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For Amateur & Experimenter

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CRYSTALS
CRYSTAL CIRCUITS
CRYSTAL DETECTORS
CRYSTAL RECEIVERS OF ALL KINDS

SPLENDID PLATE IN FULL COLOURS OF

CRYSTAL - VALVE SET WITH ONE CONTROL

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

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

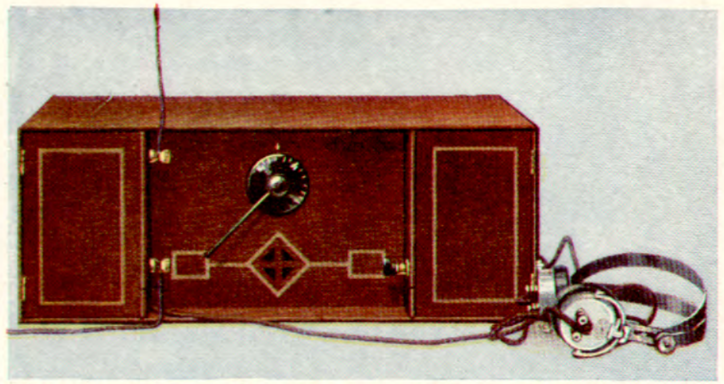

Fig. 100. The self-contained set complete and connected to aerial and earth ready for use

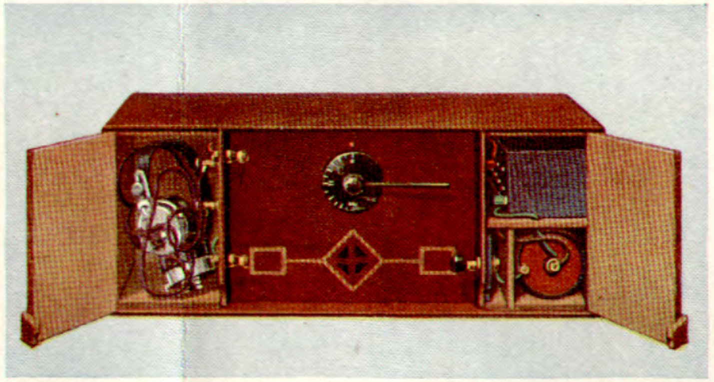

Fig. 101. Cabinet open, showing method of storing batteries and telephones

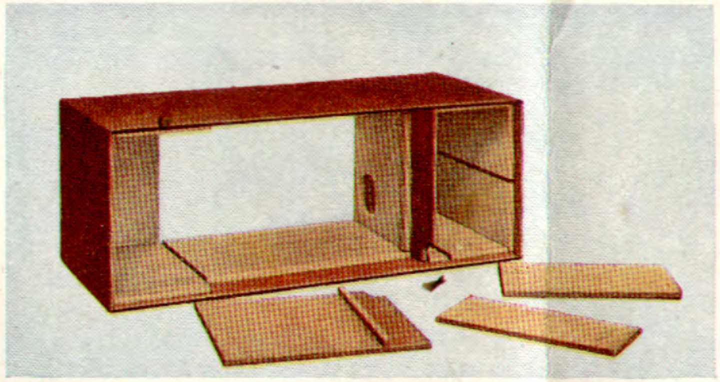

Fig. 102. Mahogany cabinet, partly assembled, with movable partitions and shelf

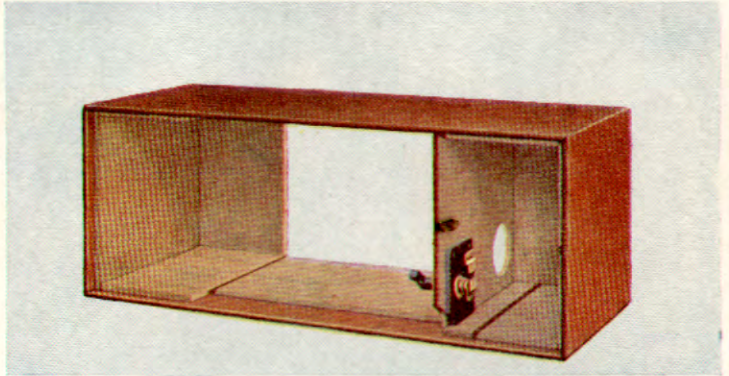

Fig. 103. Interior of cabinet from front, with amplifying valve switch in place

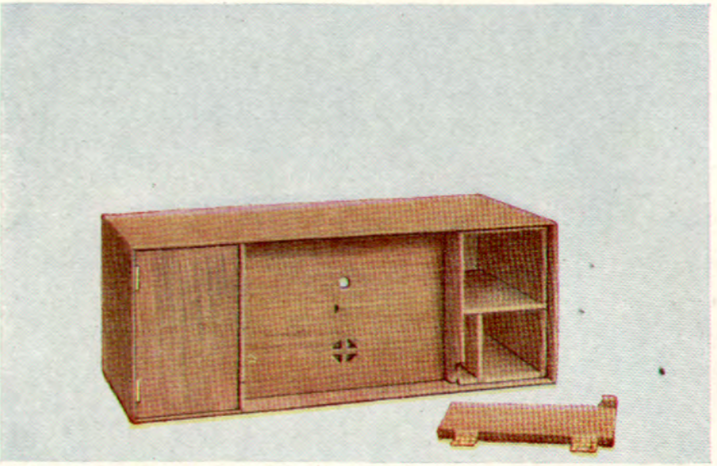

Fig. 104. Front panel and partitions in position, with one door fitted. Note simple method of fastening door

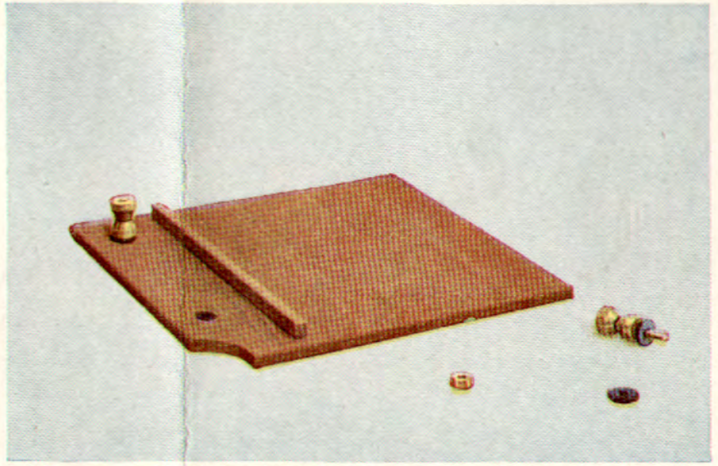

Fig. 105. Partition for telephone cupboard, showing ebonite bushings for terminals

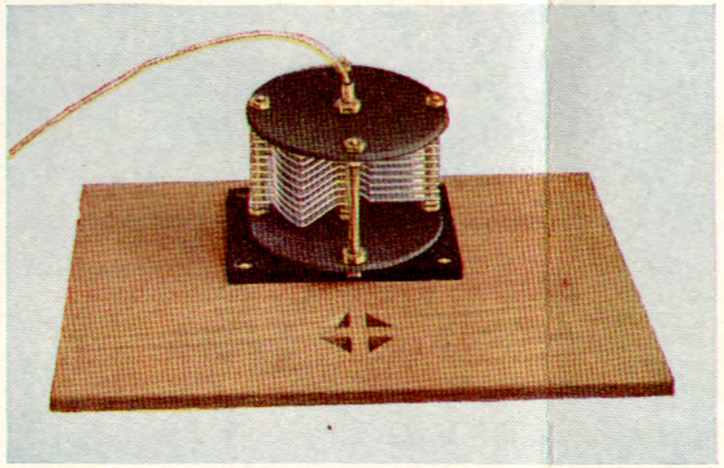

Fig. 106. Tuning condenser mounted on back of front panel, with valve peep-hole

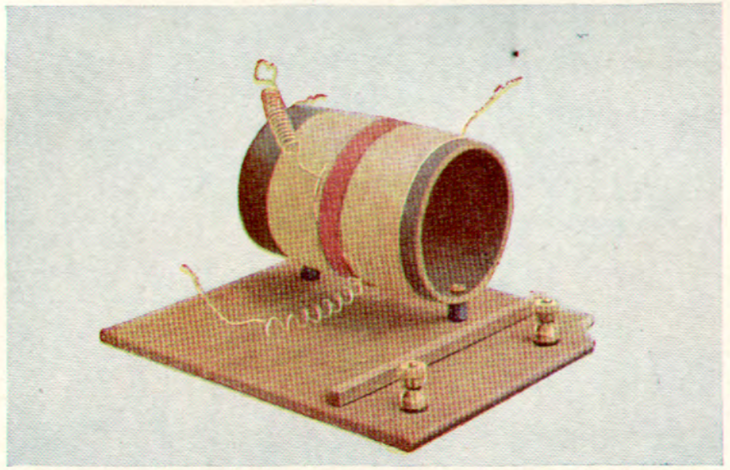

Fig. 107. Aperiodic inductance mounted on ebonite legs on left-hand partition, showing double winding

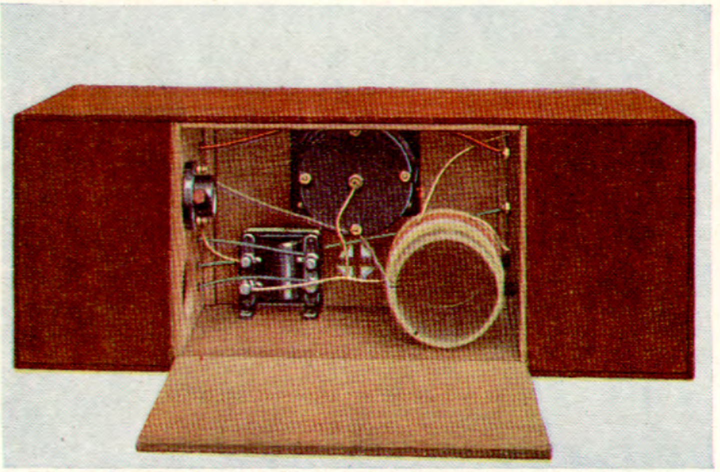

Fig. 108. Back of cabinet, with instruments in place and wiring completed

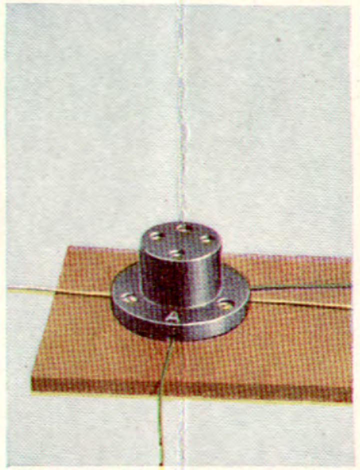

Fig. 109. How the valve holder is mounted on the partition

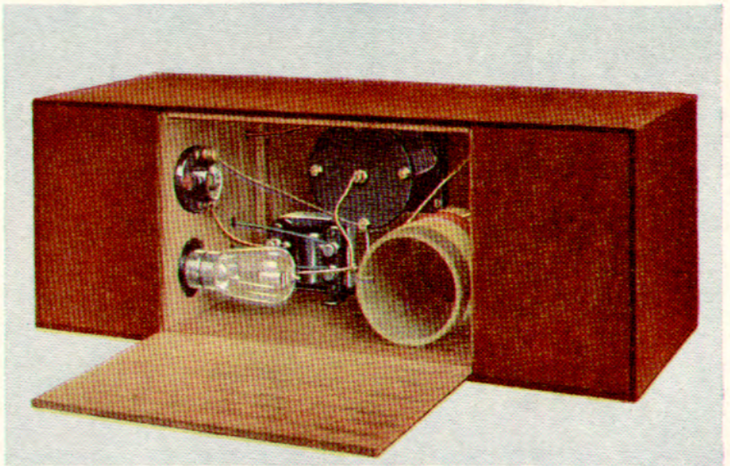

Fig. 110. Second view of back of cabinet, showing valve in place and stable crystal detector

