rather than a distinct cut. After the engraving has been completed it may be filled in with chalk. A more lasting effect is obtained by using white enamel, but it has the disadvantage of being more difficult to apply. Chalk may be rubbed in from the solid stick and the surplus rubbed off, as shown in Fig. 15, with a clean rag.

Where it is desired to have a high polish on ebonite objects, such as condenser dials, a polishing mop run at a high speed in a lathe or polishing head is used. Such a mop is seen in Fig. 16, where the operation of polishing a condenser dial is in progress. A useful abrasive powder may be made by using rottenstone and oil or brickdust and water. Tripoli may also be used. Care should be taken to use the powder wet, and not to run the bob at a speed at which the water is liable to be thrown off, unless some provision is made to prevent it soaking the operator. Care must be taken to keep all the edges sharp and clean, as a slightly rubbed and rounded edge is detrimental to a good finish.

Tools Required for Turning Ebonite

The turning of ebonite calls for the use of very sharp tools with plenty of top rake and clearance. Those used in a lathe can be of the general forms employed in turning mild steel, but they must be sharp. A round-nosed tool is adaptable to many jobs, and leaves a neat fillet or radius in the corner of shouldered work. This is a desirable feature whenever it is possible to incorporate it into a design. The point of the tool should be kept in perfect condition by the use of an oilstone, as only a very sharp and keen tool will turn out good work.

Hand tools are used in a similar way to the processes of brass turning, and a simple operation with a round-nosed tool is illustrated in Fig. 17, where a tube is shown in the act of being reduced to form a shoulder at one end. The lathe should run at a very high speed and a very light cut be taken to avoid overheating the tool, as it is surprising how quickly a good tool can be ruined on ebonite if the tool is allowed to heat or the cut is not continuous.

It is imperative that the tool should cut evenly and constantly, and if a finishing cut is taken with a very light cut, and at a high speed with a slow feed, the result will be a practically perfect polished surface.

Another turning operation is shown in Fig. 18, where a former for a variometer is seen held in a lathe chuck, while the edge is being turned with a side or facing tool clamped in the tool post of the slide rest. With a screw-cutting lathe most of the turning is best effected with a very fine automatic feed, accomplished by setting up the wheels for the slowest sliding feed. The lathe should run at as high a speed as possible. Small bushes and other work of

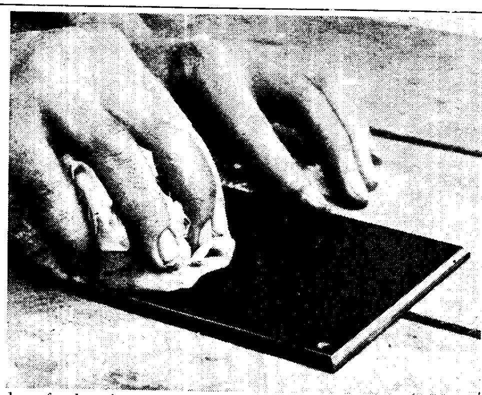


Fig. 12 (left). Surfaces of many components made of ebonite have to be matted. This process is performed with emery paper. Fig. 13 (right). Superfine finish is imparted by the use of emery powder and oil, or dry brickdust may be used

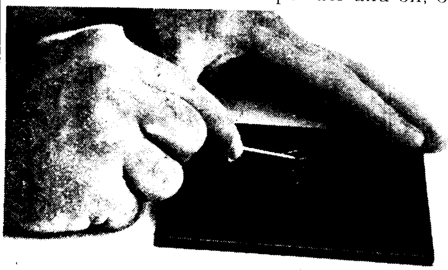


Fig. 14 (left). Calibrations may be engraved on an ebonite panel. The tool used in small parts of this kind may be a graver or burin. Fig. 15 (right). After the incisions have been made they are filled in with white paint or chalk. The surplus is then wiped off

Fig. 16. In this photograph the operator is seen holding an ebonite calibrated disk. A wool mop is fixed in a lathe and the disk is applied as the mop rotates. This method gives a very fine polish. The disk, or any other component to be polished, can be applied to the polishing mop so as to operate upon part at a time

Fig. 17. Turning ebonite by hand and lathe is shown in progress. A short piece of ebonite bushing or tube is held in the chuck of a light lathe, and the operator is holding a round-nosed hand tool, resting his left hand on a support. The end on the piece of ebonite is being rounded

MATTING, POLISHING, AND ENGRAVING EBONITE COMPONENTS

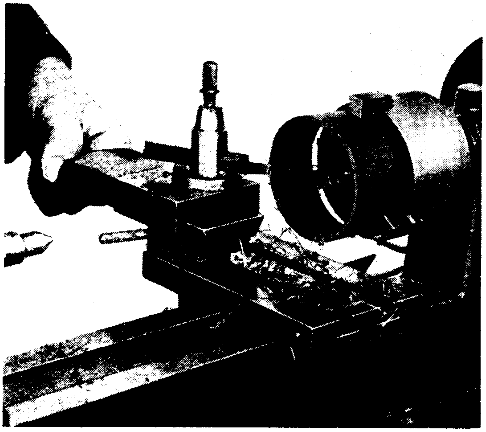


Fig. 18. Ebonite tube former for a variometer held in the chuck of a lathe for turning. The tool is held on a slide rest

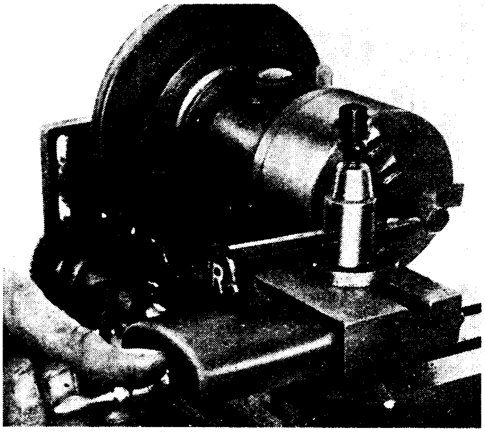


Fig. 19. This photograph shows the method of turning a small ebonite bush in a screw-cutting lathe

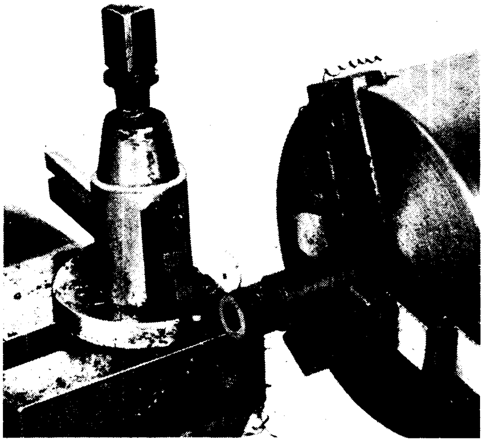


Fig. 20. One method of cutting a screw thread on an ebonite component is illustrated. The work is done on a lathe

Fig. 21. Heat treatment is applied in this case. An ebonite handle is being fitted to the contact arm of a switch

VARIOUS METHODS OF WORKING IN EBONITE

a like character is carried out in a screw-cutting lathe in the manner shown in Fig. 19, by grasping the work in the drill jaws of a lathe chuck and running down the ebonite rod with a side tool having ample top and side rake.

The cutting of screw threads in the lathe is carried out in the same way as on metal, by using a V-pointed tool, as in Fig. 20, with a very keen edge. A final finish is imparted by clamping a chaser in the tool post and using this to clean up and polish the threads.

Small screw threads are generally cut with dies and taps, and in such cases the ebonite is first drilled, and the tap worked down by gradual stages, backing the tap out of the work at frequent intervals to avoid the tool clogging. If it does the threads will be stripped and spoiled. Precautions are to use plenty of lubricant, such as turpentine or soft soap and water. Taps, drills, and reamers should all be backed out frequently for the same reason.

Ebonite is amenable to treatment by heat, and one way to take advantage of this fact is illustrated in Fig. 21, where a handle is shown in the act of being fixed to a brass lever or contact arm. The latter is drilled in the centre and the arm heated in the flame of a blow-lamp; if pressed on to the end of the handle as shown, the heated brass will soon slip into the handle, and when cold will be firmly held in place.

Ebonite can be milled in a milling machine, or in an attachment on a lathe, and along the same lines as for milling brass or mild steel.

Cracks in ebonite are sometimes stopped by running a heated soldering iron over the crack on each side, and also running in a little more ebonite by melting a portion from a small cutting or strip of thin ebonite. When cold, the surface is polished or matted as desired. Small holes in ebonite can be filled with black sealing wax or Chatterton's compound worked in hot, and when cold levelled off with a scraper and the surface repolished. Larger holes are filled with plugs either driven in or screwed into place and secured by application of a hot iron to both sides.

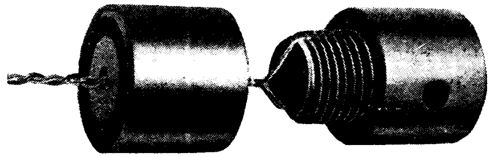
Sheet ebonite that has bent can readily be straightened or flattened by placing it between two sheets of wood or other material previously warmed, and as soon as the ebonite is warm, weights are placed on the topmost plate and the whole allowed to flatten and set.

Knurled work, as the milling on the edges of knobs and other handles, is accomplished by well-supporting the work in the lathe and running it at a slow speed while the knurling tool, held in the tool post of the slide rest, is forced into contact with the revolving work with considerable pressure. Soft soap can be used in this operation with every success.—*E. W. Hobbs.*

EBONITE CONDENSER. Name given to a type of condenser in which ebonite is used as the dielectric. Such condensers, made by Marconi's Wireless Telegraph Co., have very thin sheets of ebonite arranged between metal plates. In the Fleming cymometer (*q.v.*) the variable condenser consists of a long brass tube sheathed with thin ebonite, over which another metal tube slides.

Though ebonite is an excellent insulator, it has the disadvantage of being very liable to alter in its properties with the lapse of time, especially on the surface, and its dielectric loss is relatively high.

EBONITE INSULATOR. Name given to an aerial insulator made throughout in ebonite. It consists of two cylindrical parts, one having an external screw thread formed upon it, and the other a hollow member screwed correspondingly and provided with a small circular hole for the passage of the aerial wire. This is attached to the body by passing it through a hole drilled at right angles to the screwed portion and twisting the other end of the conductor around itself for a distance of two or three inches.

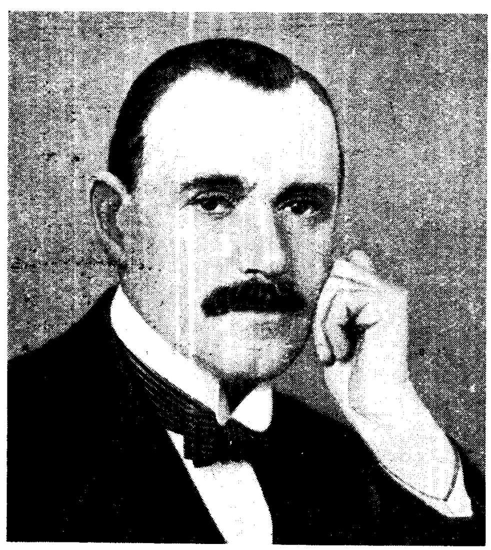


EBONITE INSULATOR

One part of this insulator holds the ends of two wires, the other part is screwed on like a cap, with one of the wires passing through its centre

Shallow grooves are formed in the screwed portion of the body, so that the wire can rest in them below the level of the screw threads. Consequently, when the cap is screwed firmly in place, it holds the wire securely. A hole is drilled at right angles through the body as a means of attachment to the aerial.

ECCLES, W. H. British scientist. Born at Furness in Lancashire, in 1875, and educated at the Royal College of Science, South Kensington, he was appointed demonstrator in the physics laboratory there, and in 1898 he obtained first-class



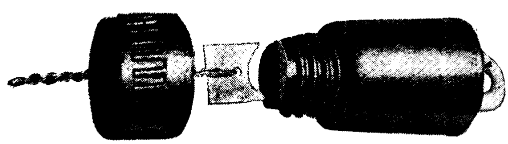
DR. W. H. ECCLES, F.R.S.

First Chairman of the Wireless Section of the Institution of Electrical Engineers, this well-known scientist did much to advance the progress of wireless research, especially in connexion with his investigations of electrical oscillations in aerial wires. He contributes the article "Valves for Transmission" to our Encyclopedia.

honours in physics at London University. In the following year he joined Marconi, and at Chelmsford carried out a brilliant series of researches in wireless, particularly in connexion with coherers. In 1901 he was appointed head of the mathematical and physical department at the South-Western Polytechnic, Chelsea. In 1916 Dr. Eccles became Professor of Electrical Engineering at Finsbury Technical College and afterwards Dean of the College. He is Vice-President of the Institution of Electrical Engineers, of the Physical Society, and of the Institute of Physics. Eccles was the first chairman of the Wireless Section of the Institution of Electrical Engineers, is President of the Radio Society of Great Britain, and is Honorary Secretary of the British Association Committee for Radio-Telegraphic Investigation.

Dr. Eccles is one of the leading men in wireless, and has written widely on the subject for many scientific periodicals. He is also the author of one of the standard textbooks on the subject. Dr. Eccles has written the article "Valves for Transmission" for this Encyclopedia.

ECON INSULATOR. Type of insulator adapted for use in connexion with aerials, or for any purpose where it is desired to terminate an electrical conductor. As can be seen in the illustration, the fitting



ECON INSULATOR WITH FOUR PARTS

Between the two ebonite parts is a metal plate to which the wire is attached. This is held in the body of the insulator when the two ebonite parts are screwed together. A metal ring is attached to one end for supporting the insulator

comprises four essential parts. First, the body, made of moulded insulating material having embedded in it a metal eyebolt, which forms a point of attachment for the halyard or other means of support.

The opposite end of the body is formed with a coarse screw thread and has a slot cut diametrically across it. The third element comprises a metal plate with two holes pierced through it, and the stranded conductor is placed through these holes and the free end of the conductor twisted round and round itself. This little plate is then inserted in the slot on the top of the insulator. The cap or fourth element is screwed on to the body.

It thereby presses the plate firmly in the slot and makes very secure connexion. Should the wire twist, it will not have a tendency to unscrew the cap, as the plate is held in the slot in the body and is consequently unable to move.

EDDY CURRENTS. Eddy currents are stray currents which circulate in the iron cores of an electro-magnetic apparatus, or, more accurately, are currents circulating in closed paths in any metal, being excited on the spot by varying magnetic induction.

One of the commonest electric machines in which the effects of eddy currents are noticeable is the dynamo. Since iron is a conductor as well as a magnetic substance, and is cutting the lines of force in its rotation, currents will be generated in the core in exactly the same way that they are in the windings.

All currents generated in the armature, whether in the core or in the windings, necessitate power being expended in their generation. Since the eddy currents cannot be collected and have no useful purpose, they clearly represent so much wasted energy. Apart from that, moreover, they heat up the armature. Eddy currents, therefore, are bad from these two points of view.

The most efficacious method, and that invariably adopted, to prevent eddy currents, is to split the armature core into a number of thin laminations. A very large number of laminated disks, stamped to the exact shape of the finished core, are threaded upon the armature spindle. The heat treatment which these plates undergo during manufacture results in a hard, flaky scale being formed upon them. This scale is quite a good insulator, and it is general practice, particularly on smaller machines, to thread them up all together, fix the thicker plates at the ends, and bolt or rivet the whole into one solid formation.

Some manufacturers, however, place paper between each lamination to make a better and surer insulation. It will be seen that by building up the cores in this manner the insulation between each lamination is a preventive of the passage of any current which may tend to be generated.

The magnetic reluctance of the core is not increased by dividing it in this manner, since the magnetic lines of force from the field magnets run across the armature laterally in the same directions as the lamination. The laminating furthermore performs the function of ensuring quick demagnetization of the core, an essential feature in any machine in which the polarity is always changing.

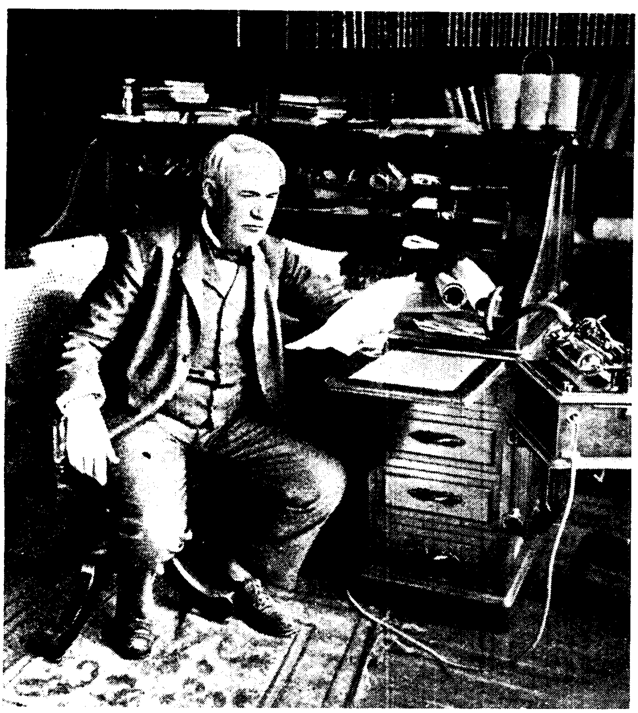
EDGE EFFECT. In condensers an effect on the capacity of a condenser due to the lines of electric stress being curved at the edges. Most of the formulae giving the capacity of a multiple-plate condenser make the assumption that the lines of electric stress at the edges of the plates are perpendicular to the surfaces, which is not the case in practice unless a guard ring is provided.

A guard ring consists of a metal ring or rim round the outside edge of each metal plate of the condenser and separated from the plate by a narrow gap. When the guard ring and its plate are both at the same potential the lines of stress on the condenser plate are at right angles at the edges and the curving takes place on the outer edge of the guard ring.

Sir J. J. Thomson has shown that in the case of a condenser having plates with straight edges the edge effect may be allowed for, if the linear dimensions of the plates are large compared with the distances between them, by assuming an additional strip of width equal to $\cdot 11d$, where d is the distance between the plates. For circular plates Maxwell gives the extra strip as being $\cdot 4413d$. *See* Capacity; Condenser; Electrostatic Capacity.

EDISON, THOMAS ALVA. American inventor and scientist. Born on February 11th, 1847, at Milan, Erie County, Ohio, at fifteen he became a telegraph operator and first began to make studies of and experiments in electricity which were to make him world-famous. Before he was twenty-one he invented an automatic repeater enabling a message to be transferred from one wire to another automatically.

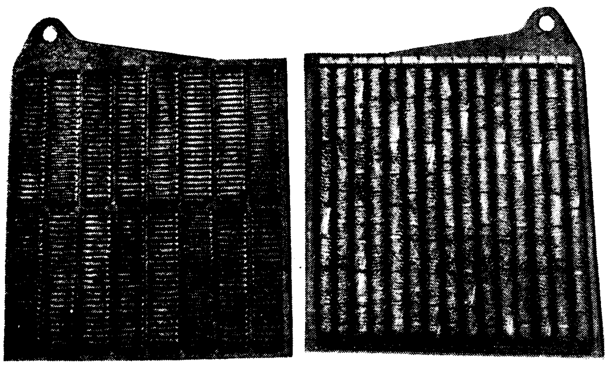
With his invention of an improved form of printing telegraph, for which he received £10,000, he was enabled to establish his laboratory and factory in Newark, where he carried out his early experiments in electricity before removing ultimately to West Orange. A very large number of important inventions are due to Edison, among the principal being his system of duplex telegraphy, afterwards developed into quadruplex and sextuplex systems; the carbon telephone transmitter; the phonograph; the cinematograph; the electric incandescent lamp; and many others. Wireless owes a considerable debt to Edison, since it is largely due to his researches on the Edison effect in carbon filament lamps that the two-electrode and ultimately the three-electrode electric valve came to be invented. More than 900 patents have been granted to him for his inventions, and he has been honoured by innumerable scientific societies and universities.



THOMAS ALVA EDISON

Patent devices invented by Edison are known throughout the world. Wireless science has gained many advances by his discoveries. It was largely through his researches on the Edison effect in carbon filament lamps that the valves universally used in wireless came to be developed

EDISON CELL. A proprietary accumulator or storage cell having electrodes of nickelled steel and an electrolyte of potassium hydrate solution. It differs radically from the great majority of storage cells, in which the plates are made of lead with diluted sulphuric acid as the electrolyte.



EDISON POSITIVE AND NEGATIVE PLATES

Fig. 1. On the right is an Edison positive plate, consisting of a row of 15 tubes held together in a steel framework. Each of these tubes has eight strengthening rings. On the left is an Edison negative plate, composed of many small nickelled steel pockets containing iron oxide with a little mercury

Courtesy Edison Accumulator Co.

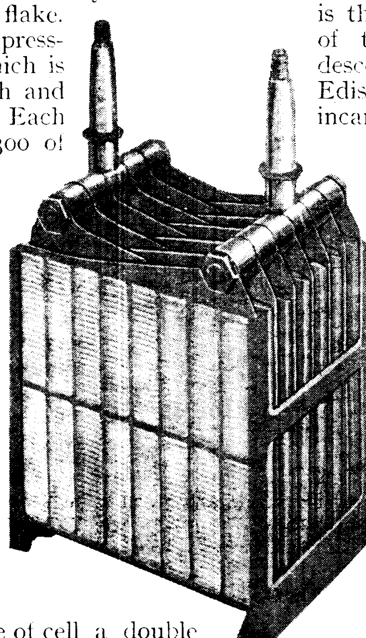
In the Edison cell the active material of the depolarizing or positive electrode is nickel hydroxide and fine metallic nickel flake. The former is an imperfect conductor of electricity, for which reason the nickel is added to make a better conducting material. A helical tube made of finely perforated nickelled steel strip is filled with alternate layers of nickel hydroxide and fine metallic nickel flake. These layers are compressed into the tube, which is about 4 in. in length and $\frac{1}{4}$ in. in diameter. Each tube contains over 300 of the layers.

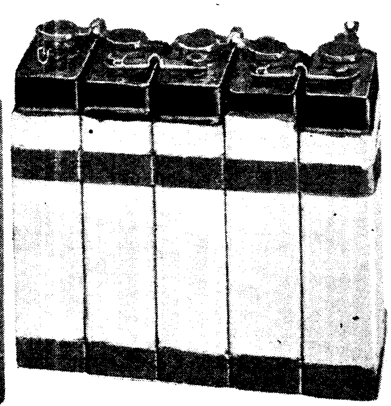
The tubes are strengthened and their conducting power increased by eight steel rings placed equidistantly on each tube. The positive plate contains a number of such tubes arranged in line and held in position by a light punched nickelled-steel framework. This is shown in the right-hand plate in Fig. 1.

In a common size of cell a double row of 15 tubes is used. The negative plates are similarly constructed of small units of oblong form. The oblong pockets, also made of finely perforated nickelled-steel strip, are filled with a special preparation of iron oxide with a trace of mercury to make a better conductor. A negative plate is seen on the left in Fig. 1. The plates in both positive and negative electrodes are bolted together with long steel bolts passing right through the set of plates. Suitable spacing washers are employed to separate the plates from each other, and hard rubber strips are used to separate the positive from the negative plates.

Fig. 2 illustrates this feature, which shows the assembled plates. The container is made of cold-rolled steel sheet, welded at the seam. The electrolyte consists of a solution of potash in distilled water. Fig. 3 shows a battery of five Edison cells removed from a carrying box. In this type the cell is covered with Para rubber for purposes of insulation. This type of battery is suitable for supplying current for lighting valves or other wireless work where a steady supply of current is required.

EDISON EFFECT. The Edison effect is the phenomenon of the blackening of the inside surface of an incandescent electric lamp bulb during use. Edison, who was the inventor of the incandescent lamp, noticed during his





CONTENTS OF EDISON CELL AND A BATTERY

Fig. 2 (left). Edison cell, removed from its case, showing method of bolting the plates together. At either end of the plates will be seen rubber separators. Fig. 3 (right). A battery of Edison cells is shown covered with Para rubber for insulation purposes

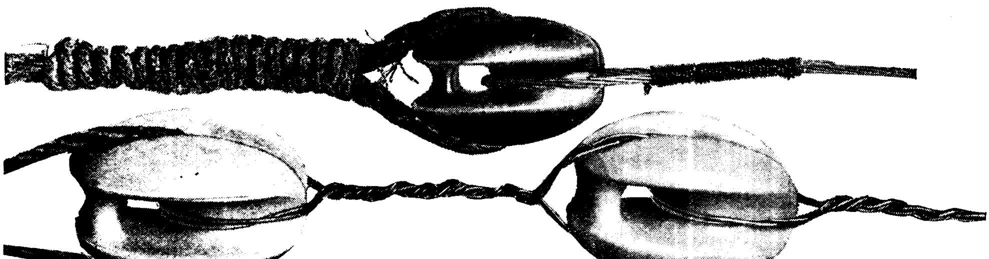
Courtesy Edison Accumulator Co.

experiments that as the lamp burned, the bulb became black, finally becoming almost opaque. The blackening occurred on practically every part of the interior surface.

Edison's investigations into the cause of the blackening led to the development of the thermionic valve, for he found that it was the emission of electrons which was responsible for the phenomenon, and, furthermore, that they were flung off from the filament with a considerable velocity. Further experiments of his, coupled with those of Professor Fleming, led to the discovery that the addition of a positively charged sheath or plate surrounding the filament would considerably accelerate these emissions, and, further, that it would attract the electrons to it—the principle of the two-electrode valve. *See* Electron; Fleming Valve; Valve.

EGG INSULATOR. A small porcelain insulator, so named on account of its shape. Figs. 1 and 2 show the characteristic shape of this type of insulator and its arrangement of the holes and grooves. The holes are arranged in the manner shown so that the strain brought upon the insulator when the aerial is in position shall be a compression and not a tension. This is because porcelain and similar materials are better able to withstand compression than tension.

The aerial to earth wire should be passed through one of the holes, and either spliced or whipped with wire in the manner illustrated in Fig. 1. The halyard is then passed through the other hole and spliced or seized as shown. It will then be noted that should the insulator break, the aerial wire will not fall, as the loop of the halyard passes through that on the end of the aerial.



SUPPORTING AERIAL WIRES BY EGG INSULATORS

Fig. 1 (above). One of the most common uses of an egg insulator is the connexion of wires for an aerial wire and its support. In this case a rope support is insulated from the aerial wire. Fig. 2 (below). When two wires are to be insulated from each other it is usually found most efficient to use at least two egg insulators in this way

A better effect is obtained by arranging the insulators in the manner shown in Fig. 2, where two are employed. The aerial terminates at one of them, and the second is connected to the first by means of a short and twisted stranded wire. The halyard is fixed in the manner already described. In choosing egg insulators, accept only those which are perfect and quite free from any cracks or flaws, or these may speedily develop worse faults and allow the electric waves to leak away to earth.

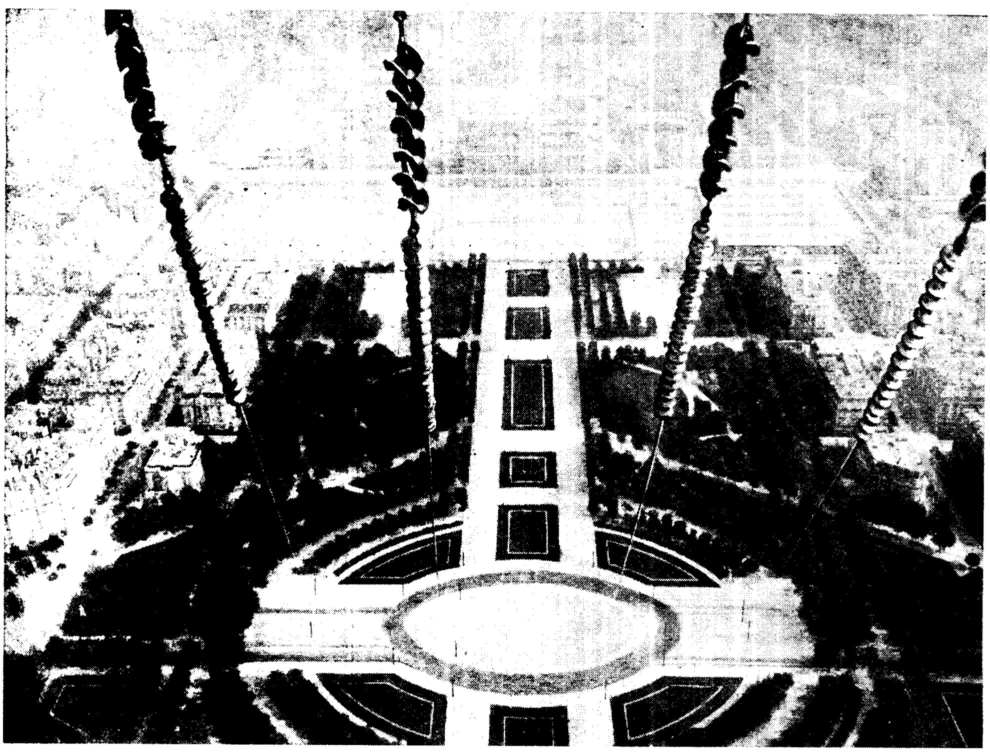
THE EIFFEL TOWER STATION AND ITS EQUIPMENT

A Complete and Graphic Description of One of the Most Important Wireless Stations

Here is a comprehensive account of the great Paris station, known to all amateurs on account of the high power of its transmission. The photographs illustrating the article were specially obtained for this Encyclopedia by arrangement with the French Government. See also Arc Transmitter; Broadcasting; Transmission

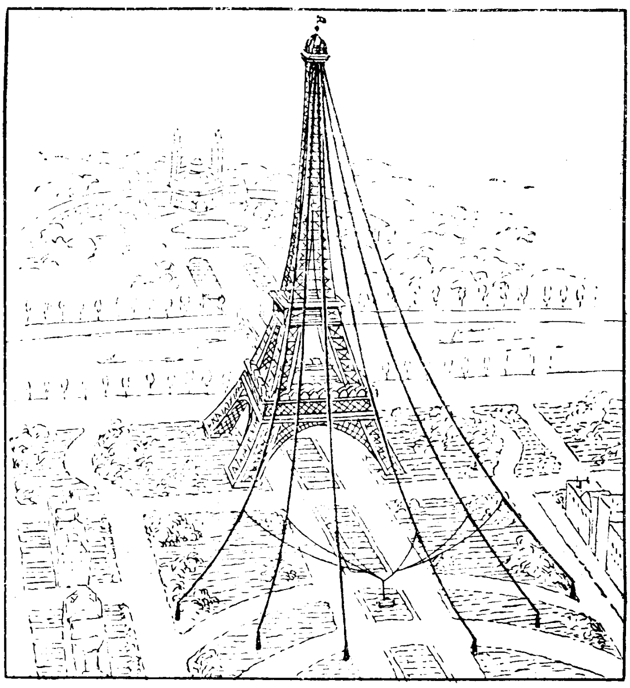
The Eiffel Tower is one of the chief of the Continental wireless stations, situated, as its name implies, in the Eiffel Tower, Paris. It is under government control.

The power supply of the station has been arranged to minimize as far as possible the likelihood of enforced inactivity through a breakdown in the current supply. In addition to the electrical energy generated at the station itself, two outside sources of supply are available. One of these is supplied by the State Electric Railway in the form of three-phase alternating current, at the



EIFFEL TOWER AERIAL INSULATORS

Fig. 1. Four of the wires of the aerial at the Eiffel Tower are seen at the point of insulation at the top. Note the way the insulators are used



AERIAL SYSTEM OF F L, PARIS

Fig. 2. Transmitting aerials of Eiffel Tower, known to all amateurs as F L, Paris. Some idea of the size of the aerial may be gathered from the fact that the tower is 948 ft. in height

effective voltage of 5,000 and a periodicity of 25 cycles.

This supply, largely owing to its generation on a very extensive scale, is found the cheapest, and is put into use whenever possible.

The other outside power supply is generated by the Paris municipal authorities, and consists of a monophase alternating current at 3,300 effective volts and a periodicity of 42 cycles. At the station this current is stepped down by means of a transformer to 220 volts for the power supply and to a voltage of 110 for lighting the rooms and workshops of the station, which is almost entirely underground. A diagram of the aerial system with the lead-in wires is given in Fig. 2, the insulators near the top of the tower being seen in the photograph, Fig. 1. The internal supply, used as a stand-by if the outside current should fail, is primarily generated by a 240 h.p. Diesel engine, to which is coupled, by belt drive, a direct current dynamo. This engine is assisted by three subsidiary power units, which are shown in Fig. 3, representing one section of the power station. The output from this dynamo is converted into the various forms of electrical energy required by means of four motor-generator units.

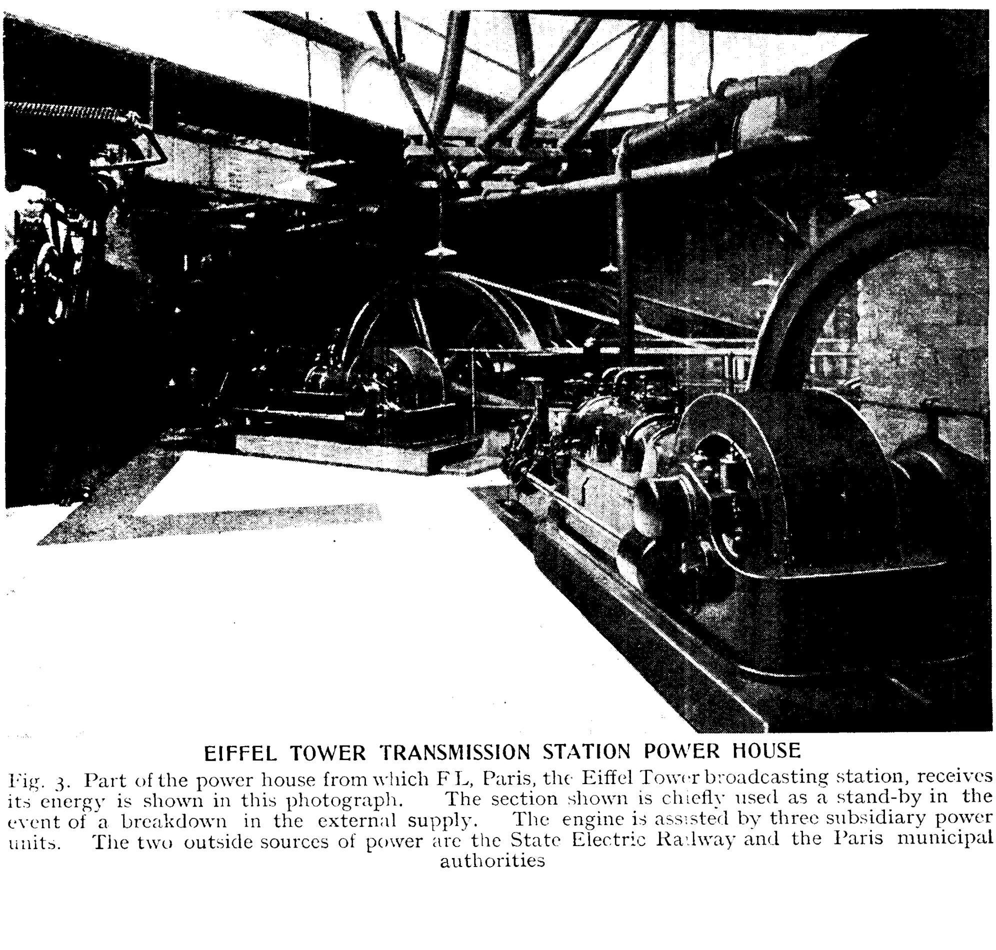
There is a 1,000 volt direct current generator direct-coupled to a three-phase 500 volt alternating motor which is not shown in Fig. 4. It is placed against the remaining wall of the power room. Many combinations of power are possible from the method of grouping the generators.