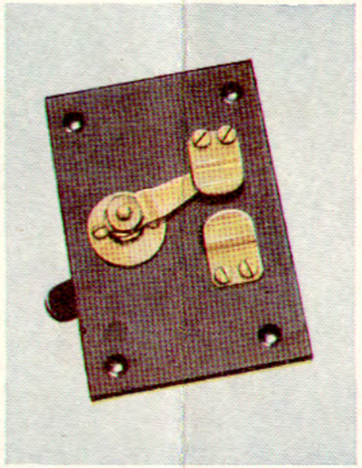

Fig. 111. How the filament switch is made and fitted

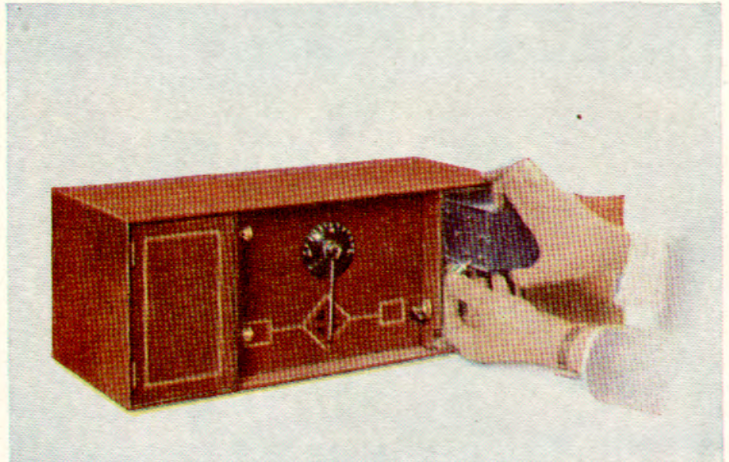

Fig. 112. Plugging-in the high-tension battery preparatory to reception

CRYSTAL RECEIVER: HANDSOME SELF-CONTAINED CRYSTAL RECEIVING SET IN MAHOGANY CABINET WITH SINGLE CONTROL AND COMPLETE WITH AMPLIFIER AND BATTERIES

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Specially constructed and photographed for Harmsworth's Wireless Encyclopedia

In Fig. 2, where C is the common coupling capacity,

$$k = \frac{\sqrt{C_1 C_2}}{C}$$

In general, the coupling between two circuits is given by the expression

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

where X_m = the common or mutual reactance between the two circuits (either inductive or capacitive or both) X_1 = the corresponding total primary reactance, and X_2 = the corresponding total secondary reactance.

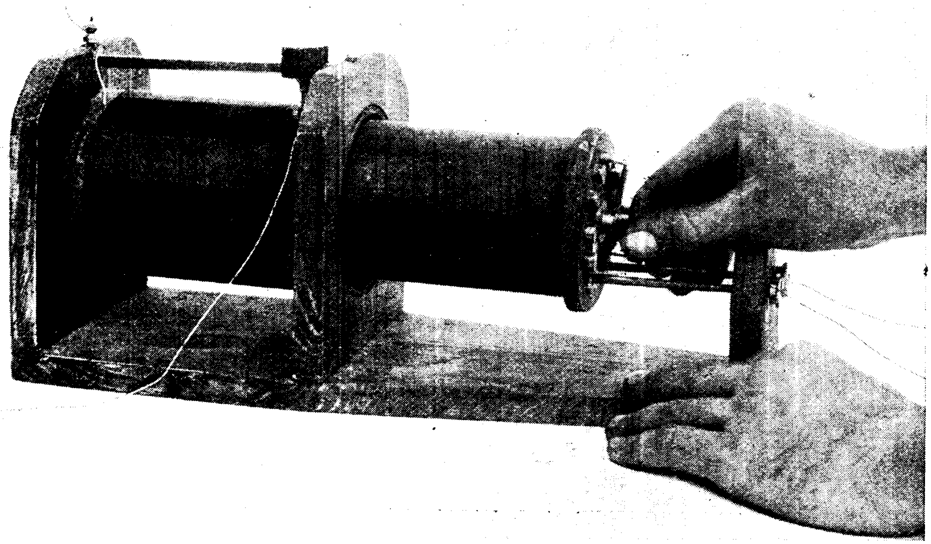
Intervalve Coupling is the method by which the output current of one valve is made to affect the input circuit of another. It can be effected in three ways, namely, by the use of transformers (*q.v.*), by resistance capacity coupling, and by reactance capacity coupling.

Transformers, either of the type designed to cover a considerable range of wave-lengths, or of the "plug-in" type, in which a separate transformer is used for each of several bands of wave-length, can be used for radio-frequency amplification, the output circuit of the high-frequency amplifying valve including the primary winding of the high-frequency intervalve transformer, and the secondary circuit of the latter being connected to the grid of the detector valve.

Intervalve transformer coupling is also used for audio-frequency amplification, but the transformer here is of a different construction, having an iron core (*see* Transformer). The coupling in this case is variable according to the type of transformer used, but, as a general rule, the plate of the detector is joined to the I P terminal of the transformer, and the O S terminal to the grid of the next valve, the O P and I S terminals being joined to high-tension positive and filament negative, respectively.

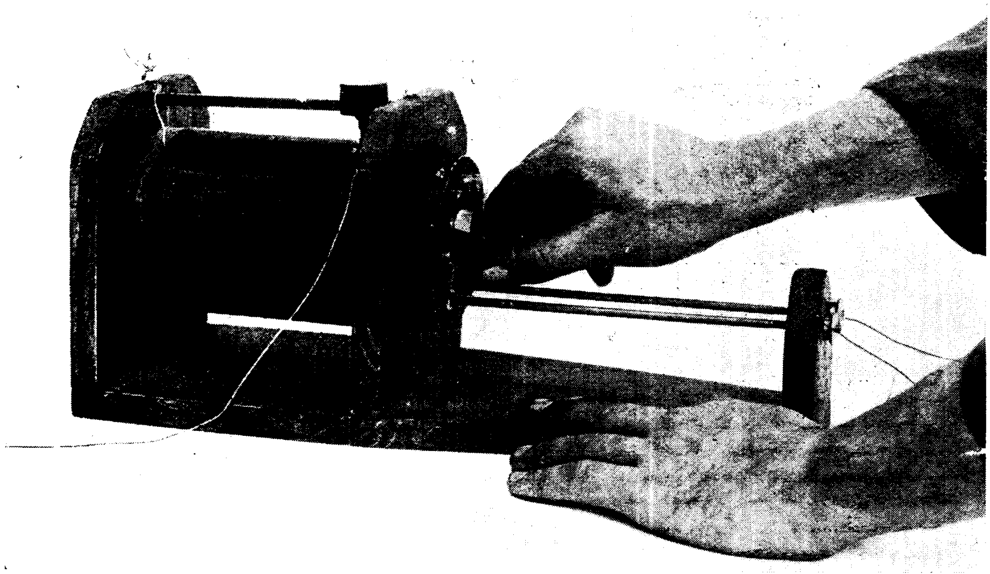
Transformer coupling, again, is used with telephones of low resistance, the effect being to remove the telephones from the plate circuit of the last valve of the receiver, and to couple them to that circuit magnetically. The telephones (*see* Telephone) thus receive only the alternating components of the plate circuit from the secondary winding of the transformer.

Intervalve Resistance Coupling is a method by which the amplified radio-frequency current in the plate circuit of



ARRANGEMENT OF COILS KNOWN AS LOOSE COUPLING

Fig. 4. This form of coupling consists in the insertion of one coil within a second, the amount of the insertion being varied according to the inductive effect required. The outer coil has a sliding contact, by means of which its inductive value can be varied. The smaller coil is tapped internally, the tappings being taken to a switch, which the operator is manipulating

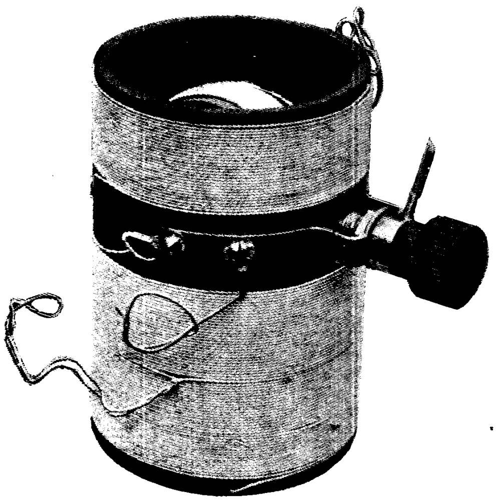


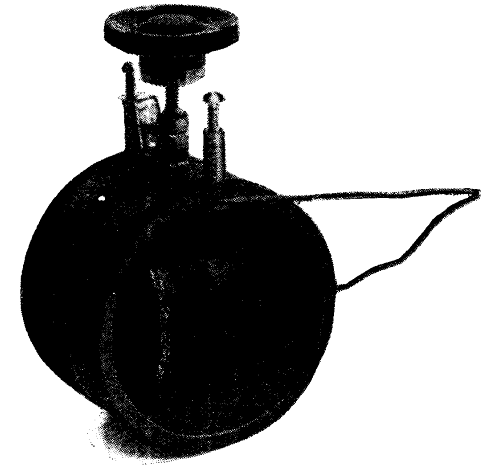
TIGHT COUPLING WITH A SLIDING COIL LOOSE COUPLER

Fig. 5. When the smaller coil of a loose coupler is inserted within the larger to a considerable extent, the arrangement of the two coils is known as tight coupling. In the above photograph the loose coupler seen in Fig. 4 is now very tightly coupled

a high-frequency valve sets up an amplified potential across a high resistance, this potential being utilized to affect the grid of the next valve. The reader should also consult the article High Frequency and such articles as Heterodyne.