In addition, a battery room is arranged to supply a potential of 110 volts for 300 ampere-hours. This supply is largely used in the signalling circuits.

The power available is used for four distinct systems of transmission, which are as follow :—

1. Spark transmitter.
2. Poulsen arc.
3. High-frequency alternator.
4. Valve transmitter.

For the spark transmitter single-phase alternating current is used, having a frequency of 1,000 cycles. This method of transmission is most largely used for the issuing of time signals and meteorological observations, and is sent out on such a high power as to enable it to be received in England on a crystal set. These time signals, which are sent out every morning at 10.30 a.m., Greenwich time, are on a wave-length of 2,600 metres. The inductance that determines this wave-length consists of 40 turns of brass pipe, the diameter of each turn being three feet. The long distance of reception with which the Eiffel Tower time signals are credited is more easily understood when it is realized that the



EIFFEL TOWER TRANSMISSION STATION POWER HOUSE

Fig. 3. Part of the power house from which FL, Paris, the Eiffel Tower broadcasting station, receives its energy is shown in this photograph. The section shown is chiefly used as a stand-by in the event of a breakdown in the external supply. The engine is assisted by three subsidiary power units. The two outside sources of power are the State Electric Railway and the Paris municipal authorities

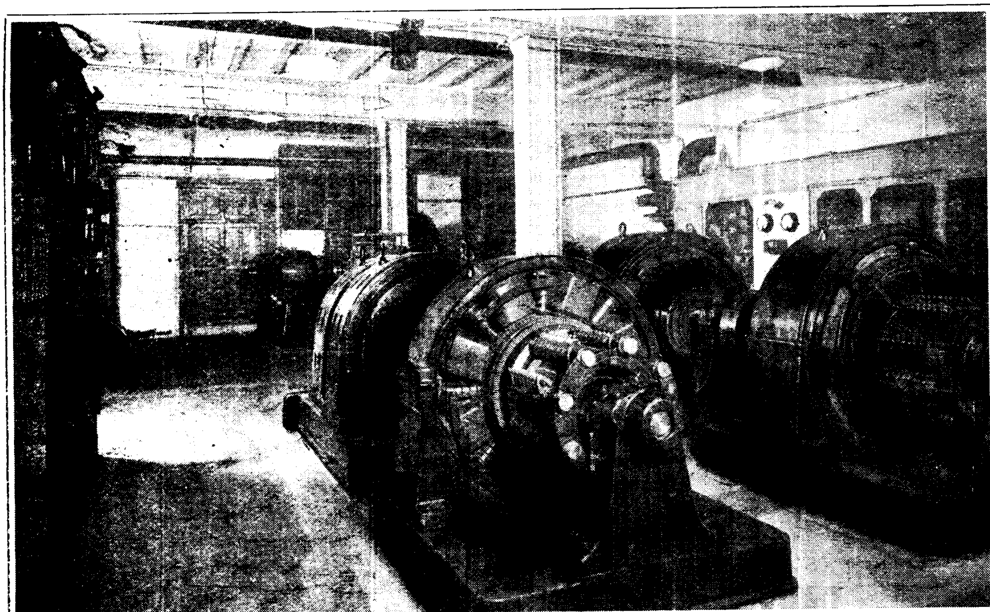


Fig. 4. External supply as well as the internal generators are connected to the switchboard on the extreme left. This view of the generating room shows the motors and generators. In the centre is a 110 volt direct current motor. Just behind is a 1,000 volt three-phase motor; on the right is a 5,000 volt three-phase motor

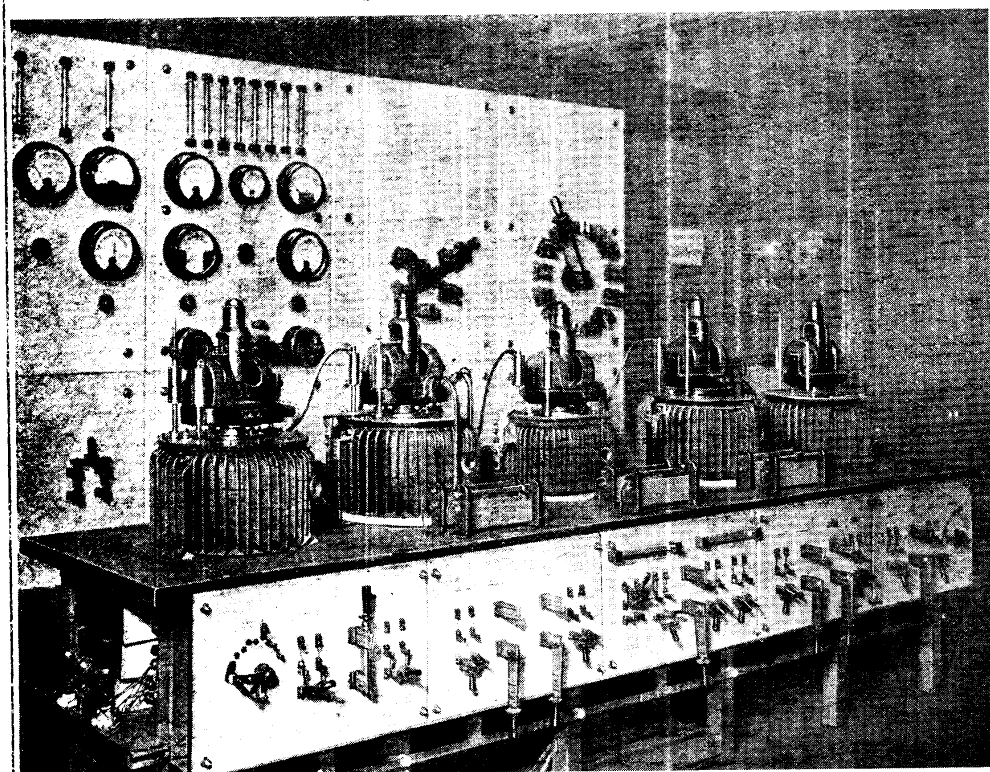
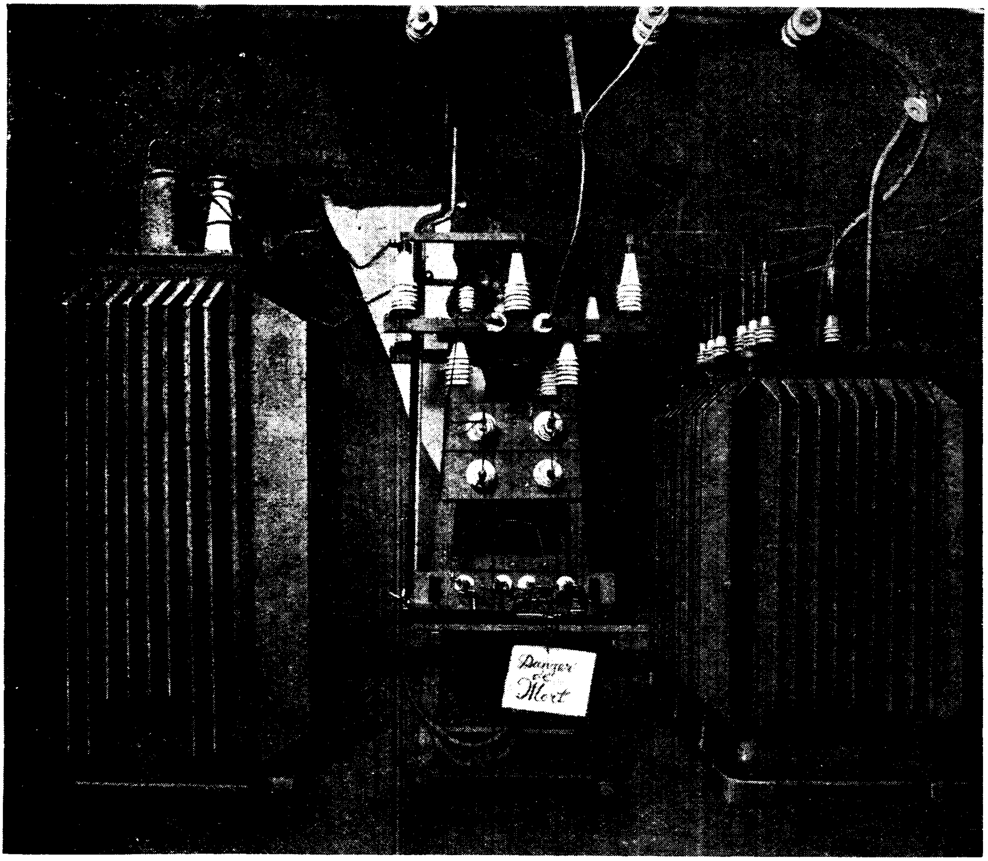


Fig. 5. Mercury contact breakers of the Eiffel Tower spark transmitter are illustrated. These are for interrupting the excitation of the alternator, and consist of vertical motors which drive centrifugal pumps. The principle is to intercept by a shutter a stream of mercury thrown up, thus breaking contact

APPARATUS USED AT THE EIFFEL TOWER WIRELESS STATION

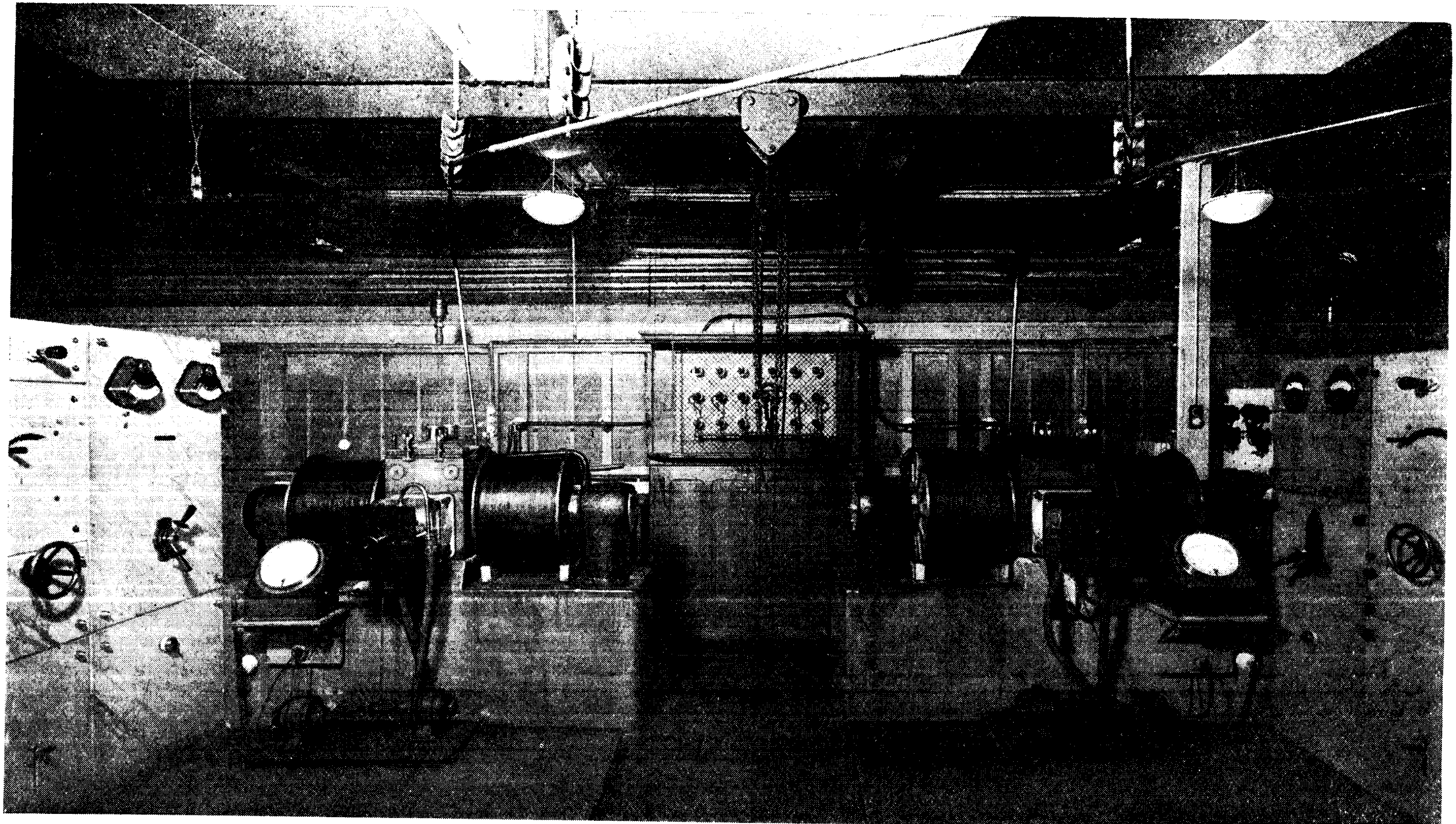


PNEUMATIC CREED RELAY OF EIFFEL TOWER SPARK TRANSMITTER

Fig. 6. In the centre, with the "Danger" warning displayed, is the pneumatic Creed relay used with the spark transmitter of the F L, Paris, wireless station. On either side will be seen high-tension transformers. Compressed air is employed for extinguishing the arc which occurs when the high-tension circuit is broken

aerial current is in the order of 80 amperes. An interesting feature of the spark transmitter is the method of controlling the spark. It will be seen that special arrangements are necessary when a very large current is required to make and break contact with the rapidity of the dots and dashes required in Morse code signalling. Unless preventive measures were taken, the high-powered current would jump the spark gap, resulting in the metallic contacts being burned up. The method of overcoming the difficulty is done by varying the excitation current of the alternator.

When the circuit is closed a big increase of exciting current is occasioned, resulting in a torrent of sparks across the spark gap. This circuit is controlled by means of mercury circuit-breakers, shown in Fig. 5. Each of these consists of a vertical motor driving a centrifugal pump. The pump sucks up a quantity of mercury at the bottom of an insulated metallic tank and flings it horizontally on to a metallic ring integral with the motor spindle and revolving with it. The method of making and breaking contact consists of a shutter which may be raised or lowered to intercept the mercury stream projected to the revolving ring. When the shutter is lowered the mercury stream is prevented from reaching the ring, and consequently contact is broken. On raising the shutter the stream of mercury completes the circuit between the tank and the revolving ring. It will be seen that, owing to the revolving electrode, the spark occurring at the break of contact will occur in a different place each time, and thus the likelihood of overheating is obviated. To prevent oxidation the tank is charged



INTERIOR VIEW OF THE CURRENT CONTROL ROOM OF THE EIFFEL TOWER ARC TRANSMITTING STATION

Fig. 7. Two arc machines are shown in this photograph, with current indicator and control to the left and right respectively. It is interesting to note the compound insulators carrying the direct current supply near the roof. The Poulsen arc transmitter is operated by current supply delivered at a pressure of 1,000 volts. Practically the whole of this station is underground, as indicated by the leading-in wires in the diagram on page 806

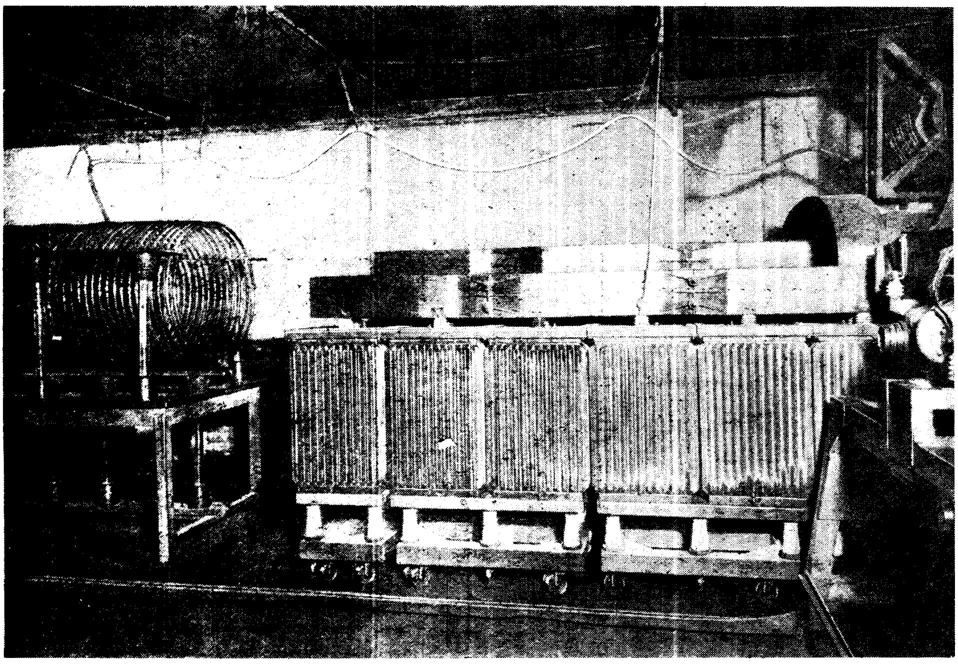


Fig. 8. Part of the aerial tuning inductance of the Eiffel Tower station is seen on the left, and on the right the transmitting Gaiffe condensers. These condensers have a maximum capacity of ·55 mfd. This is a portion of the spark transmitter apparatus