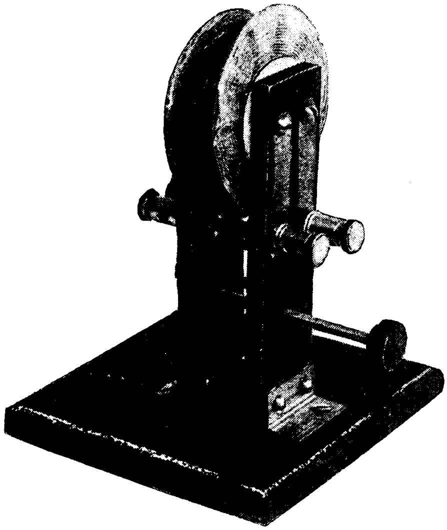
Reactance Capacity Coupling is in principle similar to the foregoing, but instead of a high resistance, a choke coil is employed. Details of this method and of the coupling used in ordinary reaction circuits are given under the headings High Frequency and Reaction respectively.

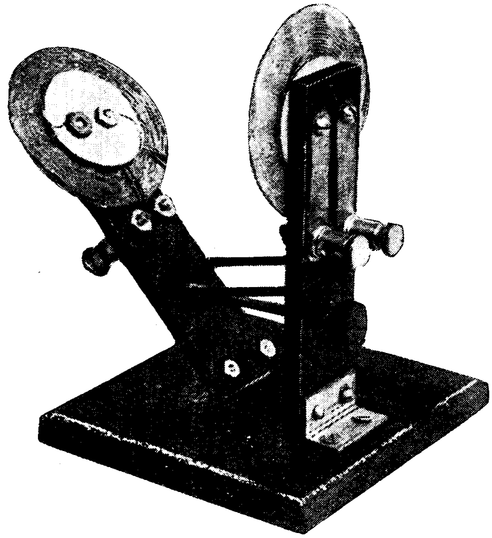




VARIO-COUPLER AND VARIOMETER TUNING INDUCTANCE

Fig. 6 (left). Inside the outer coil of the vario-coupler is a smaller coil which rotates on a spindle. When the two coils have their surfaces parallel, they are coupled as tightly as they can be, but when the coils are at right angles, as in the above photograph, they are as loosely coupled as possible. Fig. 7 (right). Coupling of two coils may be on the same principle as the vario-coupler, except that instead of the two coils being independent, their windings are continuous, flexible connecting wire allowing the rotor to move. This is a variometer





COUPLING OF BASKET COILS

Fig. 8 (left). Basket coils are frequently coupled in this way for the purpose of tuning in short wave-lengths. In this case the coils are shown tightly coupled. Fig. 9 (right). In this photograph the same two coils as in Fig. 8 are shown loosely coupled. Variation of coupling is governed by the turning knob attached to a long screw-threaded rod, which moves the two coils farther apart against the strain of an elastic band

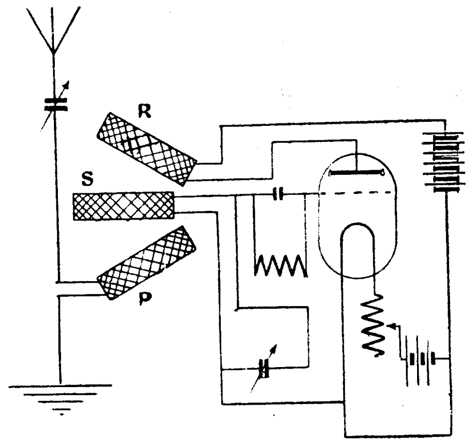
Inductive Coupling for Tuning. Among the many forms of inductive coupling probably the most common is its application to the tuning devices of receiving stations. It has been found that a closed circuit energized by and oscillating to the frequency of a open oscillatory circuit possesses considerably finer tuning and therefore greater selectivity.

Fig. 4 shows a popular method of obtaining this effect in an instrument known as a "loose coupler." The outer inductance, usually the open circuit from aerial to earth, is generally tuned by means of a spring-loaded contact housed in an insulated knob sliding on a rod just above and parallel to the inductance wires. The insulation is cleared, the path of the contact piece allowing more or less wire in the circuit in order to vary the tuning as the sliding contact moves along. The secondary circuit generally consists of a tapped inductance capable of motion in or out of the primary inductance. A small condenser, dependent in size on the inductance between each tapping, is used for finer tuning. This coil, with the condenser in parallel across it, connects to the grid and high-tension negative. Fig. 4 shows the inner inductance very loosely coupled, and in Fig. 5 the coupling is shown very tight. A disadvantage with the loose coupler method of tuning lies in the dead end effects of the wire not actually used in the tuning circuit, but still directly coupled to it. A somewhat similar type of coupling is the vario-coupler, shown in Fig. 6. In this the inner inductance revolves inside the outer one instead of being withdrawn from it. An adaptation of this method is shown in Fig. 7. illustrating a variometer. This differs from a vario-coupler in that one end of the rotor is attached to one end of the stator, giving direct coupling as well as magnetic or inductive coupling.

The arrangement provides a very efficient method of tuning. Dead end effects and sliding contacts are eliminated. This type of tuning is common in crystal sets, owing to its simplicity and compactness.

Figs. 8 and 9 show a basket coil arrangement of coupling which is advantageously used on short wave-lengths. The coils are wound on a boss having an uneven number of radial arms, the wire being alternately placed on opposite sides of the arms. The appearance of the edges is of a diamond pattern designed to give a low self-capacity and a high inductive value. Fig. 8 shows two such coils tightly coupled. They are mounted so that their mutual inductance is capable of being varied by means of a screwed rod towards the base of the coil-mounting device. Fig. 9 shows the coils loosely coupled, their mutual induction being of a low order.

The basket coil has two distinct disadvantages. Owing to its fragile construction it is very easily damaged, and it is also difficult to adapt for mounting into plug-holders. Its use has been largely replaced by the duo-lateral coil, which is becoming more and more the standard method of tuning and coupling. The duo-lateral coil is usually mounted in an ebonite holder having a socket and plug fitting the plug and socket of the coil itself. Variable coupling between two such coils is obtained by having one coil holder loose, allowing it to move, by a suitable handle attached, to or from the fixed coil. Where three coils are employed two movable holders are fitted, one to each side of the fixed one.



COUPLING IN A COMMON CIRCUIT

Fig. 10. Instances in which the coupling shown in this circuit diagram is varied are illustrated in the photographs, Figs. 11-19

Fig. 11

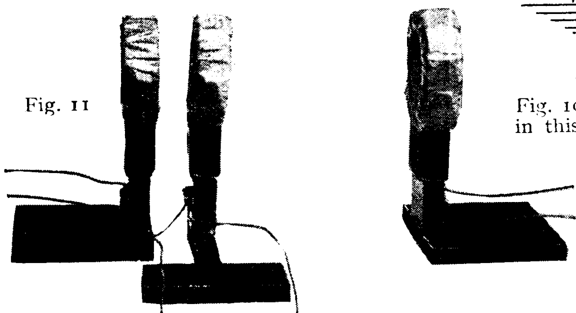


Fig. 12

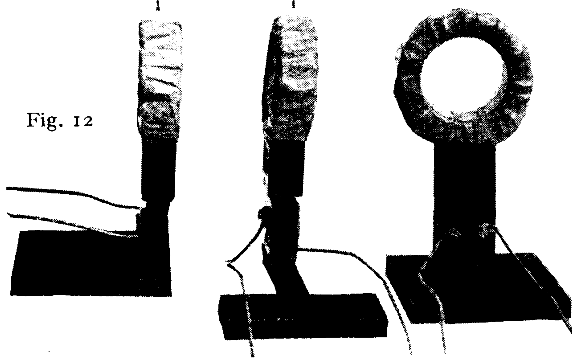
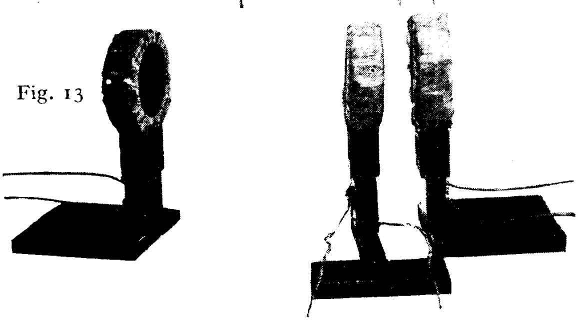


Fig. 13



COUPLING OF DUO-LATERAL COILS

Fig. 11. Coupling between P and S of Fig. 10 is shown tight, while R is only loosely coupled, giving little reaction. Fig. 12. R, the reaction coupling of Fig. 10, is shown at right angles to the secondary coil, S, and the coupling of P and S is not so tight as in Fig. 11. Fig. 13. Coupling here is opposite to that shown in Fig. 11, reaction coupling being tight and that between primary and secondary loose

A novel and very efficient method of coupling duo-lateral coils is shown in the series of illustrations, Figs. 11-19.

Three bases of ebonite are cut to the shape shown in the illustrations, allowing tight coupling when the bases are fitted together. On these at convenient positions at the edges are mounted coil holders, flex leads being taken from them.

In this series the coils represent, in order from left to right:

P, Primary tuning coil,
S, Secondary tuning coil,
R, Reaction coil.

A very common circuit in which these coils are used is shown in Fig. 10, representing an open oscillatory circuit in which P is the tuning coil, S the tuning coil in the closed circuit, and R the reaction coil arranged to transfer some of its energies to S for re-amplification from the grid.

In Fig. 11 the coupling between P and S is tight, allowing a large energizing of the secondary coil. R, on the other hand, is very loosely coupled, and practically no reactive effect is obtained.