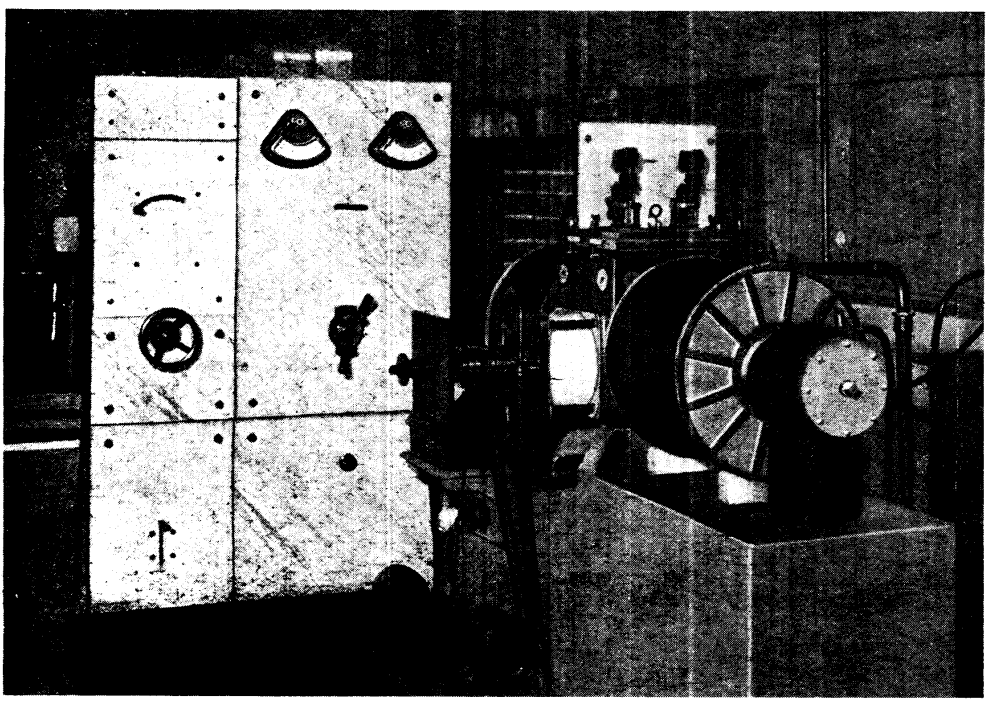
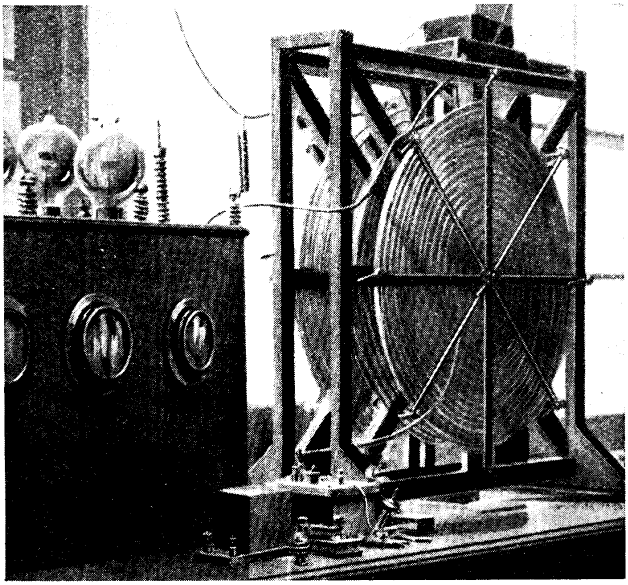


Fig. 9. On the right is the Poulsen 60 kw. arc transmitter. The powerful electro-magnets are used for steadying the arc. To the left of the machine is the control panel. The electrodes of the arcs consist of a carbon cathode and copper anode. The electrodes are in a water-cooled chamber

CONDENSER, AERIAL INDUCTANCE AND ARC TRANSMITTER OF F L, PARIS with coal gas. The switches and fuses controlling this circuit are mounted on the side of the table on which the circuit-breakers are mounted. The shutters seen to the left of each instrument are controlled by a direct current at 110 volts operated by a Morse tapping key.

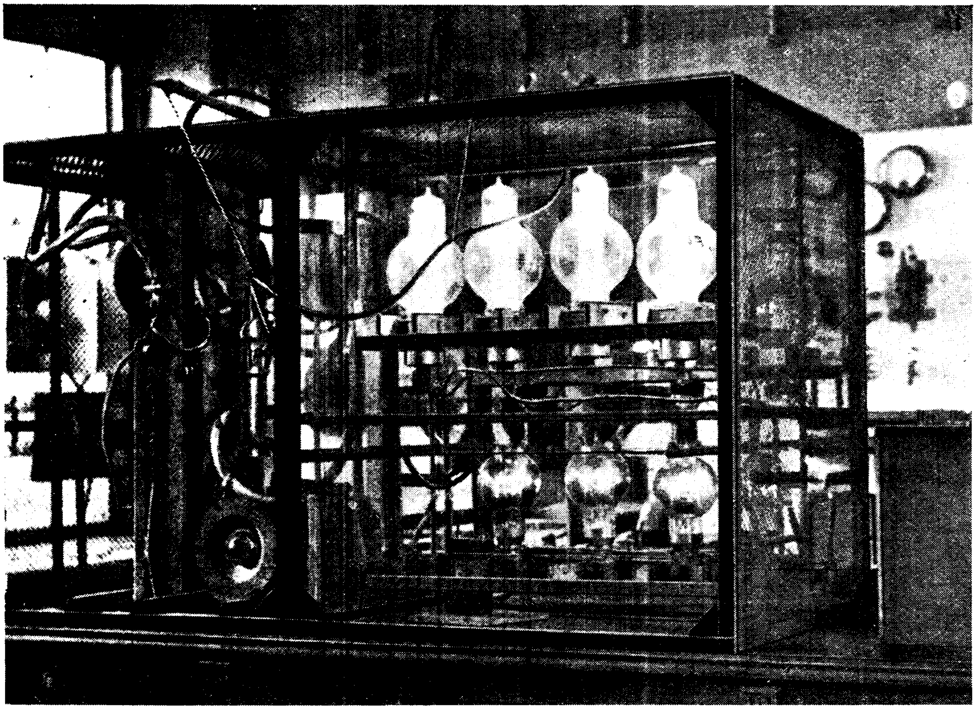
Fig. 6 shows a pneumatic Creed relay used in the high-tension side of the step-up transformer, on either side of which a high-tension transformer is seen. The arc occasioned by the breaking of the high-tension circuit is extinguished by compressed air.

The transmitting condensers, seen in Fig. 8, consist of flat aluminium sheet electrodes with a dielectric of glass plates. The condensers are contained in oil tanks, which, as seen in Fig. 8, have a corrugated exterior. Considerable heat



RADIO-TELEGRAPHY VALVE UNIT AT EIFFEL TOWER

Fig. 10. Transmissions of C.W. telegraphy at the Eiffel Tower station are sent out from a 1 kw. valve transmitter. To the right of the valve unit is seen the spiral aerial tuning inductance. The unit comprises six valves in all



BATTERY OF VALVES FOR TELEPHONIC TRANSMISSION

Fig. 11. Holweck tubes are shown mounted vertically in a rigid iron framework in the 5 kw. valve transmitter of the Eiffel Tower Broadcasting Station. On the left of the apparatus will be seen the molecular pump

is occasioned in these condensers owing to dielectric losses, and the corrugated surface of the tanks helps in its dissipation. Each condenser has a capacity of ·05 mfd. and the total capacity is ·55 mfd. Only a part of these is seen in the illustration. The aerial inductance referred to earlier in the article is seen to the left of the transmitting condensers.

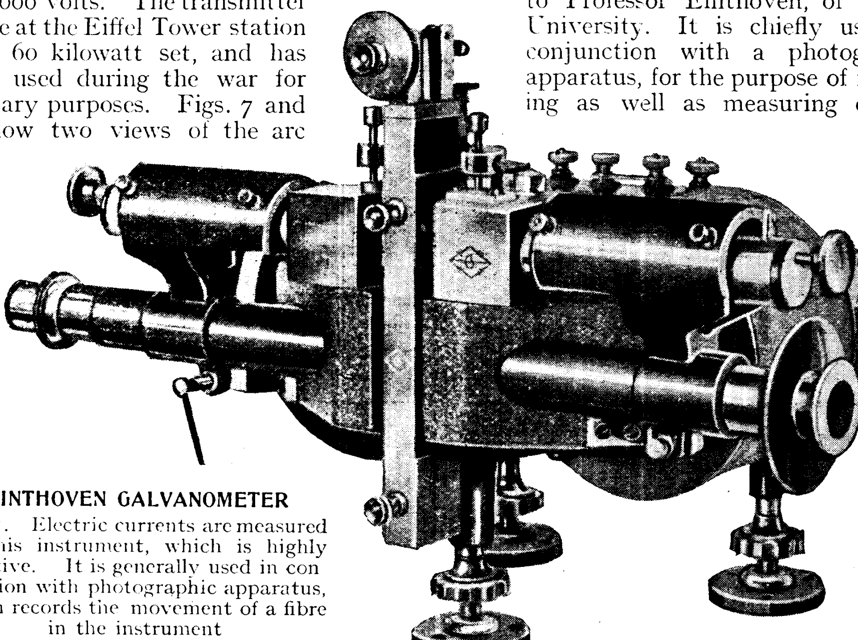
The Poulsen arc transmitter is worked from direct current supply at a pressure of 1,000 volts. The transmitter in use at the Eiffel Tower station is a 60 kilowatt set, and has been used during the war for military purposes. Figs. 7 and 9 show two views of the arc transmitter. The electrodes of the arcs consist of an anode of copper and a carbon cathode. These electrodes are arranged opposite to each other in a water-cooled chamber. Two powerful electro-magnets, clearly seen in both illustrations, are placed at right angles to the electrodes, so that the magnetic flux from the former has the effect of keeping the arc steady. The magnet windings are in series with the arc. When working, the chamber is fed with coal or hydrogen gas, which enters at the bottom of the chamber and passes out through the top.

At the front of either machine in Fig. 7 a large ammeter is seen which gives a direct reading of the amount of current passing through the arc. A close-up view showing the control panel is seen in Fig. 9.

The valve transmitters, parts of which are seen in Figs. 10 and 11, are used for continuous-wave telegraphy and telephony. Fig. 10 is a 1 kilowatt transmitter, and its use is now restricted to radio-telegraphy.

Two spiral aerial tuning inductances are seen to the right of the valve unit. The telephony set shown in Fig. 11 is used in broadcasting in conjunction with Holweck tubes and molecular pump.
—*W. W. Whiffen.*

EINTHOVEN GALVANOMETER. Special form of galvanometer primarily due to Professor Einthoven, of Leiden University. It is chiefly used, in conjunction with a photographic apparatus, for the purpose of recording as well as measuring electric currents. Essentially it consists of an extremely fine thread wire. Silvered quartz fibre and silvered glass have been successively employed, stretched in a strong magnetic field, *i.e.* between the poles of a strong magnet. The thread is in series with a rectifying detector, with the result that the passage of oscillations sets up a current in the thread, causing the latter to be displaced in consequence of the surrounding magnetic field. The displacement is observed by a microscope, and, if desired, the magnified record can be photographed on a moving strip of sensitized paper.

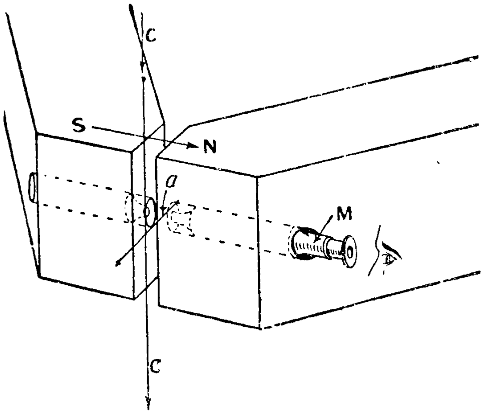


EINTHOVEN GALVANOMETER

Fig. 1. Electric currents are measured by this instrument, which is highly sensitive. It is generally used in conjunction with photographic apparatus, which records the movement of a fibre in the instrument

Courtesy Cambridge & Paul Instrument Co., Ltd.

Fig. 1 shows a typical Einthoven galvanometer as made by the Cambridge and Paul Instrument Co. The instrument is extremely sensitive and has a short period. It is dead beat and possesses practically no self-induction or capacity.



CONDUCTIVE FIBRE IN EINTHOVEN GALVANOMETER

Fig. 2. When a current passes down the fibre in the gap a movement outward, as indicated by the arrow, takes place. The deflection is observed through the microscope, a path of vision being provided through the pole pieces

The galvanometer is of the moving coil type, the coil and suspension being replaced by a fine wire, or conductive fibre, which is stretched in a narrow air gap between the poles of a powerful electro-magnet. The arrangement is shown diagrammatically in Fig. 2, and effects a great reduction in the moment of inertia of the moving system.

When a current passes down the fibre CC, the latter is deflected in the direction of the arrow A, that is, at right angles to the magnetic field, N S. The deflection is observed either by means of a microscope, M, which passes through a hole bored in the pole pieces, or by projecting an image of the fibre on to a screen or photographic film.

The fibre used in these instruments is generally of glass covered with a thin metallic coating, and is 65 mm. in length and from 0·002 to 0·005 mm. in diameter. The resistance varies from 2,000 to 4,000 ohms, depending on the thickness of the coating. If a low-resistance fibre is required, the standard fibre is replaced by a fine copper wire, the resistance of which is 12 to 15 ohms only.

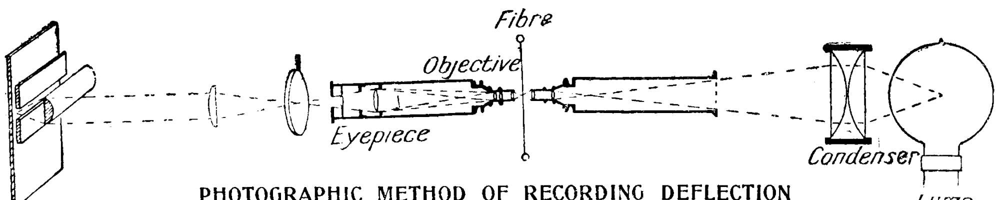
A fine screw enables the tension of the fibre to be adjusted and the sensitivity controlled, a stop eliminating all risk of breaking the fibre by over-tightening. The electro-magnet is so shaped as to concentrate the field in the air gap in which the fibre moves.

The optical system is supported from the electro-magnet by geometric fittings, which permit it being readily alined and focused. The arrangement of the optical work depends on whether the deflections of the fibre are to be observed by means of a microscope, projected on a screen, or recorded photographically. The latter method is usually adopted, and the optical work is arranged as shown in Fig. 3. The light from the lamp is concentrated by lenses on the fibre, and a slit is placed between the cylindrical lens of the camera and the photographic plate to cut off any extraneous light. *See* Galvanometer.

ELASTANCE. Another name for the reciprocal of capacity. *See* Capacity.

ELASTICITY. Property of matter in virtue of which it resists change in shape or bulk, and tends, after distortion, to recover its original shape or bulk when allowed to do so. Fluids have no fixed shape and therefore no power to resist change of shape; they have no elasticity of form, in other words, but they resist compression and have elasticity of bulk. Solids possess both kinds of elasticity.

The property which most bodies possess of returning to their original shape after the distorting force has been removed is one of great importance in all forms of engineering. Springs are examples of the use of this property, and the uncoiling of the main-spring of a clock or watch through suitable gearing to move the hands round is so



PHOTOGRAPHIC METHOD OF RECORDING DEFLECTION IN EINTHOVEN GALVANOMETER

Fig. 3. Instead of the eye watching the deflection of the fibre, photographic apparatus is so arranged that the concentrated light of the lamp at the opposite end of the path of vision projects upon the plate, a slit being placed between the cylindrical lens of the camera and the plate to exclude extraneous light

familiar as to be almost commonplace. The compression of a gas by a piston and its subsequent release is another example which is widely used.

The elasticity of a body is measured by the magnitude of the force that must be applied in order to produce unit change of shape in a body of unit dimensions. The change of shape is known as the strain, and the applied force is usually called the stress.

It is commonly said that rubber, for example, is more elastic than glass or steel. But it is not true, since elasticity is measured by the force which must be applied to produce unit change of shape, and this force is considerably greater for glass and steel than for rubber.

The elasticity of materials varies within very wide limits. Of the metals, lead, for example, has little elasticity, while steel is extremely elastic. When a material has been subjected to such loads that it will not return to its original shape after being distorted, it is said to have been stressed beyond its elastic limit. Up to that limit the distortion is proportional to the load, but beyond it the law ceases to hold. This law was first enunciated by Hooke in 1676, and is a very important one. Thus, by the law, if it takes a certain load to stretch a rod a given amount, say one inch, then it will take twice that load to stretch it twice that amount, that is two inches.

The loads applied to any material should never exceed those which will stress it beyond the elastic limit, or there will be a permanent set in the material which may become dangerous. The material will not return to its original shape when the distorting force has been removed.

One of the commonest things in which the wireless experimenter is concerned with the theory and practice of elasticity is in the stretching of wires. All wires stretch when a sufficient load is applied to them, and this fact should be taken into account to some extent in the construction of aerials, guy-ropes, etc. To carry out the necessary calculations on the amount of stretch a wire will undergo under a given load it is necessary to know the modulus of elasticity of the material of which the wire is made.

The modulus of elasticity, more commonly known as Young's modulus, may be defined as the ratio of the stress per square inch to the elongation in the length of one inch caused by this stress. It may be more correctly defined as the ratio of intensity of stress to unital strain Young's modulus of elasticity for annealed copper wire is about 15 million pounds per square inch, and for unannealed about 18 million; for annealed iron wire 15 million, and for unannealed iron wire 25 million; for steel wire about 30 million; for aluminium 11 million, and for lead only one million pounds per square inch. Up to the elastic limit the elongation of a wire may be calculated from the formula

$$e = S/E$$

where e is the elongation, S the load per unit area, and E Young's modulus.—*J. L. Pritchard.*

ELASTIVITY. This is a name for the reciprocal of inductivity or specific inductive capacity. *See* Dielectric.

ELECTRIC ABSORPTION. The quality of a condenser of gradually "soaking" up a charge of electricity and, conversely, retaining a part of it when momentarily discharged. The latter effect is known as a residual charge. After receiving a charge the mica or other dielectric is strained to a greater extent than a corresponding air dielectric, as it sets up a less opposing influence to the machine charging it up (in the same way a strip of elastic offers less opposition than a similar piece of cord), thus allowing the charge to soak partially into the dielectric, which will remain in this state even if the plates forming the condenser are removed. The same cannot be said of a condenser having an air dielectric, in which electric absorption is almost absent.

ELECTRIC FIELD. (1) The region surrounding an electrified body, in which the electrical influence of that body can be noticed. There is an electric field, for instance, in the dielectric of a condenser when the plates of the latter have a current passed into them. (2) Any region in which there is electric force, whether steady or varying. The term is also sometimes used quantitatively to denote the amount or intensity of the force. *See* Electricity; Flux; Magnetism.

ELECTRIC INDUCTION. The transfer of an electric state from an electrified body to a non-electrified body without contact. It differs from electro-magnetic induction (*q.v.*) in that each line of force starts at a unit positive charge and terminates at a unit negative, whereas in the case of electro-magnetic induction the lines reenter upon themselves, forming closed rings. *See* Induction.

ELECTRICITY: ITS CHARACTERISTICS & MODES OF ACTION

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

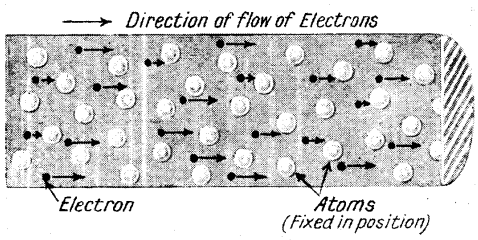
In this article Dr. Roberts, late of the Cavendish Laboratory, University of Cambridge, gives in clear and simple language an essentially scientific explanation of the most modern theories of electricity and its manner of action, with special reference to the needs of the amateur in wireless. The article is illustrated with ingenious diagrams and photographs. See also Magnetism and special headings such as Capacity; Electron; Induction, etc.

The notion of electricity has not been rendered less incomprehensible to the layman by such definitions as "matter is electricity," "electricity is a force," "electricity is life," and so on—vague half-truths which have been much heard of recent years. It is true that there are certain important limitations to our understanding of the nature of electricity and of electrical and magnetic action, but otherwise it is possible to obtain, comparatively easily, a working conception of electricity quite sufficient for an intelligent understanding of its behaviour and of its practical manipulation. As the latter represents the main purpose of this article, we need devote but a little consideration to the nature of electricity—a metaphysical rather than a physical question.

Electricity as a Fluid

As it is proposed in this article to treat electricity as a fluid, it should be explained at the outset, in order to avoid any possible misunderstanding, that electricity as we ordinarily know it—as it flows along a wire, or through the filament of an electric lamp—is a fluid in the sense that it is a collection or stream of particles of electricity, just as sand is a fluid formed of a collection of grains, air is a fluid formed of a collection of molecules of oxygen and nitrogen, and so on. When we say that electricity is a fluid, therefore, we do not mean that the individual particle of electricity (*see* Electron, Proton) is necessarily a fluid. It is only in very special experiments that we ever deal with individual particles of electricity: for all ordinary purposes we deal with collections or streams of such particles, and it is in this sense that we think of electricity as a fluid.

Now, electricity is not an *imaginary* fluid, as some suppose: it is very real and definite. The mass, for instance, of the unit quantity of electricity has been accurately determined. Electricity can be accumulated, stored, transferred from one place to another. It is, however, invisible and intangible in that it is not ordinarily perceptible by the senses. All this is mentioned in order to emphasize the fact that although electricity cannot be seen or handled, it is nevertheless a *real* thing—as real as ordinary matter: in fact, as we shall see presently, ordinary matter is probably a collection of positive and negative electrical particles arranged and fixed in a special way. When we speak of the flow of electricity along a wire, we use no mere figure of speech; a stream of electrical particles may actually flow along a wire (Fig. 1), just as a stream of drops of water may flow along a pipe.



ELECTRONS FLOWING THROUGH A CONDUCTOR

Fig. 1. This is an imaginary view of a solid substance through which an electric current is flowing. The atoms are fixed in position, and vagrant electrons are seen passing through inter-atomic spaces. Arrows show the direction of negative current

It has already been stated that electricity, as it is ordinarily employed, consists of a flow of electrical particles, usually negative particles only (*see* Electron), but sometimes both negative and positive particles (*see* Proton), and it has been hinted that ordinary matter is probably entirely electrical in nature and consists of these same electrical particles built up into complex structures. To use very popular language, we may say that we have "fluid electricity," which is electricity as we ordinarily know it, and "solid electricity," which is these same electrical particles or grains built up into atoms and molecules of matter. A simple analogy is that of ice and water: the "fluid electricity" would correspond to the water, and the "solid electricity" or matter, to the ice. This analogy is extremely crude and must be recognized as such.

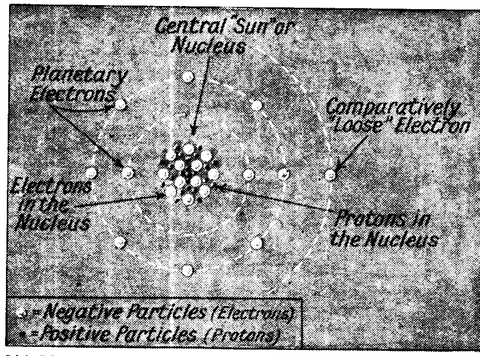
Now if matter consists of electrical particles in a special arrangement, and "electricity" consists of a swarm or stream of the same particles in a comparatively free or mobile state, the question naturally follows: What is the nature and composition of this electrical particle? If the electron, for example, is a particle of pure electricity, in a sub-atomic or sub-material state, disembodied and separated from ordinary matter as such, what is the nature of the *stuff* out of which the electron itself is made. In other words, if "electricity" is a collection of particles of electricity, what are the particles made of?

This question brings us to the threshold of the unknown. We may say the electron is a "corpuscle of ether," but since we know as little of the ultimate nature of the ether as we do of the nature of electricity, we are no further, and our terms, for practical purposes, become meaningless.

There are certain other fundamental mysteries which appear to be beyond our ken. Why do electrified or magnetic bodies attract or repel one another? What is the nature of electrical force, or of magnetic, gravitational, or, in fact, of any other force? It may be that these are processes more fundamental than the process of thought itself, or that the phenomena in question are manifestations associated with a state outside the sphere of our so-called "three-dimensional" existence. But without venturing into the domain of metaphysics, let us say that to the question, "What is the ultimate composition of the electrical particle?" no useful answer (in terms of anything with which we are familiar) can at present be given.

It will be convenient, at this point, to refer again in a little more detail to the question of the relationship or identity of matter and electricity. According to the universally accepted chemical theory, matter is built up of *molecules* (*q.v.*), whilst each individual molecule consists of *atoms* (*q.v.*), sometimes only one atom, but more usually several atoms linked together in a special way. Until comparatively recent years, since the atom was the smallest particle of matter which had ever been observed to take part in any chemical reaction, it was thought to be the ultimate unit of which all matter was built up. But during the past few years it has been discovered from special experiments that the atom, in turn, is a minute solar system, in which the sun and planets are minute positive and negative electrical particles (Fig. 2).

Furthermore, it has been found that these particles are identical with those



VAGRANT ELECTRON LEAVING SODIUM ATOM

Fig. 2. Grouped in the centre of this imaginary picture of the atom of sodium is the nucleus, consisting of 23 protons, or positive particles, and 12 electrons, or negative particles. In addition there are 11 more electrons in the external orbits, but one has left the outer orbit and become a vagrant electron carrying electric current, as seen in Fig. 1

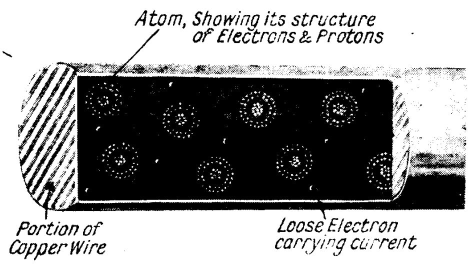
which, when moving in streams, constitute electric current. The atom is thus made up of electrical particles, and since atoms are built into molecules and a collection of molecules constitutes a portion of ordinary matter, it follows that ordinary matter is, in fact, a vast aggregation of infinitesimal electrical particles.

The Electricity within Matter

Now when the atoms and molecules are built up into matter there are spaces between them, just as there are spaces in a quantity of potatoes or of loaf sugar. Some of the electrical particles (particularly the negative ones) may not be very closely held by the atoms to which they rightly belong, and so may wander about in the spaces between atoms (called inter-atomic spaces). Thus we have a substance consisting of electrical particles built up into matter (and thus having the ordinary properties of matter) whilst within its minute pores and atomic cavities are free negative particles of electricity, not built into atoms, and therefore possessing the properties of electricity as distinct from those of matter.

It should be mentioned that the inter-atomic spaces referred to are almost inconceivably small, far beyond the most powerful microscope; the electrical particles are infinitesimal even compared with the spaces in which they move.

Let us use an illustration to make clear the idea of the electricity within matter. Imagine a sponge soaked in water. The water remains in the pores and cavities of the sponge, but can be brought into evidence by a certain operation (in this case, squeezing). The sponge corresponds roughly to the matter, and the water-drops to the electricity within it. The operation by which the electricity is brought into evidence will be considered presently.



WHY COPPER WIRE IS A GOOD CONDUCTOR

Fig. 3. Atoms of a copper wire are imagined in this sectional diagram. Clusters or systems of electrical particles are seen, each cluster representing an atom. The loose electrons which leave the outer orbits, as illustrated in Fig. 2, are available for carrying current. A good conductor, as copper, has plenty of these loose electrons, an insulator has few, or they are difficult to move

Again, to use a somewhat closer illustration, imagine a "sponge" made out of ice—picture a block of ice traversed by innumerable pores and channels, the spaces being filled with water. Here we have the idea of the "sponge" and the fluid being of the same nature, but in different states—the ice is identical with the water, but is at a lower temperature.

Matter consists of the electrical particles built up in a special way, whilst the free particles may be moved about, and it is upon these latter that the electrical behaviour of the substance largely depends (Fig. 3). Perhaps a third illustration may be helpful. A town usually has a fixed population and a "floating" population. The fixed population may be compared to a substance, and the floating population corresponds to the loose electrical particles between the atoms of the substance.

It will be observed that the electrical particles which are built up into atoms do not, in general, exhibit their electrical properties, and it is only by special experiments that their electrical nature may be rendered evident. The ordinary electrical properties of a substance depend upon the comparatively free mobile particles. For example, if a current of electricity is made to flow round a closed copper ring, what is happening is that the loose negative particles between the atoms are moving round the circle in one direction; if the current is increased, they move faster, so that a greater number of them pass any given point per second.

It should also be remarked, although we cannot go further into it, that in general the "fixed electricity," which constitutes matter, includes all the positive particles of the substance and most of the negative, the "fluid electricity" consisting of the remaining negative particles. Leaving aside the rather special cases of the conduction of electricity through *liquids* and *gases*, we may say broadly that in *solid* conductors the "floating population" consists of negative particles only. Thus under most ordinary circumstances, a "current of electricity" consists of the flow of a stream of "electrons."

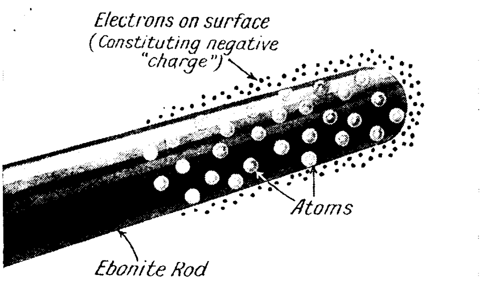
What is Meant by "Electric Charge"

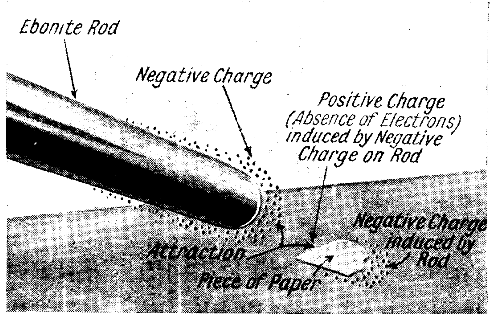
It may be asked why, if this electrical fluid is present in all bodies, it does not ordinarily manifest itself. The complete answer to this question would carry us beyond our present scope (*see* Electron), but it may be said briefly that it is because the total number of positive electrical particles in a substance is normally equal to the number of negative particles: these two kinds of particle are complementary, so that equal numbers form a satisfied whole.

When, however, the balance is by any means upset, and some particles of either kind are superadded to or abstracted from a body, the body does, in fact, exhibit certain new properties and is said to be "electrified," or to possess an "electric charge." It is important to note that when we say it possesses an electric charge, we mean that it possesses an electric charge which is *manifest*: it already possesses a charge of electricity, as we have pointed out, but its normal charge is balanced and therefore not evident.

The characteristic properties exhibited by an electrified body may now be considered.

If an ebonite rod is rubbed against the coat sleeve, for example, some of the negative electrical particles of the surface atoms of the rod are accumulated upon the surface, and so form a negative charge of electricity upon the ebonite (Fig. 4). If the rod, whilst so charged, is brought near to a light object, such as a tiny piece of paper, the electrical particles of the latter are temporarily displaced in such a way that a charge of positive electricity is "induced" on the part nearest to the rod: the positive charge on the paper and the negative charge on the rod attract one another (the reason is unknown), and so the paper is attracted to the rod (Fig. 5). The production of a charge of electricity on the paper owing to the influence of the neighbouring charge on the rod is an example of the phenomenon known as "electrostatic induction"—an electric charge always tends to "induce" a charge of opposite sign on neighbouring bodies.





ELECTRICAL EFFECT OF FRICTION UPON AN EBONITE ROD

Fig. 4 (left). Owing to the effect of friction some electrons from surface atoms of the ebonite have been temporarily dislodged and accumulated upon the surface, constituting a "negative charge" upon the rod. Fig. 5 (right). The rod approaching a tiny piece of paper, the negative charge repels the negative charge in the paper. The positive charge in the paper then being nearer than the negative, the result is attraction of the paper to the rod

Electric Potential

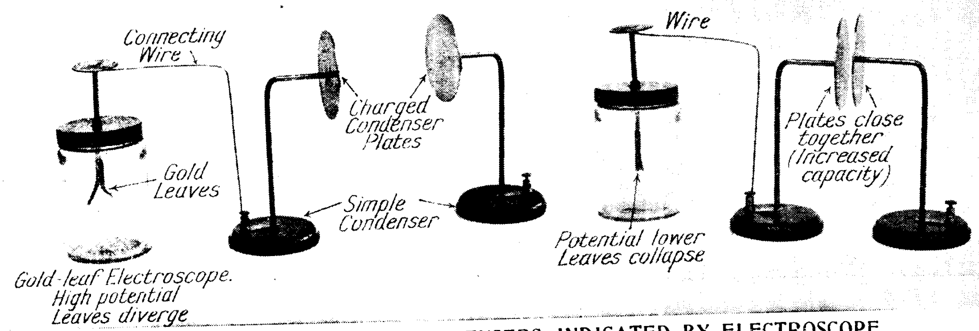
If a body has a charge of electricity upon it (by which we usually mean, as already explained, if it has *more* or *less* than its normal quantity of the negative electrical particles) there is a tendency for the body to return to the neutral condition, either by yielding electricity to some neighbouring body or by receiving electricity from some neighbouring body, as the case may require.

The tendency for such a transference of electricity will evidently be greater the greater the electrical charge upon the body, and we may think of the condition as one of pressure, tending to drive the electrical fluid along any available conductor. The name "potential" has been given to this "pressure": thus a body may be at a higher negative or positive potential than its surroundings. If it is at a higher negative potential, negative electricity will be ready to flow away from it, and if it is a higher positive potential, negative electricity will be ready to flow to it from surrounding bodies.

This may well be illustrated by the analogy of heat and temperature. If two similar bodies possess different amounts of heat they will be at different temperatures, and there will be a tendency for heat to flow from the one at the higher temperature to the one at the lower temperature. The temperature is a "pressure" tending to cause the flow of heat. Similarly electrical "potential" is a "pressure" tending to cause the flow of electricity.