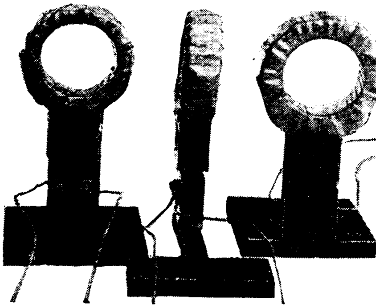


Fig. 14. Coupling of reaction and primary and secondary are here very loose

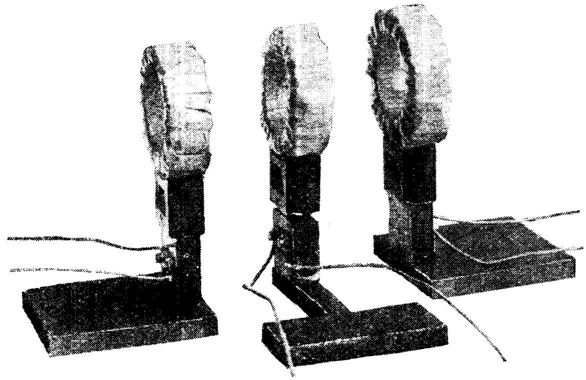
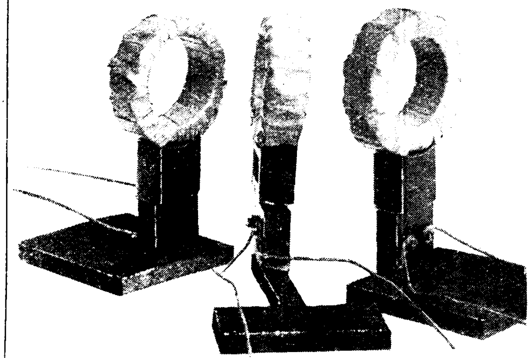


Fig. 15. Moderate inductive coupling occurs here, or a normal amount of coupling likely to be met with in a receiving circuit



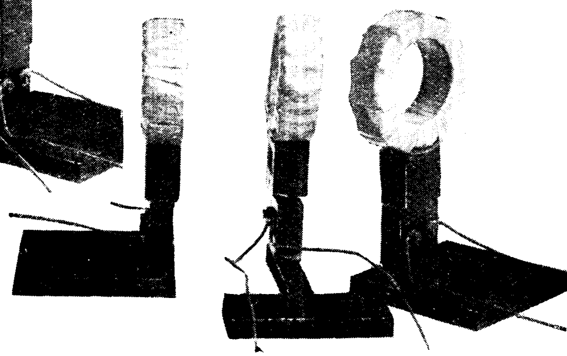


Fig. 16 (left). Coupling tighter on primary than on reaction coil. Either may be quickly slewed round to give tighter or looser coupling. Fig. 17 (right). Looseness of coupling is shown when the reaction coil is turned sideways

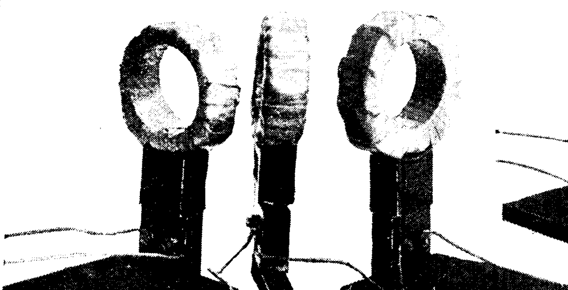


Fig. 18. Primary and reaction coils are turned at an angle from the secondary coil, giving considerably less mutual induction than when directly facing it

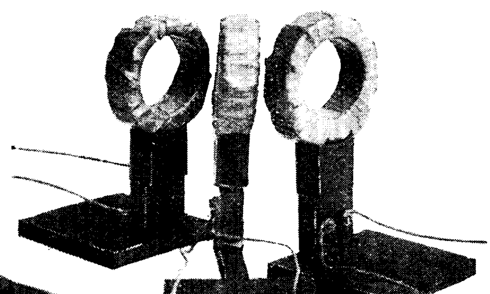


Fig. 19. Although these coils nearly touch, coupling is very loose. Primary and reaction coil may both face the secondary, when a very tight coupling is effected without altering position

DEMONSTRATIONS OF THE VARIABILITY OF DUO-LATERAL COUPLING

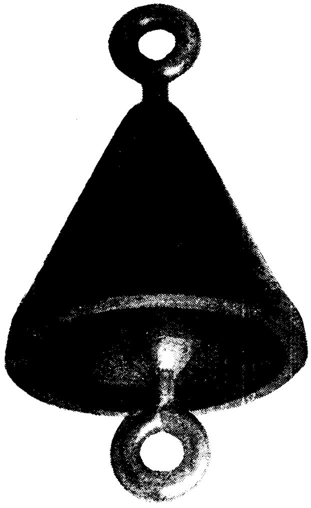
A similar coupling is shown in Fig. 12, where R is at right angles to S. Owing to its position there is practically no coupling here, and the coupling of P and S is not quite so close as in Fig. 11. The illustration in Fig. 13 is the opposite to Fig. 11, the reaction coupling being very tight and the primary and secondary very loose.

The coupling of both P and R in Fig. 14 is very loose. The couplings in Figs. 15, 16, 17, 18, 19, are more practical arrangements. Advantage is obtained of an oblique tuning of the coils to obtain a somewhat vernier arrangement. Except in Fig. 15, showing a moderate inductive coupling, this slantwise position is adapted in the remainder of couplings.

If the coupling R to S is too tight, too much energy will be transferred to the grid circuit, when the set is said to break into self-oscillation, which will be continued until the coil is withdrawn.

Another method of using the duo-lateral coils in this arrangement is as high-frequency transformer coupling. In this application the coils should be of the same size and suited to the wave-length of the aerial tuning coils. One coil is connected to to high-tension positive and anode and the other to grid of the second valve and high-tension negative. Reaction may be applied to this coupling instead of the aerial direct. This method is to be recommended, as self-oscillation is restricted in a greater extent to the set itself and not so easily transferred into the aerial, to the disturbance of others in the neighbourhood having receiving apparatus.

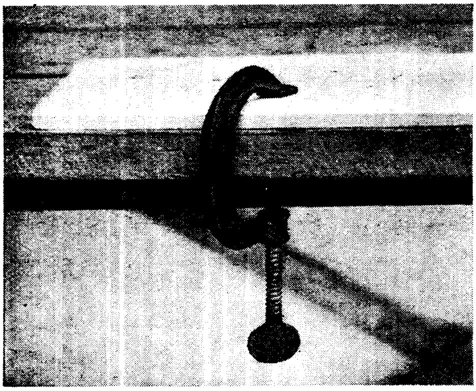
COWL INSULATOR. Name given to a type of insulator characterized by its conical shape. In the example illustrated the cowl, or insulating portion, is made more or less hollow, and when it is set in a vertical position all moisture drains downwards and drips off the sharp edges, thereby tending to keep the insulator dry and retard the passage of surface currents or leakage. The body is often made of moulded ebonite, and the brass eyes embedded in place during manufacture. They are thus very secure and seldom pull out. The shape of the cowl is such as to present a long path between the two points of attachment, and thus makes this a very efficient insulator, especially suited to amateur aerials.



LONG PATH INSULATOR

Cowl insulators, of which this is a specimen, are employed because of their long path of insulation between points to be shielded. This type of insulator is very efficient

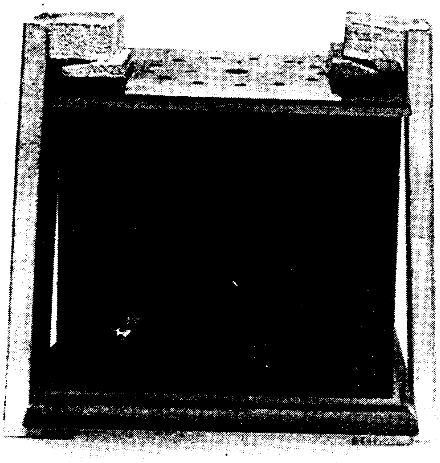
CRAMP. A portable device for exerting pressure on an object held by and between the jaws. There are very many types of cramp, some made of malleable iron, as in the example illustrated in Fig. 1, where the cramp is known as a "G" cramp, and is shown in use holding a baseboard to the work bench. The cramp is in essence a U-shaped frame, one of the ends or jaws is flattened, the other drilled and tapped for the set-screw which exerts the pressure, when the screw is rotated on anything between its head and the opposite jaw. A somewhat similar type is made in wood and used for woodwork, as, for example, in the construction of a cabinet set.



PORTABLE CRAMP

Fig. 1. In order to hold an object, as the plank of wood shown above, to a bench or other support a cramp is very useful

Varieties are available that are very lightly made, are generally forged from solid steel, and are particularly durable. Home-made cramps can be extemporized readily in the manner shown in Fig. 2, where the cramp is made from a length of batten with cross-pieces of wood nailed on at each end. Pressure is applied by means of wooden wedges forced in between the face of the work and the jaws of the cramp. In the application illustrated in Fig. 2 the panel of a piece of wireless apparatus is held in place to the case



HOME-MADE CRAMPS

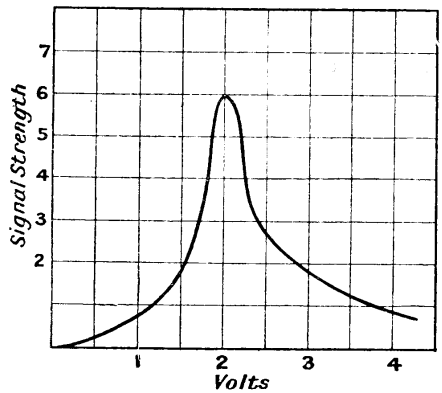
Fig. 2. On either side of the cabinet in the photograph will be seen cramps made of wood to hold the case during gluing. The cramps are simple devices consisting of wooden bars with blocks at either end and wedges

while the work is in progress. Such cramps are made up in a few minutes, and have many uses in the construction of wireless appliances.

CREOSOTE. A distillate of tar obtained as a by-product during the manufacture of the latter. It has excellent preservative properties when applied to woodwork, and is specially valuable for treating aerial masts, spreaders, and the exterior of small wooden buildings, such as an amateur's workshop or wireless cabin. It can be applied on all small work with a brush. It is most economically purchased in a 40-gallon barrel or cask, and a smaller quantity drawn off into a paint kettle or other container and used as required. When treating timber, small parts can be totally immersed, but in general the amateur will find it best to apply it with a brush.

CRITICAL POINT. Term used in electrical work synonymously with optimum point to indicate a condition of a regulated piece of apparatus when a slight alteration to its adjustment in either direction is such that it is followed by a drop in efficiency.

It is largely applied in wireless to the peak of the curve in the graphical representation of the functioning of a valve. Another example of critical point is shown in the adjustment of potential across a carborundum crystal by a potentiometer. In such a case a position will be found where a signal comes in at greatest strength, and any alteration from this point, however slight, will reduce the strength of the signal and throw the crystal off its critical point. A purely arbitrary example is illustrated, and supposes that the point of

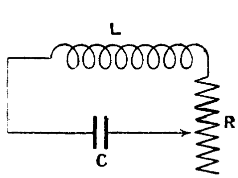


CRITICAL POINT IN A CURVE

The curve shown is a purely arbitrary one. It gives volts plotted against signal strength, the peak of the curve being the critical point

maximum efficiency is found when the potential of 2 volts is applied to the crystal. The abscissae of the graph are plotted in terms of $\frac{1}{2}$ volts, and the ordinates in terms of signal strength. The critical point in the graph occurs where the voltage applied is between $1\frac{3}{4}$ and $2\frac{1}{4}$.

CRITICAL RESISTANCE. All metallic electrical circuits have resistance, although in wireless telegraphy it is generally the endeavour of the designer to reduce this resistance to a minimum.



Critical resistance in an oscillatory circuit is represented. The inductance is shown at L, the capacity C, and variable resistance R

There are times, however, when it is advisable to insert resistance into a circuit in order to prevent that circuit oscillating. If the figure represents an oscillatory circuit having capacity C, inductance L, and resistance R, the circuit can be made to oscillate, provided the resistance R is not too large. There are, therefore, values of resistance in spite of which the circuit can be made to oscillate.