We may usefully employ this analogy further. For if two bodies (say two pieces of iron, one of 1 lb. and the other of 10 lb.) possess equal quantities of heat, the first one will be at a higher temperature than the other because, its capacity for heat being less, a given quantity of heat will raise its heat "pressure"—*i.e.* temperature—to a greater extent.

A similar law holds in electricity. Every body has a certain electrical capacity. Generally speaking, a large body will have



ELECTRICAL CAPACITY OF CONDENSERS INDICATED BY ELECTROSCOPE

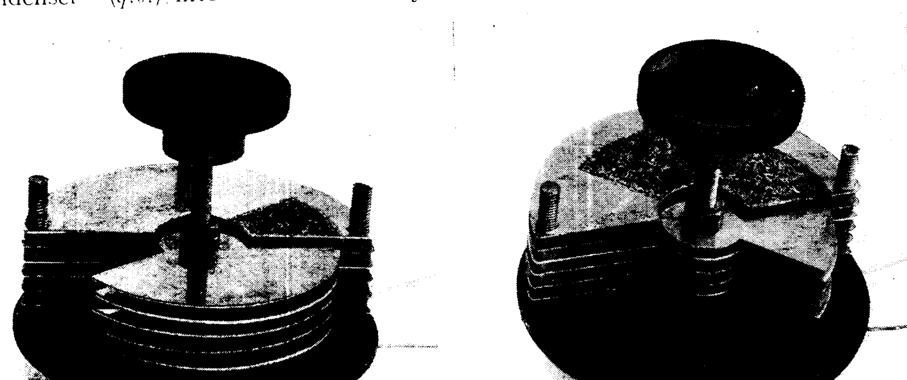
Fig. 6. Two tests are illustrated showing the increase of electrical capacity of two bodies on being brought closer together. Divergence of gold leaves of an electroscope indicates potential. If bodies approach the capacity is increased, and potential therefore drops (for the same charge) as indicated by reduced divergence of leaves in the electroscope

a greater electrical capacity than a small body. It will be evident that if a body of small electrical capacity and a body of large electrical capacity be given equal electrical charges, the potential (*i.e.* the electrical pressure tending to make the charge flow away again) will be raised to a greater extent in the case of the small capacity than in the case of the large capacity.

The electrical capacity of a body has the very curious property that it depends not only upon the body itself, but also upon the proximity of neighbouring bodies (Fig. 6). Generally speaking, the combined capacity of two bodies is increased by bringing them closer together. This circumstance is very useful in some cases, for it enables us to make a device known as an electrical "condenser" (*q.v.*) into which a relatively large amount of electrical charge may flow for a given potential difference created between its parts. Furthermore, by making the parts of the condenser adjustable in position relative to one another, the capacity of the condenser may be varied (Fig. 7). Such a condenser is known as a "variable condenser" and is much used in wireless, the two "bodies" consisting of the two sets of metal vanes, one set fixed and one set moving.

The potential difference between two bodies is measured in units called "volts" (*q.v.*). Since it tends to cause the flow or motion of electricity, potential difference is sometimes referred to as electro-motive force (E.M.F.).

So far we have dealt with the electricity resident in a body or stored upon it. We have seen how the potential or



PRACTICAL METHOD OF ALTERING ELECTRICAL CAPACITY OF A CONDENSER

Fig. 7. Variable condensers as used in wireless sets are shown with the relative positions of the two bodies, in this case, sets of metal plates, marked according to the extent of overlap of the two sets of plates, by means of which the capacity of the condenser is adjusted to the desired value

"pressure" tends to make the electric charge flow between one body and another. But we have not considered what happens when the electricity actually does flow.

The Electric Current and its Effects

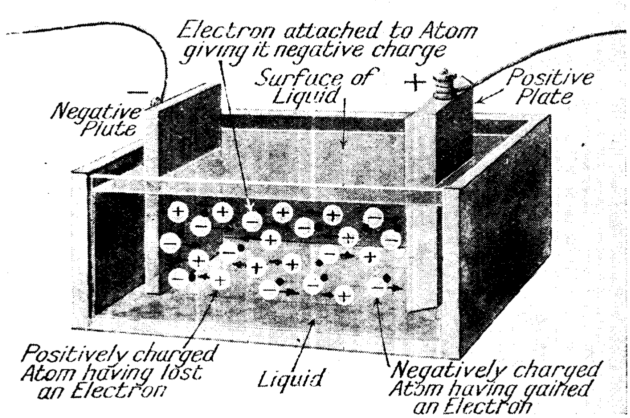
If two bodies at different potentials are connected together by means of a "conductor," such as a metal wire, the electrical particles from the one body will flow along the wire to the other body until the potentials are equalized. Such a flow of electricity is known as an "electric current."

In flowing along the wire the electricity produces certain effects. In the first place, it heats the wire. This is due to the electrical particles hitting the molecules of the metal of the wire as the particles rush through the spaces between the molecules. The molecules of the metal are thus agitated and (as is known from the science of heat) such molecular agitation constitutes heat. (In certain substances the molecule consists of one atom only.)

Familiar examples of the employment of this heating effect will occur to the reader—the filament lamp, the wireless valve, the electric fire. The second effect of the current when flowing in the wire will be dealt with presently.

The current may also produce chemical effects. For example, if two copper plates are dipped into a water solution of copper sulphate and current is made to flow through the liquid from one plate to the other (Fig. 8), the molecules of the copper sulphate will be decomposed and metallic copper will be deposited upon one of the plates (*see* Electrolysis). Effects of this kind are used in electro-plating, and in a great variety of industrial processes.

Another curious phenomenon, which should be mentioned at this point, is that if different substances are placed in contact with one another, they assume different electrical potentials automatically—that is, electricity passes over from one to the other, and the substances are only "content" when this potential difference exists between them. This may seem to be in contradiction to the statement that bodies in contact endeavour to attain uniform potential. It is due, however, to chemical action, and is not in conflict with the general statement referred to. The effect may be turned to very useful account. For example, if a piece of carbon and a piece of zinc be immersed in a water solution of salammoniac, the carbon assumes a higher positive potential than the zinc. If the carbon and the zinc be connected together, externally to the liquid, a current will flow between them tending to equalize their potentials (in accordance with what has been said), but owing to the peculiar property just mentioned above, chemical action will at once set in, tending to maintain the difference of potential. This arrangement constitutes a very useful source of electric current, and is known as a primary battery (*see* Cell; Leclanché Cell). There are numerous other types of battery (*see* Accumulator).

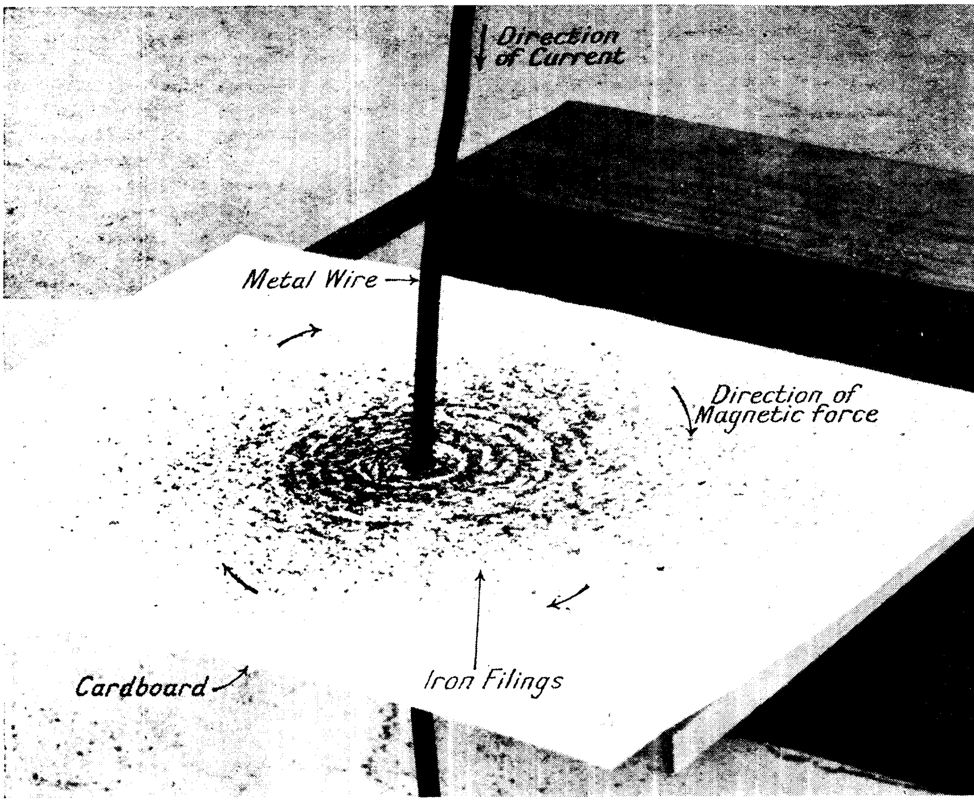


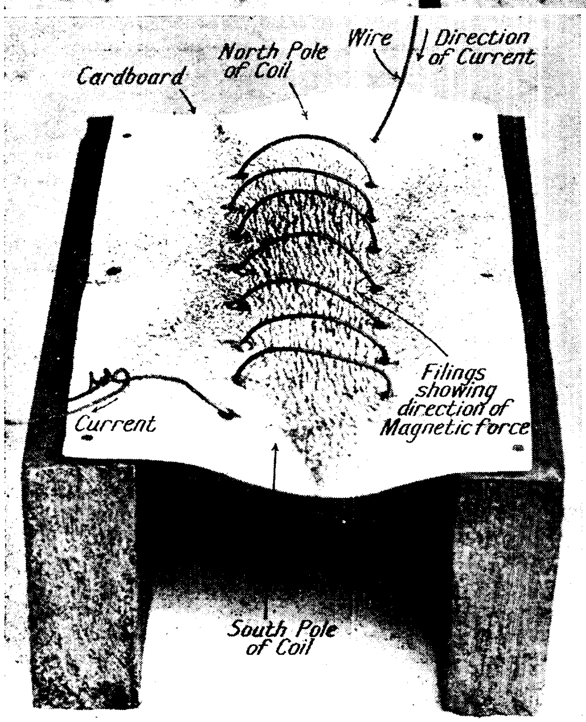
HOW ELECTRICITY TRAVELS THROUGH LIQUIDS

Fig. 8. The loss of an electron leaves the parent atom positively charged. In a solid substance the atom cannot move, but in a liquid, or gas, it moves in the opposite direction to the electron. Vagrant electrons mostly attach themselves to other atoms in these circumstances, thus forming negatively charged atoms. In gases the exact mechanism depends upon the pressure of the gas

Electro-Magnetism

Perhaps the most important effect of the electric current, however, is the electromagnetic effect. When an electric current is flowing (*e.g.* along a wire), *magnetic* effects are exhibited (Fig. 9) in the vicinity. This is a fundamental phenomenon which has to be accepted. As regards its ultimate explanation, it may be placed in the same category as the mysteries already





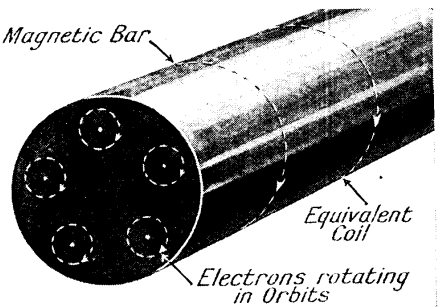
MAGNETIC EFFECTS OF CURRENT-CARRYING WIRE AND COIL

Fig. 9 (above). Magnetic effects are exhibited in the region surrounding a vertical wire carrying a current. The iron filings have arranged themselves. Fig. 10 (left). With a coiled wire carrying a current the filings show that the coil behaves exactly as a magnet. Both illustrations are actual photographs of experiments

referred to. If the wire be formed into a coil, the coil behaves as though it had a bar magnet placed along its axis, the effect being exhibited, however, only so long as the current is flowing in the wire (Figs. 10 and 11). This is the principle upon which the electric motor is based.

If a small compass-needle be placed at the centre of the coil, it will evidently be affected by the magnetism, and the needle will, in general, be deflected (Fig. 12). The strength of the magnetic effect, and, consequently, the amount of the deflection, will depend upon the strength of the electric current in the wire of the coil, and hence an arrangement of this kind may be employed for measuring the strengths of electric currents. This is the principle of the galvanometer, ampere-meter, milliam-meter, and certain other instruments.

Just as the flow of electric current in a coil of wire will produce a magnetic "field" in the region of the coil, so the introduction



MAGNETISM OF A STEEL BAR

Fig. 11. Electrons in atoms are assumed to be rotating, and are thus equivalent to innumerable infinitesimal current-carrying coils. The magnetism of the bar is thus the resultant of the magnetism due to the atoms

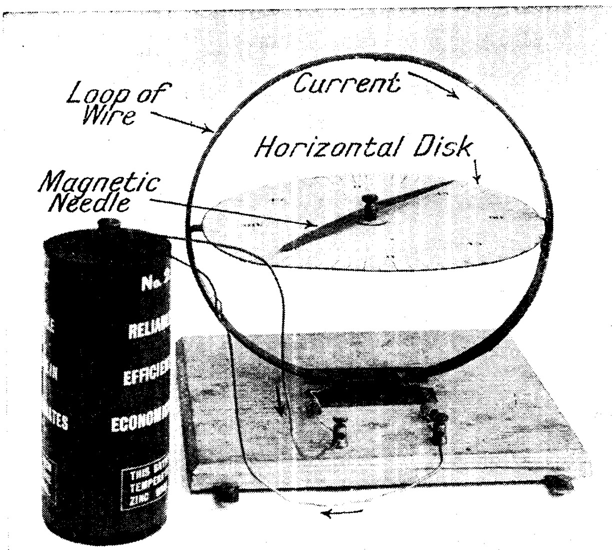
of a permanent magnet into the region of the coil will cause a momentary *current* in the wire of the coil (Figs. 13 and 14). Such a current is said to be "induced," and is called an "induced current" (*q.v.*). If a magnet be alternately inserted into and withdrawn from the coil, a momentary current will be induced in the coil at each movement of the magnet, the current being in one direction when the magnet is *approaching* the coil and in the opposite direction when the magnet is *receding* from the coil. If the magnet be continually inserted and removed, an "alternating current" may thus be drawn from the coil.

This is the principle of the dynamo or electrical generator, which is employed as the source of current for electric lighting and power plants, and for many other purposes. Instead of the magnets being inserted into the coil, however, magnets and coils are rotated on a shaft, so as to pass one another with great rapidity.

It will easily be seen that the motion of a magnet *past* a coil will have a similar effect to the insertion and removal of a magnet. As the magnet is approaching the coil the amount of magnetic *flux* is increasing, and it is greatest when the magnet is exactly opposite the coil; from that point the flux begins to decrease.

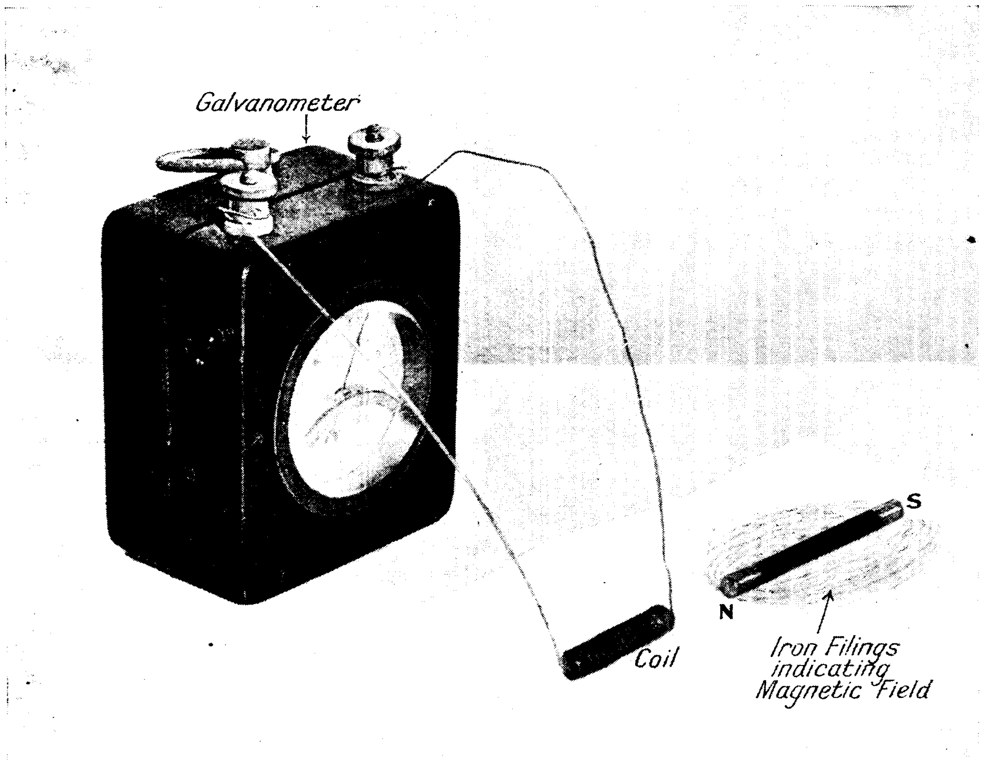
Thus there is a reversal of the current in the coil at the moment when the magnet passes it. Usually an electrical generating machine has a number of magnets and coils; frequently each consists of an iron core wound with many turns of insulated wire. The number of reversals of the current per second from an alternating current generator is called the frequency or "periodicity" of the alternating current. The periodicity is spoken of as so many *cycles* per second; a frequent value for electric-supply mains is 50 per second.