There is one value of resistance, the "critical value," which is just sufficient to make the oscillating condition unstable. Then there are the higher values of resistance, which will prevent oscillations altogether.

These values are as follows:

When R^2 is less than $\frac{4L}{C}$

the circuit will oscillate.

If R^2 is greater than $\frac{4L}{C}$

the circuit will not oscillate.

Whilst if R^2 is equal to $\frac{4L}{C}$

the circuit will not be stable. This is called the critical case.

This relationship is shown more thoroughly by Lord Kelvin in the formula for the time constant of an oscillatory circuit where T = time, L = inductance, and C = capacity, as before.

$$T = \frac{2\pi}{\sqrt{\left(\frac{1}{LC} - \frac{R^2}{4L^2}\right)}}$$

Now if $\frac{R^2}{4L^2}$ is less than $\frac{1}{LC}$

i.e. R^2 is less than $\frac{4L^2}{LC}$

i.e. R^2 is less than $\frac{4L}{C}$

we have seen that the circuit will oscillate.

This is shown because T is positive, and is the actual measure of the time of one complete oscillation.

If, however, $\frac{R^2}{4L^2}$ is greater than $\frac{1}{LC}$,

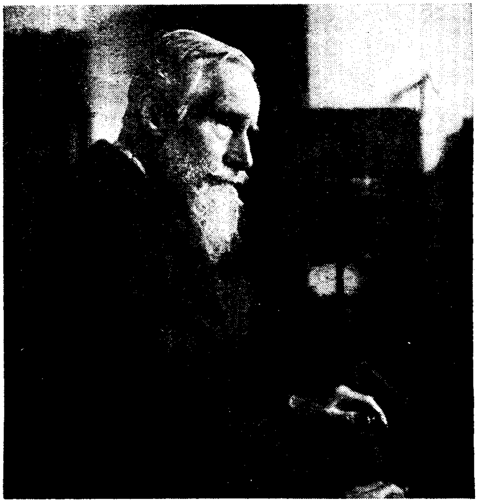
i.e. R^2 is greater than $\frac{4L}{C}$,

we have the second condition, and T becomes imaginary, or, in other words, the circuit will not oscillate. The quantity under the square root sign is negative and has no root.

In ordinary wireless circuits it is usual to assume that the resistance is so small when compared with the inductance, that we may neglect $\frac{R^2}{4L^2}$, and the formula for the time constant becomes

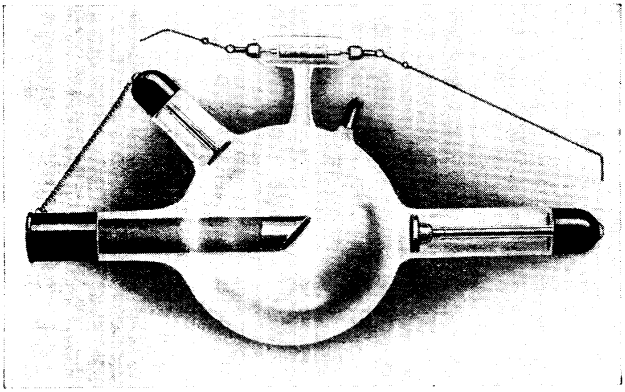
$$T = 2\pi\sqrt{LC}$$

CROOKES, SIR WILLIAM (1832-1919). English chemist and physicist. Born in London, June 17th, 1832, Crookes was educated at the Royal College of Chemistry and afterwards became assistant in the meteorological department of the Radcliffe Observatory, Oxford. In 1855 he obtained a chemical post at Chester.



SIR WILLIAM CROOKES
Inventor of the Crookes tube and discoverer of phenomena which led to the generally accepted electronic theory

Crookes early began that series of brilliant researches which has left its mark on the scientific progress of the nineteenth century. In 1861 he isolated the new element thallium, during the investigation of the atomic weight of which he made the discovery of his radiometer. This led to his researches on the phenomena



MODERN FORM OF CROOKES TUBE
By means of this apparatus Crookes was enabled to investigate phenomena which greatly influenced the path of wireless research

of electric discharges through highly exhausted tubes, or Crookes tubes. The illustration shows such a tube. When a current is passed through it, cathode particles travel along it. His discoveries on these phenomena led directly to the development by Sir J. J. Thomson of the now generally accepted electronic theory. In 1883 he began his study of the rare earths, and in 1892 he prognosticated wireless telegraphy on the strength of Lodge's and Hughes' experiments.

Knighted in 1897, Crookes was awarded the Royal medal in 1875, the Davy medal in 1880, and the Copley medal of the Royal Society in 1904, and the O.M. in 1910. He died in London, April 4th, 1919.

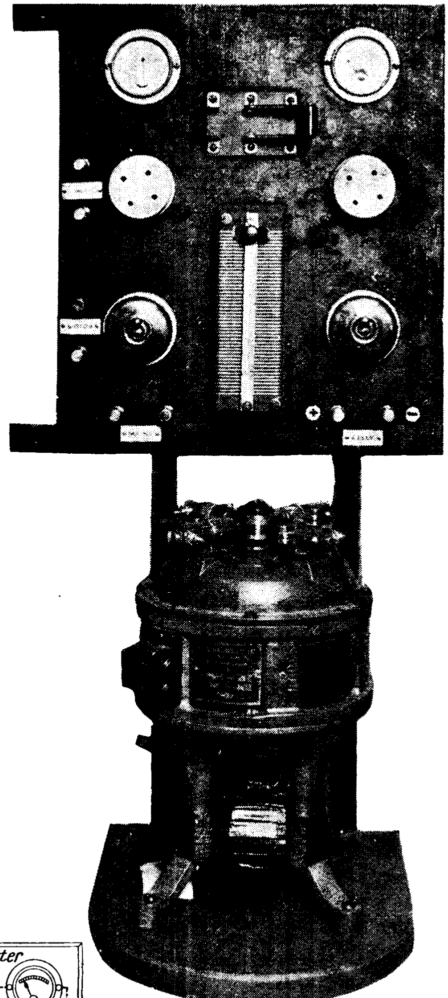
CRYPTO COMMUTATING RECTIFIER. The Crypto commutating rectifier is a special type of rotary converter primarily designed for accumulator charging from A.C. mains. The machine is made in two sizes:

(*a*) {10 volts, 5 amperes; 15 volts, 5 amperes;

(*b*) 15 volts, 10 amperes.

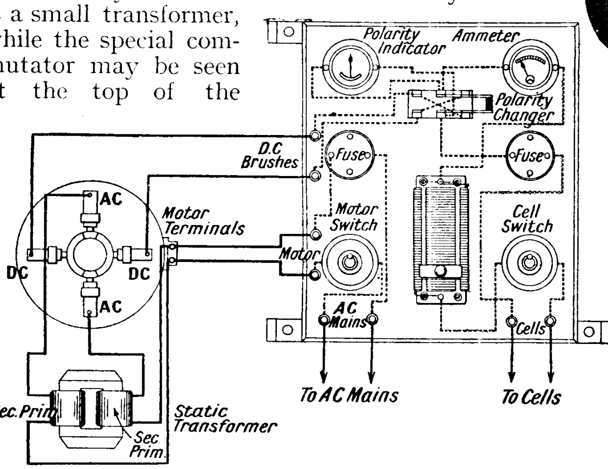
It will thus be seen that for anyone who has a fair amount of charging to do it is of a very convenient size, and, moreover, represents a most electrically efficient method of rectification.

Fig. 1 gives an idea of the general arrangement of the machine, which consists essentially of a small synchronous A.C. motor, the spindle of which is vertical. Immediately underneath the motor body is a small transformer, while the special commutator may be seen at the top of the machine. The A.C. supply is fed to the synchronous motor, and also to the transformer. This transformer is a step-down one, and the secondary windings (low tension) are fed to the commutator, which converts the A.C. into unidirectional current. In order to understand fully the rectifying action of this commutator, reference must



CRYPTO RECTIFYING COMMUTATOR

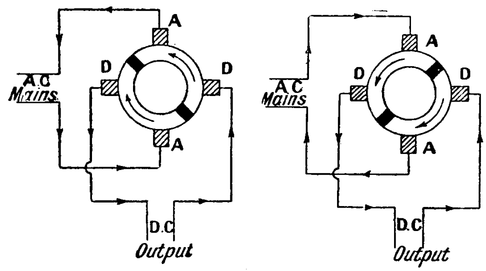
Fig. 1. Rotary converters of this kind are designed for accumulator charging. Above is a general view of the Crypto commutating rectifier, showing the switchboard and motor



CIRCUIT OF CRYPTO COMMUTATING RECTIFIER

Fig. 2. At the top of the machine is the special commutator. A small synchronous A.C. motor is arranged with its spindle vertical. The small transformer is beneath the motor body. The right-hand portion of the diagram should be compared with the switchboard in the photograph, Fig. 1

be made to the diagrams Figs. 3 and 4, and also Fig. 5, which is a close-up view of the commutator. As the illustration shows, the commutator has four sections —two large copper parts separated by two insulated sectors. The four brushes are



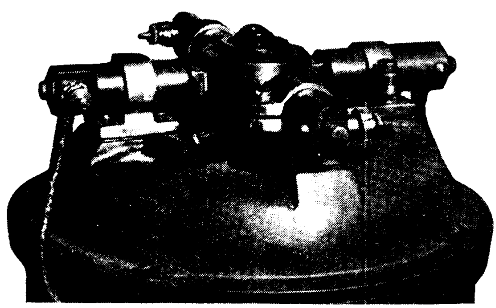
BRUSH CONTACTS OF A CRYPTO COMMUTATOR

Fig. 3 (left). Separated by two insulated sectors, marked black, are two copper parts of the rotating commutator. Four brushes, A, A, D, D, change the A.C. current into D.C., whether the position is as shown in Fig. 3 or in Fig. 4

placed at 90° with each other, the A.C. being fed to two diametrically opposite brushes. The motor is driven at synchronous speed, *i.e.* in step with the frequency of the supply.

Figs. 3 and 4 are practically self-explanatory, and show that, in whatever direction the A.C. flows, the commutator passes the current on unidirectionally through the other pair of brushes.

A feature of the machine is that it is self-starting, which is not usually the case with synchronous motors. The



COMMUTATING RECTIFIER

Fig. 5. This photograph gives a close view of the four brushes marked A, A, D, D, in the diagrams above. The revolving copper parts, with their separating insulator sectors, are seen in the centre like the hub of a wheel

necessary starting torque is obtained by a special starting winding. When the machine is at rest this winding is in circuit, so that when the starting switch is closed the current passes through it. The rotor carries with it, however, a centrifugally operated switch, which comes into play as soon as the motor starts and automatically cuts out the starter winding. The motor then runs up to synchronous speed, and rotates continuously at that constant r.p.m. A further feature worthy of note is that there is no electrical connexion between the high-voltage mains and the batteries, thus rendering a shock from the A.C. mains impossible.

The switchboard shown in the photograph with the rectifier is specially designed for use with it. A complete diagram of connexions is shown in Fig. 2. It will be seen that a charging regulator resistance is fitted, enabling any desired amount of current, from a convenient minimum to the maximum, to be obtained. Further than this, if for any reason a very small charge indeed is required (such as for charging secondary high-tension batteries of very small capacity) a lower voltage tapping is provided in the secondary winding of the transformer.

The erection of the machine and switchboard is a very simple matter. The terminals are plainly marked for their various uses. Before starting the motor the cells should be connected. The starting switch should then be closed, when it is probable that it will be found that the direction of flow of the D.C. is reversed. This is indicated by the combined polarity indicator and voltmeter on the left-hand side of the board. Should the current direction prove to be wrong, the change-over switch in the centre of the panel must be reversed. The regulator must then be adjusted until the ammeter gives the correct reading for the particular battery or cell on charge. *See* Generator.

CRYSTAL. Term used in wireless to denote a mineral rectifier of high-frequency currents.

F. Braun, in 1874, noticed that certain pairs of substances, when placed so that only a small area was in contact, offered a much greater resistance to an electric current in one direction than in another. These substances, of which there are a very large number, clearly, therefore, possess the power of rectifying high-frequency alternating currents. They act, indeed, as an electric valve, as it were. Such pairs of substances are tellurium and aluminium, silicon and copper, carbon and steel, etc. As a particular example of the difference of current which can be passed in either direction, L. W. Austin found that with a silicon-steel combination an E.M.F. of 2·5 volts could pass a current of ·025 ampere from steel to silicon, but only ·006 ampere from silicon to steel. The well-known Perikon detector, patented by Pickard, first made use of a contact between fused oxide of zinc and a brass point.

In 1906 H. H. C. Dunwoody made the discovery that crystals of carborundum could be used in exactly a similar way to rectify high-frequency alternating currents. The crystal could be used for the purpose with or without a local E.M.F. for the purpose of rectification, though better rectification is obtained when a small E.M.F. is passed through the crystal. Pickard and Pierce found that not only did carborundum possess unilateral conductivity, but that this conductivity did not obey Ohm's law. With a good carborundum crystal as much as forty times as much current may be passed one way as the other with an impressed E.M.F. of 2 volts. With an E.M.F. of 30 volts the current passed was three to four thousand times as great in one direction as in the other.

The Best Crystal Combinations

Since the discovery of this peculiar and important property of carborundum crystals, it has been found that a large number of mineral crystals possess the same property of rectifying high-frequency currents when in contact with a small piece of metal, usually in the form of a wire. Example of such minerals are galena, iron pyrites, molybdenite, bornite, chalcopyrite, carborundum, silicon, zincite, and cerusite.

The rectifying power of these crystals depends not only upon themselves, as it were, but upon the contact that is made, the material making the contact, and also the temperature. In the case of carborundum, for example, it ceases to become a rectifier at low temperatures, while at high temperatures, up to 400–500° C., it increases in its rectifying powers.

Among the best of the more common combinations of materials and crystal rectifiers may be mentioned zincite-chalcopyrite, or Perikon, in which two crystals are used pressed together; zincite-bornite, or crystallite; carborundum and a fine steel point; zincite and tellurium; silicon and steel; molybdenite and copper or silver; galena and a gold, silver, copper, or graphite point.

The things to look for in a good commercial crystal are that it should rectify with very small changes of potential, that it should be constant and reliable in operation, that it should be unaffected by atmospheric conditions, and that it can resist small mechanical shocks.

When using a wire or cat's-whisker contact with a crystal, the wire should be of fine gauge, 32 or 34 S.W.G. The wire should be springy, so that as light as possible a contact may be obtained, and the contact gradually increased in pressure as necessary. The most sensitive point on a crystal and the most sensitive adjustments are best found by means of a buzzer (*q.v.*).

How to Make Contact

With some soft crystals it is often a better plan to use a bundle of fine wires in place of the usual single wire cat's-whisker. Not only is it easier to strike a sensitive spot with this arrangement, but the wires are each feeding separate sensitive spots, and are acting in parallel to pass a greater supply of current through to the telephones. Though a light contact is best with many crystals, in others, as carborundum-steel and the Perikon combination, a firm contact is better.

Once the contacts of these last two combinations have been adjusted, they remain in a sensitive condition, even though vibration or accidental jarring takes place. With galena the best results are usually obtained with an extremely light contact, but the disadvantage of such a contact is that it may be upset by a very slight jar, even a heavy tread of a person across a room may displace it.

Owing to the light and small contact for most crystals, and also because that contact must be a good one, it is obvious that dust or any extraneous substance must be kept clear of the crystal. For that reason a crystal should be totally enclosed in a dust-proof glass or mica case. Crystals may best be cleaned with a small brush that has been dipped in carbon disulphide, and they should not be handled by the fingers. When changing crystals for experimental purposes, use a pair of tweezers. If, as usually happens after a time, due to oxidation of the surface and other causes, a crystal begins to lose its sensitivity, fresh surfaces may be exposed by flaking the crystal with a penknife, or breaking it with a small hammer. The breaking should be done as gently as possible, to retain the crystalline structure of the detector. Once that is lost and the crystal has been crushed, it entirely loses its power as a rectifier.

Dr. Fleming, who carried out a series of experiments on various combinations of materials for crystal detectors, gives the following notes on these combinations.

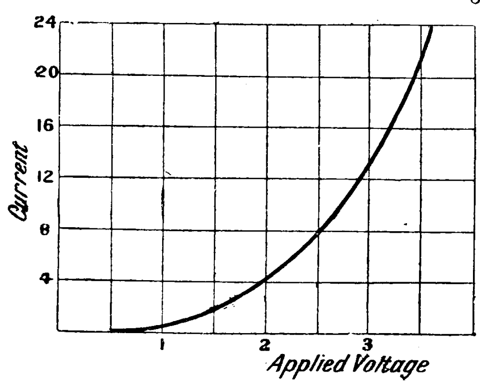
In the case of the perikon, or zincite-chalcopyrite detector, with a light to medium contact, the current is greater when the zincite is connected to the negative pole of a battery. For heavy pressure the rule still holds good down to ·002 of a volt, after which the greater current is often reversed, *i.e.* the chalcopyrite should be connected to the negative pole of the battery.

With a molybdenite-copper contact the greater current flows with the molybdenite connected to the negative pole of the battery for light pressures. With heavy pressures the current may reverse. With a zincite-bornite contact the zincite is negative for maximum current and light pressures and reversed for heavy pressures below one-tenth of a volt. The zincite is also negative in a zincite-copper contact, a zincite-galena contact, zincite-iron pyrites contact, a silicon-zincite contact and a tellurium-zincite contact. With heavy pressures in a zincite-copper contact the greater current passes, however, with the copper negative for E.M.F.'s below a tenth of a volt.

Molybdenite is negative for the greater current in molybdenite-chalcopyrite, iron pyrites-molybdenite, tellurium-molybdenite and bornite-molybdenite contacts. Tellurium-molybdenite gives the best results with a light contact. With tellurium-silicon contacts the silicon is negative, and the combination works best with a light contact.

It may as well be considered here how applied E.M.F. increases the rectifying power of certain crystal combinations. It is first of all clear that if a steady current is passing through the combination, it is periodically increased and decreased as the high-frequency current falls on the aerial. The diagram shows a characteristic curve for carborundum. The curve is obtained by plotting the applied voltage against the current passing measured in microamperes, and it will be seen that when the steady applied E.M.F. is, say, 2 volts, the current passing through the crystal is 4 microamperes. Suppose the incoming E.M.F. is 0·5 volt. This is regularly added and subtracted, making the E.M.F. periodically 2·5 volts and 1·5 volts. The currents due to these E.M.F.'s, as will be seen from the curve, are 8 microamperes and 2 microamperes respectively, the average of which is 5 microamperes, one microampere greater than that due to a steady E.M.F. of 2 volts. In other words, the addition of the alternating E.M.F. to the steady E.M.F. increases the current passing through the crystal, and this is one of the reasons why many crystal combinations work so much better with a battery than without one.

The exact nature of the action of rectifying crystals is still obscure, despite a considerable mass of experiment and research. Dr. Eccles has advanced a theory based on electro-thermal considerations, pointing out that there are two materials in contact, one or both of which are bad conductors of heat. Dr. Fleming carried out a series of experiments with powdered specimens of various crystals, and came to the conclusion that the rectifying power depended upon the crystalline structure, as the value of the crystal is entirely destroyed for rectification purposes when reduced to powder form.
—*J. Laurence Pritchard.*



CHARACTERISTIC CURVE OF CARBORUNDUM CRYSTAL

In this curve the current in microamperes is plotted vertically against the voltage horizontally. Applied electro-motive force increases the rectifying power of certain crystals, and a curve of this kind is an interesting and useful record for purposes of comparing efficiency

See under the names of the various crystals; *also* Characteristic Curve; Valve.

CRYSTAL CIRCUITS: PRINCIPLES & PRACTICE EXPLAINED

How the Crystal is Applied to Circuits of all Kinds

This is one a series of comprehensive articles dealing with the use of the crystal in a large number of varieties of receiving sets. Here the principles underlying crystal receiving circuits are explained. In following sections the practical and constructional aspects are very fully discussed and illustrated

The variety of circuits that embody a crystal detector is very great, and it is only possible to deal with a few of them, but the following are typical of the application of a crystal to various circuits. One of the simplest tunable circuits is shown in Fig. 1, and comprises a single inductance coil with a single slider. The circuit, leading from the aerial lead-in, starts with a wire attached to the terminal at the end of the inductance winding, and another wire goes from this terminal to the crystal side of the detector. The earth wire is attached to the terminal on the slider, and another from the same terminal to the telephones. A third wire connects the opposite terminal on the telephones to the second terminal on the crystal. The condenser shown shunted across the telephones is not essential, and if it is omitted there is no loss of signal strength with a very simple set, but if it is to be used with an amplifier the condenser across the telephones will be useful.