It may be useful to mention at this point that a wireless transmitter is an alternating current generator, but the frequency of the alternations is in the region of one million per second. This is enormously greater than the frequency of the alternating current used for ordinary purposes, and entirely different apparatus is necessary for the production of these high frequencies.



PRINCIPLE OF ELECTRICAL MEASURING INSTRUMENTS

Fig. 12. How a magnetic needle placed within a current-carrying coil is deflected is illustrated. This is the principle of the ampere-meter, galvanometer, and many other electrical measuring instruments. Usually a large number of turns of wire are used, instead of one only, the effect upon the needle for the same current being correspondingly greater and the instrument thus more sensitive



INDUCTANCE COIL THEORY DEMONSTRATED PHOTOGRAPHICALLY

Fig. 13. Laid on a sheet of paper is a fairly powerful bar magnet surrounded by iron filings, which have arranged themselves according to the lines of force in the magnetic field. On the left of the magnet is a coil of wire, the ends of which are connected to a galvanometer. The magnetic field entering the region of the coil causes an induced current in the coil, which is recorded by the deflection of the needle indicator in the galvanometer, as seen in the photograph

We have seen that a coil carrying a current behaves as a magnet, and also that a magnet inserted into a coil causes an induced current. Thus if we have two coils suitably placed with relation to one another and we pass a current through one coil, the establishment of the magnetic field will be equivalent to bringing up a bar-magnet to the second coil. Consequently, in accordance with what has been said, there will be a current induced in the second coil at the moment when the current is started in the first coil. A current will also be momentarily induced in the second coil at the moment when the current in the first coil is broken.

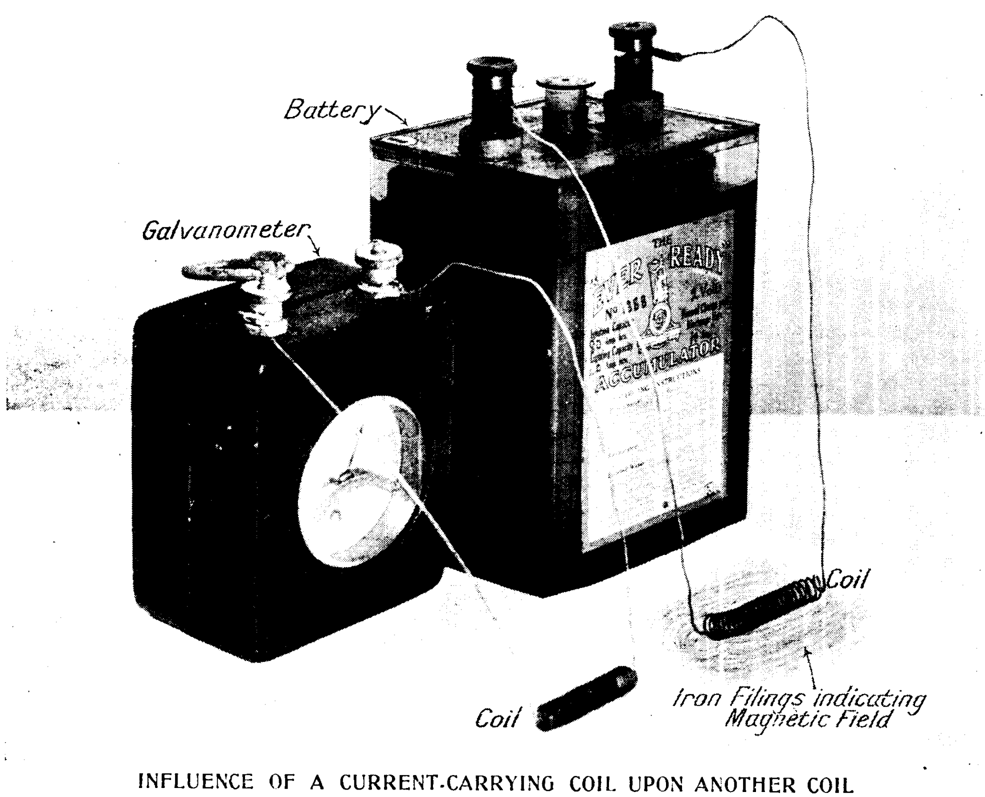
This phenomenon is known as "mutual induction," and is the principle of the "induction coil" and a great variety of other electrical devices. In particular, it is the principle of the transformer which is largely used in wireless apparatus. (*See* High-frequency and Low-frequency Transformer; Induction Coil; Jigger; Tuning Inductance.)

It may well be asked what is the cause of all these effects, but no final answer can be given. We know that when a current is flowing in a conductor, a magnetic field is set up around the conductor, and also that if a change be brought about in the magnetic field in the region around a conductor, there will be a momentary current set up in the conductor, which current will create magnetic effects tending to *oppose* the magnetic change. We have been able to utilize the phenomena of electromagnetic induction to an enormous extent—as has already been indicated, the whole of electrical engineering is built upon it. But what is the ultimate nature of the mysterious connection between a current of electricity and a magnetic field is at present unknown.

We have various theories of the phenomenon, expressed in terms of a supposed medium called the Ether. This medium is assumed to exist throughout all matter and throughout all space in the universe. It is invisible, intangible, and imponderable.

One theory of electricity assumes that the electrical particle is the ether medium in special form or state (*see* Ether). The magnetic field which surrounds a current-carrying conductor or a bar-magnet is conceived as a state of "strain" in the ether, and is sometimes referred to as magnetic "strain" or "displacement." Similarly, a stationary charge of electricity produces an ether strain known as electric strain or displacement.

The moment any change takes place in the ether strain, the readjustment begins to be propagated outwards through the ether medium, just as a disturbance on the surface of a pond is propagated outwards from the source of disturbance. A change in electric and magnetic displacement is known as an electro-magnetic disturbance: such disturbance travels away through the ether with the very high speed of about 186,000 miles per second. It is sometimes said to travel with the velocity of light: this is because light-waves are electro-magnetic disturbances proceeding from special sources. There are various other kinds of radiation which consist of electro-magnetic disturbances and which travel through the ether with the same speed as



INFLUENCE OF A CURRENT-CARRYING COIL UPON ANOTHER COIL

Fig. 14. As in Fig. 13, a coil of wire is connected at both ends to a galvanometer, but in this case the magnetic field is set up not by a permanent bar magnet, but by a current from a battery carried by another coil of wire. As before, the magnetic field is indicated by the self-arrangement of the iron filings. The coil attached to the battery is equivalent to the magnet. When the current in the right-hand coil is broken the effect upon the left-hand coil is the same as that of removing the magnet in the case illustrated in Fig. 13

light-waves. "The velocity of light" is thus a short version of the more complete expression "the velocity of propagation, through free ether, of electro-magnetic disturbance." I mention "free ether" because the velocity of some kinds of electro-magnetic radiation (light-waves, for example) is very different when the waves are travelling in ether which is within matter: the velocity of light through glass, for example, is about two-thirds of the velocity of light through free ether.

There is a special significance about the velocity of light, and we have reason to believe that it is fundamentally impossible for anything in the physical universe to travel with a velocity exceeding the velocity of light.

It may be mentioned that the ether medium is postulated, or assumed, rather, as a means of visualizing processes: its nature is, if possible, even more obscure than that of the electron. Some of the properties which it must possess can, however, be worked out comparatively simply from a knowledge of the velocity of light and certain other factors, and making certain assumptions as to the nature of light radiation.

Production of Wireless Waves

Now suppose we have two bodies at different potentials and connect them by a wire. Electricity will flow along the wire, and whilst it is flowing we have magnetic disturbances, due to the changing current, and electric disturbances, due to the changing charges on the bodies. The system will, therefore, be a source of electro-magnetic disturbance, but when the two bodies have attained the same potential, if all electrical motion ceases, no further electro-magnetic disturbance will be created. We may say that a single electro-magnetic wave has been emitted from the system. If a method can be found for causing a to-and-fro surge of the electric charge between the two bodies so that, after equalizing the potentials, it overshoots the mark, stores itself upon the opposite body, returns, again overshoots, and so on (like a pendulum), we shall evidently have the simple process mentioned above repeated a number of times, and thus, instead of one electro-magnetic disturbance being emitted from the system, a train of disturbances or a train of waves will proceed from the system.

These electro-magnetic waves are of the kind which are employed for wireless transmission, and a system such as that which we have just been considering would constitute a simple wireless "transmitter."

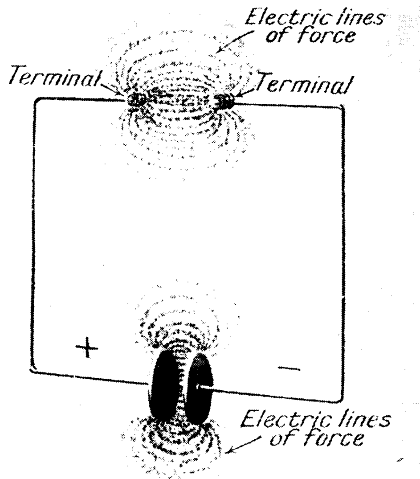
A condenser consists, in reality, of two charged bodies (each "body" being usually a set of metal plates), and if one set of plates be charged and allowed to discharge to the other set the discharge will, in general, be "oscillatory," or "electrical oscillations" will be set up (such as those we have just been considering), and electro-magnetic waves will be radiated from the system (Figs. 15 to 19). The number of times per second the charge will flow to and fro, or the "frequency" of the oscillations, as it is called (*see* Frequency), will depend upon the capacity of the condenser and the inductive properties of the system (*see* Inductance). By varying these quantities the frequency may be varied, and hence the "wave-length" of the emitted electro-magnetic waves may be varied.

Oscillations in the Receiving Aerial

Now let us suppose we have a system such as the above, but instead of employing it for producing electro-magnetic waves, let us suppose that such waves (produced by another similar system at a distance) fall upon our system. They will have the converse effect of setting the quiescent electrical fluid of the system into oscillation (just as, if we were in a boat on a pond, waves set up by another distant boat would cause our boat to rock).

The oscillations set up by the incoming waves will be greatest if the frequency of the incoming waves is the same as the frequency of the waves which our receiving system would emit if it were used as a transmitter. This frequency is called the "natural frequency" of the system, and if it does not happen to be the same as that of the incoming waves which it is desired to receive, the capacity or inductance of the system (or both) may be varied until its "natural frequency" has been adjusted to the proper value. The receiving system is then said to be "tuned" to the incoming waves.

This is the principle of wireless transmission and reception. The electrical fluid of one system (transmitter) is artificially caused to oscillate: owing to its peculiar relationship with the ether, it sets up ether disturbances (wireless waves) which travel



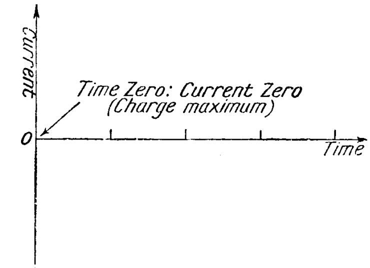
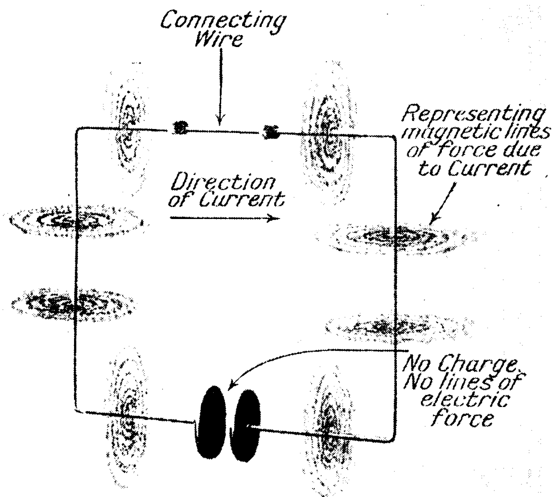


Fig. 15. On the left is shown the first stage in the series of oscillations following the discharge of a condenser. Lines of electric force are shown across the plates of the charged condenser, with no current in circuit. The condition is shown graphically in the diagram above



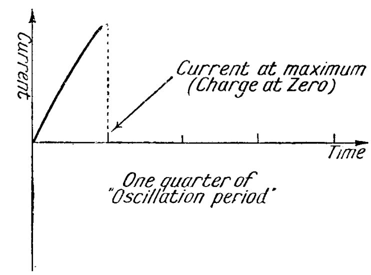
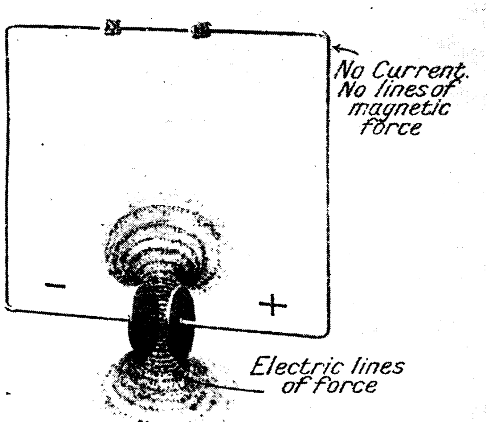


Fig. 16. Terminals are connected and the condenser is accordingly discharged. No lines of force are indicated between condenser plates, the charge being in motion as current. Lines of force due to current are shown all round the circuit. One quarter of an oscillation period has now elapsed, as shown in the diagram above



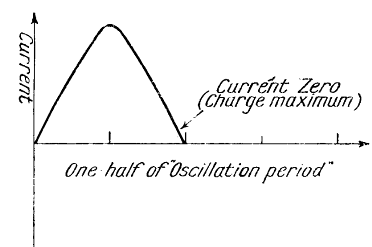
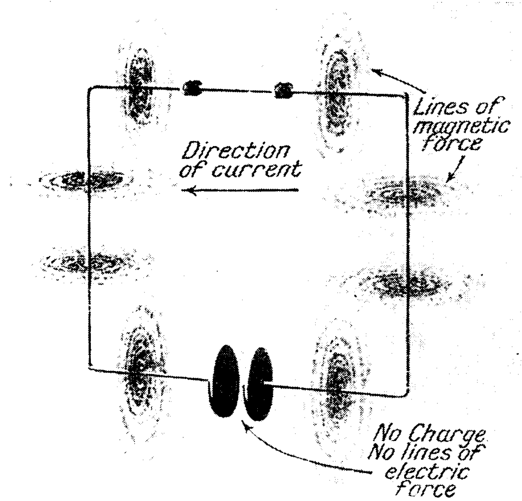


Fig. 17. The charge has run back into the condenser, charging it the opposite way round. There is no current in circuit, and no lines of magnetic force. Lines of force are shown in the condenser. This is half an oscillation period. The series is continued on the following page

SIMPLIFIED ILLUSTRATIONS OF OSCILLATORY DISCHARGE OF A CONDENSER



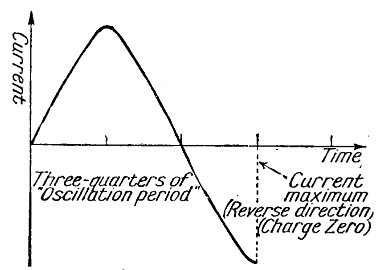
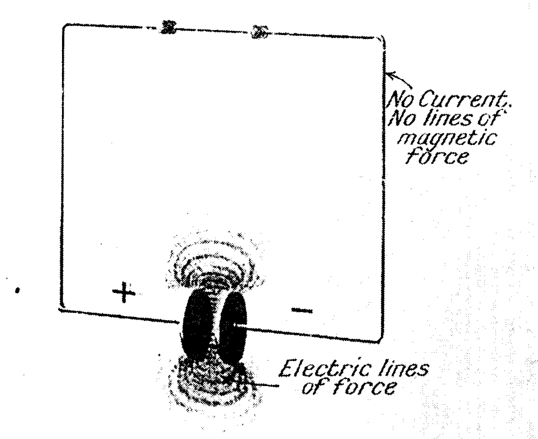


Fig. 18. At three-quarters of an oscillation period the charge has all left the condenser and is in circuit in the form of current, but in the opposite direction



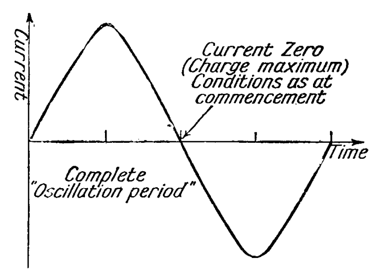


Fig. 19. Conditions are now exactly as at the commencement, and a complete oscillation has taken place and the cycle of events is about to be repeated. These diagrams are necessarily simplified and do not take account of factors which complicate the matter in actual practice

OSCILLATORY DISCHARGE OF A CONDENSER : CYCLE COMPLETE

away at high speed : when they fall upon another body or system (receiver), again owing to the mysterious relationship between the ether and the electrical fluid in bodies, they cause the electrical fluid of the second system to oscillate. Special apparatus (a detector valve or crystal) enables the oscillations of the electricity in the second body or system to be detected and interpreted.

It should be noted that the electricity which oscillates in the receiving system is the electrical fluid of that system and is not received from the transmitter. Electro-magnetic energy is received in the form of ether waves, but electricity does not travel from transmitter to receiver.

This may be illustrated by the case of a singer : the singer's vocal organs set the air into vibration, and the vibratory motion is transmitted through the air to your ear-drums, but the air from the singer's throat does not reach your ear—in fact, the singer might be enclosed in an air-tight cabinet and you would still be able to receive the sound. Similarly, the heat from a fire may warm a cold person and cause the blood to course through his veins, but he does not derive the blood from the fire—only the stimulus. The electro-magnetic waves are the stimulus which sends the electrons coursing through the inter-atomic spaces of the aerial-and-earth system of the wireless receiver.