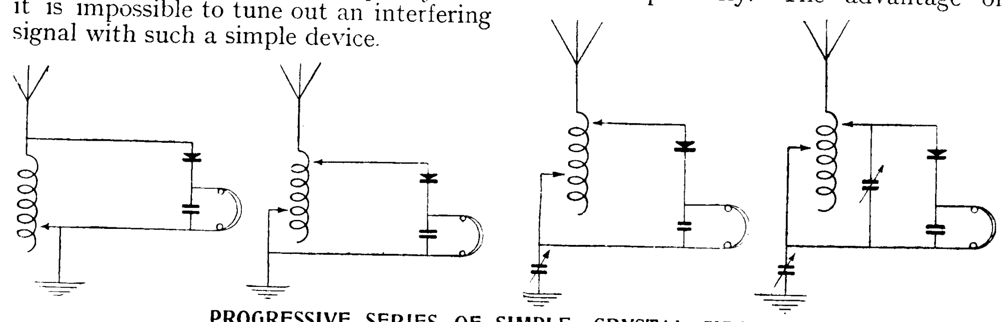
As regards values of components, these are so bound up with the design of the aerial and the length of the lead-in and earth wires, that it is impossible as a practical matter to give exact values, but for the inductance coil, No. 24 gauge D.C.C. wire wound for a length of 4 in. on a former made from cardboard tube 2 in. diameter, will be about right for the average amateur aerial. The telephones should be of high resistance, not less than 2,000 ohms, and preferably 4,000 ohms. The chief attraction of such a circuit is its simplicity, but it is impossible to tune out an interfering signal with such a simple device.

A better plan is to provide tunable circuits such as that shown in Fig. 2, where a double slider inductance coil is employed. In this case the wire from the aerial terminal to the crystal is attached to the terminal on the second slider bar, and this allows of tuning the two circuits, or, rather, the two ends of the one circuit, and thus it is possible to increase selectivity.

The experimenter with a single slider coil can easily convert it to a double slider and try the effect. Both the foregoing circuits contain only inductance, and fixed capacity apart from the natural capacity of the windings and other parts, but, by the addition of a variable condenser, as shown in Fig. 3, the selectivity may be increased to some extent and the tuning made more sensitive, as well as varying the wave-length range of the set.

The value of this condenser may be of the order of ·001 mfd. In this circuit there are three adjustments to make before the set is functioning at maximum strength. There is no great advantage in applying a condenser in a simple crystal set alone, as the condenser always reduces signal strength. But when the set is intended for subsequent amplification the condenser is of greater value. In one respect a condenser adds to the efficiency, and that is in the direction of fine tuning.

When two condensers are applied to a circuit, as shown in Fig. 4, they should be of low value. Their purpose is to tune the inductance and the earth side of the circuit respectively. The advantage of



PROGRESSIVE SERIES OF SIMPLE CRYSTAL CIRCUITS

Fig. 1. Single-slider tuning in a simple circuit. Fig. 2. Double-slider circuit with aerial wire to slider bar. Fig. 3. Added to the circuit in Fig. 2 is a variable condenser in the earth lead. Fig. 4. Another variable condenser is here added between aerial and earth

such condensers is that the tuning is more easily and accurately performed, as the slider system of tuning an inductance only permits the slider to tune to one coil space at the best, whereas the condenser can be varied by an exceedingly small amount.

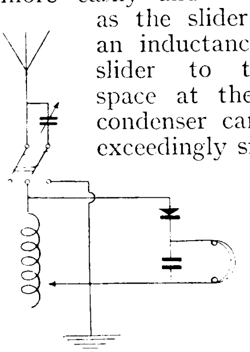
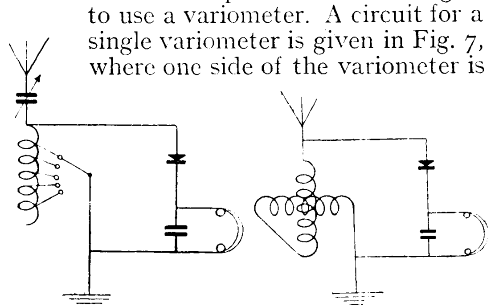


Fig. 5. Wave-length is varied in this circuit by the condenser wired to a series-parallel switch

Another way to apply a condenser in a crystal circuit is to wire it up with a series-parallel switch, as shown in Fig. 5. The switch is used to vary the wave-length range of the set, as when the condenser is in series with the inductance coil it reduces the range and makes the set capable of reception on a lower wave-length. But when the switch is thrown to set the condenser in parallel the receptive wave-length range is increased. Such condensers reduce the signal strength of a simple set, but enable amateur transmissions and others on wave-lengths above or below the normal broadcasting band to be heard without the need for loading coils.

The greatest disadvantage of a sliding contact type of tuner is the wear that is set up on the exposed part of the windings, and to avoid this failing the use of a tapped inductance coil is recommended. A circuit embodying this feature is given in Fig. 6. Fine tuning is accomplished by the series condenser, and the rest of the circuit is similar to the foregoing.

Another way to overcome the difficulties mentioned and to provide fine tuning is to use a variometer. A circuit for a single variometer is given in Fig. 7, where one side of the variometer is connected to the aerial and the other side to the earth connexions.



ALTERNATIVES TO SLIDER CONTACT

Fig. 6 (left). Tappings are taken from the inductance coil in this case, and Fig. 7 (right) is a circuit employing a variometer. These two means of varying inductance have advantages over the slider contact method

A more selective circuit is given in Fig. 8, which shows the connexions for a receiver, making use of a loose coupler. The coupling between the primary and the secondary is known as a magnetic coupling, and depends on the fact that the passage of a current of electricity through a coil of wire induces a magnetic field around it, and this in turn induces a flow of current in a second coil of wire adjacent to it. The induced current will have the same essential characteristics as the primary, but the voltage values in them may be different.

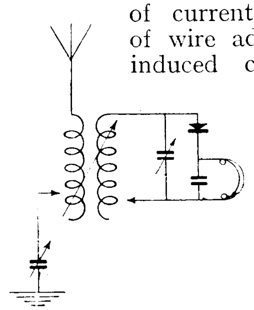


Fig. 8. Better selectivity than in the previous examples is obtained in this circuit, which employs a loose coupler

Such a feature is applied in a crystal circuit in the manner shown in Fig. 8. The primary winding is tuned by a single slider in a similar manner to the earlier examples of a single circuit. The secondary circuit is tuned with a variable condenser and a slider. The result is a selective and moderately sensitive circuit giving good results when the two circuits are properly tuned. There are five adjustments to make in this circuit, namely, the two sliders, the two condensers, and the degree of coupling. One way for the beginner to tune such a circuit is to tightly couple the two coils, then tune in on the primary as if it were a single circuit, and then adjust the secondary circuit until loudest signals are heard. When the secondary circuit is tuned the primary will need some adjustment to keep it in tune, but a little practice will indicate the methods.

When a crystal is used with a potentiometer and small battery the circuit arrangements look more difficult, but essentially are the same. One such is shown in Fig. 9, which illustrates a double-slider tuning arrangement as applied to a potentiometer-controlled crystal, such as a carborundum. Any of the other tuning circuits could be used, the potentiometer and crystal being virtually a complete item, and dealt with as such in the sense that it can be used in the place of the plain crystal. As will be seen, there are only two essential connexions between them in either case, namely, one to the crystal and one from it, connected respectively to the aerial and earth sides.

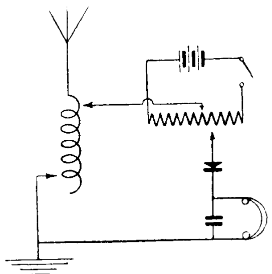


Fig. 9. Added to the crystal circuit is a battery and potentiometer. This arrangement is a very simple one

A circuit that embodies a valve is shown in Fig. 10, which illustrates the circuit when a stage of low-frequency amplification is added to a simple crystal set. The tuning is shown for a single-slider coil, but any of the others can be substituted, the amplifier circuit beginning at the telephone terminals of the original crystal set. The rectified current from the crystal flows through the primary winding of a transformer, and the induced current in the secondary thereof is amplified by the valve and the high- and low-tension batteries used with it. The details of such amplifying arrangements are dealt with under the headings Amplifiers and Crystal Receivers, How to Make (*q.v.*).

High-frequency amplification applied to a crystal set is shown in Fig. 11, and in this case a potentiometer control is used for the crystal. The use of honeycomb coils for the primary and secondary circuits should be noted, as they allow of an unlimited wave-length range by the simple expedient of changing the coils for those of appropriate values.

The combination of a stage of high- and a stage of low-frequency amplification is shown in Fig. 12, where the crystal is used for rectification. This type of circuit, with transformer coupling between the two valves, gives splendid results in practice.

The application of telephone transformers to a similar circuit is shown in Fig. 13, but in this case the high-frequency valve has a tuned anode circuit and the grid circuit is also tuned with a variable condenser. Such a circuit is extremely

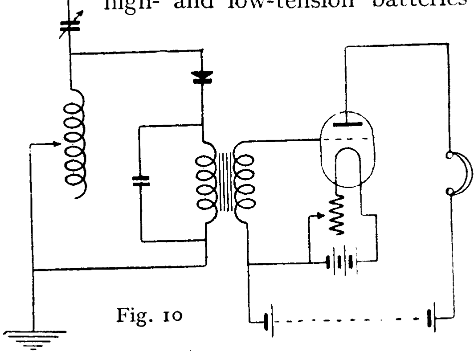


Fig. 10

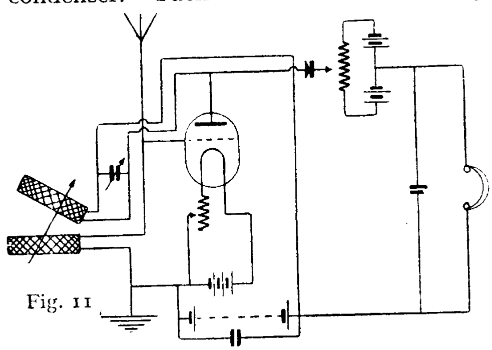


Fig. 11

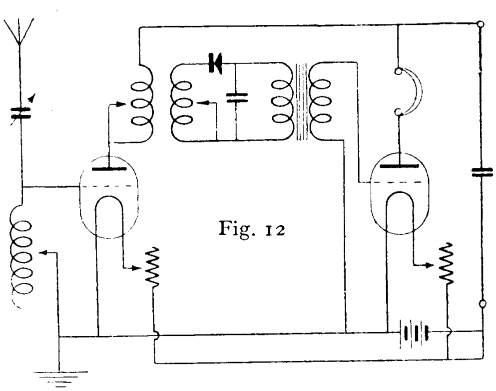


Fig. 12

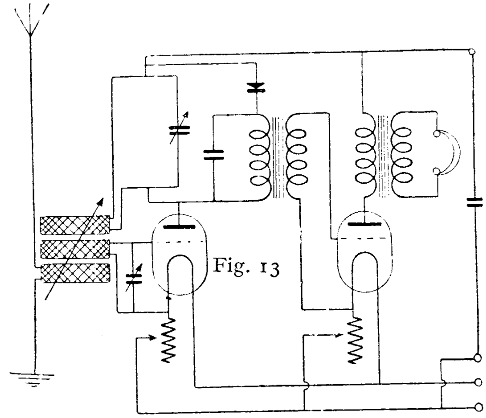


Fig. 13

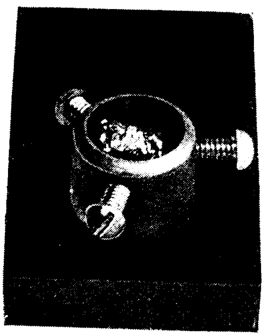
COMBINATION CRYSTAL AND VALVE CIRCUITS

Fig. 10. One stage of low-frequency amplification is added to a simple crystal circuit. Fig. 11. High-frequency amplification is applied in this case and the crystal is potentiometer-controlled. Fig. 12. Crystal rectification is here applied, with high- and low-frequency stages combined. Fig. 13. In this circuit a telephone transformer is added, and the high-frequency valve has a tuned anode

selective, and on a good aerial should bring in all the British broadcasting stations without interference from any other. Signal strength should be equal to the average three-valve set, but with the advantage of the purity of reception that is a characteristic of a crystal set. Further consideration of this class of circuit is given in the article on adding amplifiers to a crystal set, page 608.—*E. W. Hobbs.*

See Valve Circuit.