ELECTRO-CHEMICAL EQUIVALENT. The weight in grammes of each element of an electrolyte which is deposited by one coulomb of electricity. It has been found by experiment that 1 coulomb (= 1 ampere flowing for one second) will liberate 0·00001035 gr. of hydrogen, which is accordingly reckoned the electro-chemical equivalent of hydrogen. The electro-chemical equivalents of other elements can be ascertained by multiplying the figure for hydrogen by the atomic weight of the element and dividing the product by the valency of the element. Electro-chemical equivalents are employed in the application of the important law of electrolysis, which lays it down that the amount of an ion liberated at an electrode per second is equal to the strength of the current multiplied by the electro-chemical equivalent.

ELECTRODE. The terminal or pole of current-carrying conductors separated by a medium through which the current can flow from one to the other, or others, where more than two exist. The expression covers many applications, both in wireless and electrical engineering.

In wireless, the term is used for the main components of the transmitting and receiving valves, which, in the case of the three-electrode valve, consist of a filament, grid, and anode. The plates of the positive and negative poles of an accumulator are sometimes called electrodes, and the plates of the elements of primary batteries are similarly designated.

In electrical practice the expression applies to the carbon pencils of the arc lamp and the opposing conductors of a spark gap, including the points of the sparking plug used on internal combustion engines. The anode and cathode, which are respectively the positive plate and the article to be plated, in an electro-plating bath are referred to as electrodes, and similarly named are the corresponding plates used in electrolysis.

The brush electrode is a soft wire brush composed of very fine wires, used in conjunction with a Rhumkorff or shocking coil for curative purposes. *See* Accumulator; Anode; Battery; Cathode; Cell; Grid; etc.

ELECTRO-DYNAMICS. Term used for the study of the laws of electricity in motion. The study of electricity in motion first came into prominence when A. M. Ampère, in 1820, announced the results of his and D. F. J. Arago's investigations. Ampère then announced that parallel conductors through which electric currents were flowing in the same direction attracted one another, and repelled one another when the currents were flowing in opposite directions. Ampere established the laws governing this attraction and repulsion.

In this Encyclopedia the subject of electro-dynamics is dealt with under various headings. Such articles as Ampere, Volt, and other electrical units should be consulted; also the articles on Alternating Current, Current, Electricity, Magnetism, etc.

ELECTRO-DYNAMOMETER. The electro-dynamometer is another term for a wattmeter, an instrument for measuring power in a circuit. It must be understood that while in a direct current circuit it is true to assume that volts multiplied by amperes = watts = power, in an alternating current circuit this rule hardly ever holds good. In A.C. work it is necessary to differentiate between apparent watts and true watts.

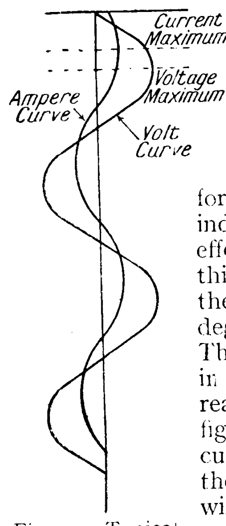


Fig. 1. Typical voltage curve plotted against a current curve

Consider the conditions obtaining in an A.C. circuit having a highly inductive load, such as a transformer or a squirrel cage induction motor. The effect of such a load in this circuit will be to cause the current to lag so many degrees behind the volts. This condition is shown in Fig. 1, which should be read downwards. In this figure a typical voltage curve is plotted against the current curve. It will be seen that the maximum volts and maximum amperes (shown by the dotted lines) are not coincident.

The power in a circuit is represented by the multiplication of the instantaneous voltage by the instantaneous amperes. In the circuit shown in Fig. 1, therefore, the power would be measured by taking the volt and ampere readings where they are vertically above one another, and multiplying these two together. The product would be the true watts, and would therefore represent a true measure of power.

The apparent watts, however, are the maximum volts multiplied by the maximum amperes, and this is the result which one would obtain by measuring the two readings given on an ordinary A.C. voltmeter and ammeter respectively. The result obtained in this way then would be totally misleading, as it would be invariably greater than that obtained by an instantaneous method, where the difference in angle, or phase, as it is generally termed, is accounted for.

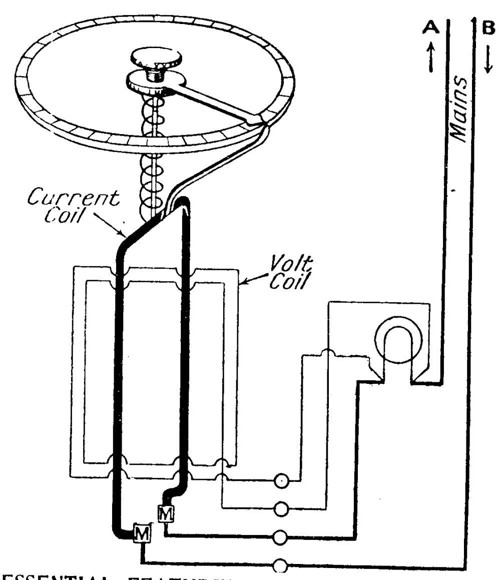
This phrase difference is expressed in degrees. While inductance makes the circuit lag behind the volts, capacity tends to make it lead in front of them. The number of degrees which the lag or lead assumes is called the angle of lag or lead, and the cosine of this angle is termed the power factor, which figure obviously cannot exceed unity. It is general practice to denote the angle of lag or lead as ϕ, and therefore the power factor is cos ϕ.

Suppose, now, a circuit to be so very inductive that the current lags 90° behind the volts (which circumstance can almost be obtained in the laboratory), then the value of cos ϕ will be zero. If a voltmeter and ammeter are applied to this circuit, both will give a reading, and the apparent power will be the product of these two readings. The true power, however, will be volts multiplied by amperes multiplied by cos ϕ. As the latter value is zero, it follows that the result is zero, which is, of course, correct, and represents the true state of affairs in that circuit. The current present in such a circuit is known as a wattless current, and this term applies to that amount of current in any A.C. circuit which is not doing useful work. The conditions obtaining in a circuit where current is applied to the primary of a transformer whose secondary circuit is left open are such that nearly the whole of that current will be wattless.

It will therefore be appreciated that in A.C. work something more than voltmeters and ammeters are required if true watts are to be ascertained, and it is for this reason that the wattmeter was designed and developed. The Siemens electro-dynamometer type of wattmeter represents the earliest form of such instruments. This type is, however, now rendered obsolete by others, chiefly because it is not particularly accurate, and also not a direct-reading instrument, *i.e.* readings cannot be obtained purely by the instrument movement causing a pointer to move along a divided scale.

A dynamometer consists essentially of two coils, one fixed and the other rotating within the fixed one. The fixed coil is wound with many turns of fine wire, and is shunted across the load. Therefore it measures the potential difference across the load, and may be termed the volt coil. The other coil, which moves within it, is in series in the circuit, has few turns of thick wire, and is termed the current coil. The passage of current through both coils simultaneously causes them to be mutually attracted, with the result that the current coil, which is normally situated at right angles to the volt coil, swings round on its pivot until both are in line with one another. The essential feature to be grasped, however, is that it is not merely the distance through which the moving coil swings which represents the watts, but the torque exerted by it. It is the torque, therefore, which has to be ascertained. The method of accomplishing this is as follows :—

Reference must be made to Fig. 2, in which the essential features of the dynamometer are diagrammatically depicted. Here,



ESSENTIAL FEATURES OF A DYNAMOMETER

Fig. 2. Connected to the mains and the load are the volt and current coils, shown thin and thick respectively. When the instrument is in circuit with the load the moving coil swings round to take up a position with the other. The top knob is rotated by hand

the volt and current coils are shown thin and thick respectively, and connected to the mains and load. The latter in this instance is a lamp. Above the coils is the scale, which is a circular one divided into degrees. The scale surrounds the control knob, which is connected to the spiral spring, the other end of which is attached to the moving coil. A pointer is attached to the knob. Another pointer, which indexes on the outer edge of the scale, is rigidly connected to the moving coil, thus indicating the latter's position.

Upon the instrument being put into circuit with the load, the moving coil, the normal position of which is at right angles to the fixed one, swings round to take up a position in line with the other. This movement having been completed, the top knob is rotated by hand in the opposite direction. The application of this torque, applied by hand to the moving coil via the spring, will naturally bring the moving coil back to its normal position. The strength of the spring being constant, every different degree of strength which the dynamometer itself exerts will mean a correspondingly different spring tension to bring it back again. Thus the number of degrees through which the knob has to be rotated represents a true measure of the dynamometer torque exerted.

As it is practically impossible to manufacture two springs having exactly the same strength, it is necessary that each instrument should be individually calibrated. Furthermore the temperature of the spring will make slight variations in its strength; therefore it is advisable to work it always at whatever temperature it was calibrated at, if really accurate results are to be obtained. *See* Power Factor; Siemens Dynamometer; Wattmeter.

ELECTROLINES. Term suggested by Professor J. A. Fleming for the lines of electric force which radiate from an electron. Fleming drew the analogy between electrolines radiating from an electron and long straight wires radiating in all directions from the centre of a small ball.

Electrolines or lines of electric force tend to keep as short as possible, and it is the attraction between positive and negative electrons which is a phenomenon of this effort on the part of the electrolines to keep short. Professor Fleming has pointed out that the electrolines possess a quality which is equivalent to mass or inertia, and this quality provides the electric mass of the electron.

Since the lines possess inertia, if the electron moves suddenly or changes its speed, the ends of the lines resting on the electron also move suddenly, but the remaining part of the lines lag momentarily behind. A kind of wave motion takes place along each electroline as the movement of the electron continues, until the electroline takes up the movement as a whole.

The movement of the electrolines causes a magnetic force to act at right angles to the lines. The wave motion along the electrolines moves outwards from the electron with the velocity of light, and this movement, combined with the resulting movement of the lines of magnetic force, or magnetolines, is called electric radiation. Such radiation may be caused by any sudden movement of the electron—that is, by it suddenly stopping or by suddenly starting.

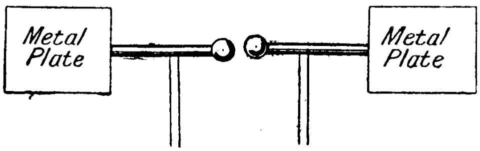
What Happens When an Aerial Radiates

Electric radiation does not always follow from any change of velocity of the electron. Thus an electron which is moving in a circular path at constant speed is continually changing its velocity, but does not radiate electro-magnetic waves. But if the electron is moving backwards and forwards along a straight line, electro-magnetic waves are radiated. If there are a large number of these electrons moving backwards and forwards in this way, as in the case of radio-frequency currents, an electro-magnetic wave is propagated throughout the surrounding medium.

This is an important fact which must be grasped fully by the reader who is interested in wireless theory, and though the conception involves high mathematical difficulties, it is one which enables a visualization to be made of what happens when an aerial is radiating waves into space.

The electrolines may be regarded as lines along which there is a displacement of electricity against the elastic force of the medium. There is a tension along these lines and a pressure at right angles to them.

The propagation of waves may be better followed by considering what happens in a simple Hertz oscillator or radiator. Fig. 1 shows diagrammatically such an oscillator. It consists of an induction coil (not shown), spark gap, and two metal plates fixed to either end of the gap. The metal plates represent a



SIMPLE HERTZ OSCILLATOR

Fig. 1. Metal plates are fixed to either end of the spark gap represented above, which is used in conjunction with an induction coil. This should be studied when considering the propagation of waves

condenser, whose opposed surfaces are widely separated, while the dielectric is air.

As the potential difference rises during the accumulation of the charge on these plates an electrostatic field is created about them. There comes a time when the difference of potential becomes so great that the resistance of the dielectric is broken down and a discharge takes place across the spark gap.

In Fig. 2 is shown a diagram with the spark gap shown vertically. On the right and left are shown the lines of electric force before discharge takes place. The source of the alternating current is omitted for the sake of clearness. The lines of electric force form closed loops, and, of course, are actually in all directions round the oscillator, forming, in fact, surfaces of which the loops shown are sections.

When a discharge takes place the strain is immediately relieved, and electric oscillations take place, free electrons vibrating backwards and forwards in the rods. One of these rods is supercharged or negatively charged, and the other is undercharged or is deficient in electrons. To put it in another way, the electrons in one rod are all crowded together, wanting elbow room, so to speak, while there is plenty of room in the other rod.

With the breakdown of the dielectric the crowded electrons immediately rush towards the rod deficient in electrons and oscillate to and fro until a state of equilibrium is restored. But, as already stated, this movement of electrons causes

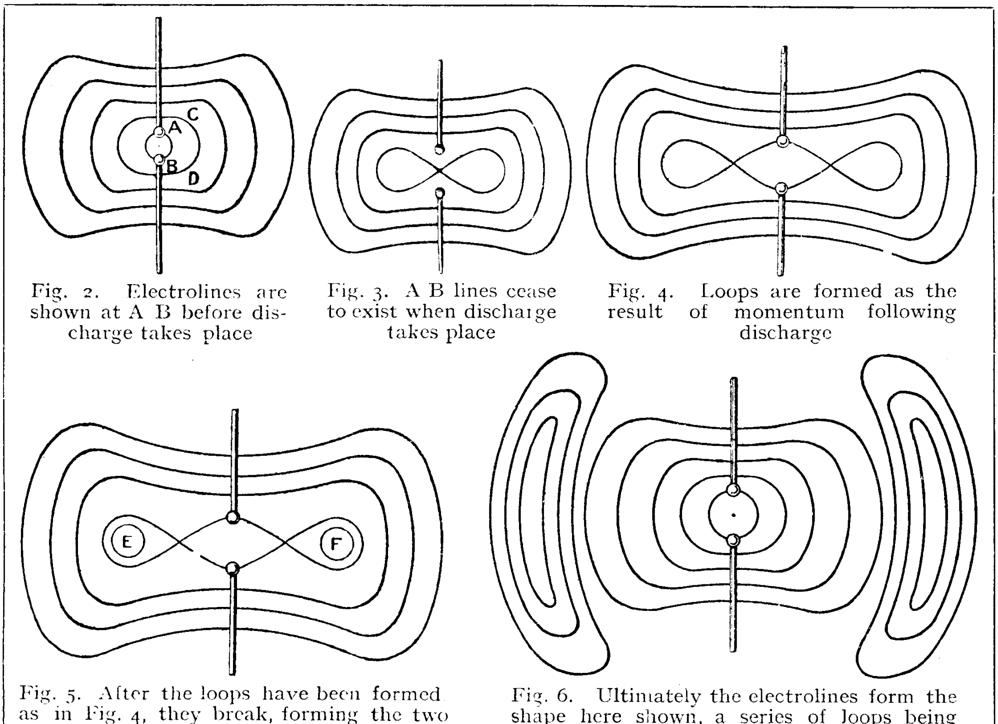


Fig. 2. Electrolines are shown at A B before discharge takes place

Fig. 3. A B lines cease to exist when discharge takes place

Fig. 4. Loops are formed as the result of momentum following discharge

Fig. 5. After the loops have been formed as in Fig. 4, they break, forming the two portions E and F

Fig. 6. Ultimately the electrolines form the shape here shown, a series of loops being thrown off

DISTORTION OF ELECTROLINES BY THE DISCHARGE OF A SPARK GAP

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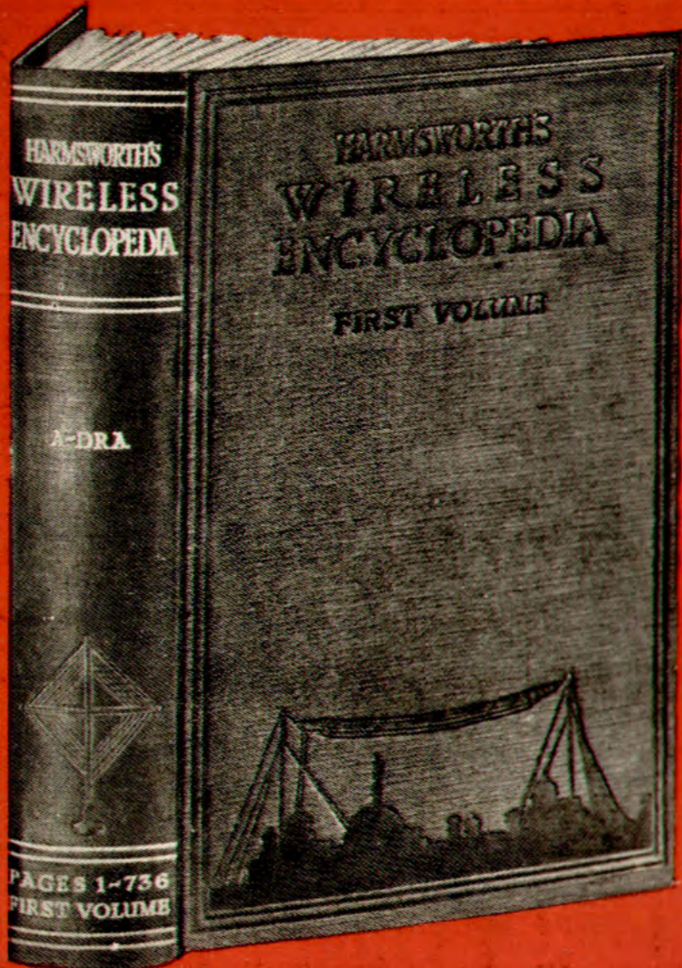

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