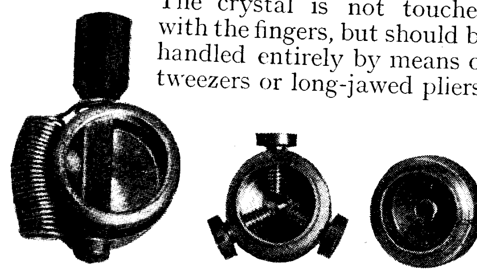
CRYSTAL CUP. Name given to a small holder, usually made of brass, wherein is secured the crystal for a crystal detector or receiver set. A very simple pattern is illustrated in Fig. 1, which shows the crystal in place in the crystal cup. The latter is machined out of solid brass bar about $\frac{5}{8}$ in. diameter. This is attached to the ebonite base by means of a screw which passes through it and also through the bottom of the brass crystal cup to make contact with the crystal. The crystal is secured by tightening up three set-screws. They should not be up too tight, or the crystal itself will be crushed, but must be tight enough for the screws to make firm contact and hold the crystal securely.



TRIPLE SCREW CUP

Fig. 1. Three set-screws hold the crystal in this common type of cup

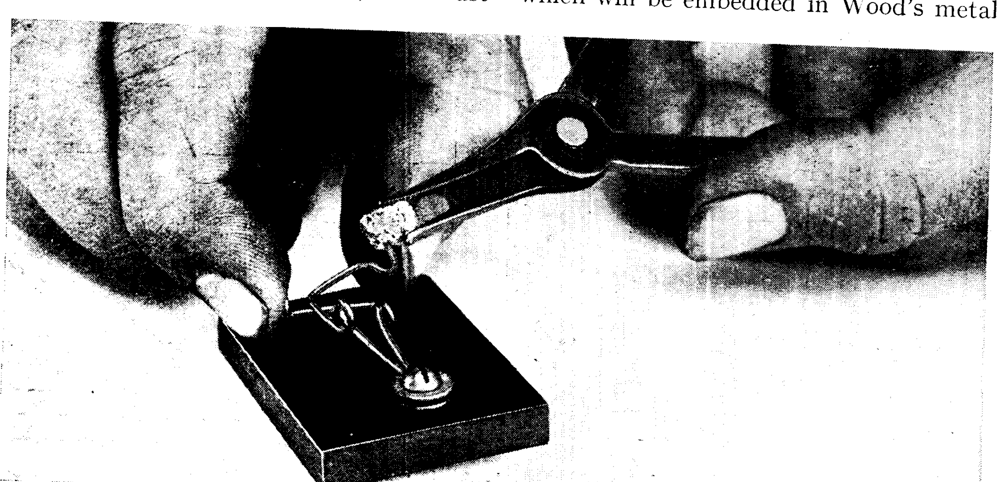
Another very simple method of holding the crystal is illustrated in Fig 2, which shows a holder made of brass wire and secured to the ebonite base by means of a round-headed screw and washer. The wire is so bent that it has a tendency to spring together. To insert the crystal, the two ends of the wire are pressed together with the fingers and thumb, as shown in Fig. 2, and the crystal inserted between the jaws formed in the wire. The crystal is not touched with the fingers, but should be handled entirely by means of tweezers or long-jawed pliers. The springiness of the brass wire holds the crystal firmly in its place.



EXAMPLES OF CRYSTAL CUP

Fig. 3. On the left is a spring lever cup. The crystal is held by pressing the ebonite knob sideways and releasing it to grip the inserted crystal. Centre is a three-screw cup. Right is a cup in which the crystal is embedded in plastic metal

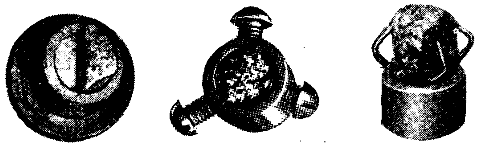
Three crystal cups are illustrated in Fig. 3. On the right is a simple pattern intended to receive the crystal, which will be embedded in Wood's metal



CRYSTAL HOLDER FOR CONTACT ON ALL SIDES

Fig. 2. Instead of a closed cup of the usual type, a wire clip can easily be made by the amateur which permits the crystal to be removed or reversed, for substitution or contact on the opposite side

or some other plastic alloy. The centre pattern shows a three-screw fastening, while on the left is an arrangement comprising a little coil spring and a lever. At the end of the lever is a small ebonite knob. The crystal is held by pressing this knob sideways so that the lever is forced back. The crystal is then dropped into



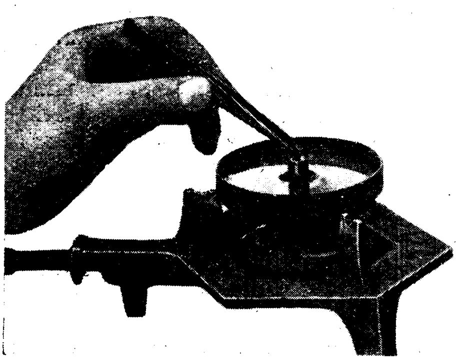
METHODS OF SETTING CRYSTALS IN CUPS

Fig. 4. Three methods of setting crystals in their cups are shown. Left is a crystal in plastic metal, centre the screw-grip method, and right is a cup with four spring claws

the cup and the tension on the coil spring released, drawing the lever closely against the crystal and holding it securely.

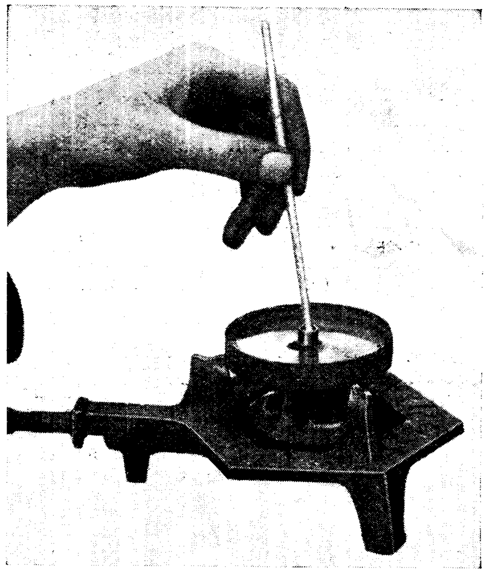
Fig. 4 illustrates three crystals mounted in their cups. On the right the crystal is held by means of four small brass wire claws soldered to the cup. The crystal is simply pressed into place and the springiness of the wires holds it firmly. On the left the crystal is shown embedded in the plastic metal.

As will have been noticed, there are two methods of mounting crystals in universal use, namely (*a*) by setting in a plastic metallic compound or in a low-temperature fusible metal, such as Wood's metal; and (*b*) by clamping with screws, springs, wire clips, and the like. While the second method has distinct advantages, particularly on account of quickness and



MOUNTING A CRYSTAL IN PLASTIC METAL

Fig. 5. Plastic metal may be melted by placing the crystal cup, with a small portion of the material, in the centre of a tin lid containing water, and heating on a gas-ring until boiling-point is nearly reached



WOOD'S METAL BEING MELTED

Fig. 6. A piece of Wood's metal is inserted in the cup, or a stick of the metal held down in it until the water in the tin is nearing boiling heat, when the Wood's metal will melt. While the substance is soft the crystal is inserted. This method avoids applying excessive heat to the crystal

easy manipulation, no doubt exists that a crystal set in a fused material will give the best results. In setting with Wood's metal, however, care must be exercised in order to prevent overheating of the crystal, for this, in many cases, may impair the sensitive surfaces.

A simple method of overcoming this is shown in Figs. 5 and 6. A small, flat tin lid, containing water up to about ¼ in., is placed on a gas-ring or over a bunsen burner. Any metallic object, such as a nut, is then immersed in the water so that its upper surface projects above the liquid. The crystal cup is placed upon the nut. By this means, not only will the temperature of the cup never become higher than the boiling point of water so long as any water remains in the tin, but the lacquer in the crystal cup will not be ruined.

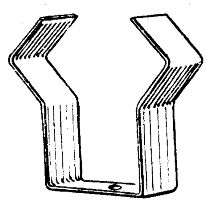


Fig. 7. Crystals may be held by this simple device, made from a metal strip bent to shape

The gas being lighted, the water is brought to boiling point, when the end of a strip of Wood's metal is placed upon the cup, as in Fig. 6. When the cup is about two-thirds full of molten metal, take the crystal in a pair of forceps, turn the gas out, and then insert the crystal in the cup, holding it there until the metal has set.

The objection to holding crystals in screws or wire clips is that the conducting surface is then very small.

Another method is to mount up two clips, as shown in Fig. 7, placed at right angles in the cup. The crystal is then sprung into position, either in the prongs of the clip or in the hollow formed by the bend. Fixing a crystal by this method cannot be considered so satisfactory as other methods. Phosphor-bronze wire (hard-drawn) should be used.

CRYSTAL DETECTORS: STANDARD VARIETIES

The Best Types for Crystal Receiving Sets and How to Use Them

This section is concerned solely with the crystal detector and its construction, and a careful selection has been made from the innumerable varieties that exist. For the use of the detector in appropriate circuits and receiving sets reference is to be made to Crystal Circuits and Crystal Receiver. See also Amplification; Amplifier

A crystal detector is a device for rectifying incoming signals from a wireless transmitting station, which includes the crystal and its supports and connexions. In its most elementary form the crystal detector need be nothing more elaborate than a piece of crystal with one wire bound tightly around it leading to the aerial and tuner, and a second wire, pointed at the end and resting lightly upon some part of the crystal, leading to the telephones.

Such an arrangement, however, would not be practical, for the reason that it would not permit of easy adjustment, nor would it be stable. The slightest vibration of the table or other support on which it is resting would entirely upset the signals. Some more secure means of holding the crystal and the provision of a controllable method of making contact is essential, so by the general use of the expression crystal detector is meant the whole of the apparatus needed for the purpose of holding the crystal and making contact therewith and supporting and controlling a wire, the cat's-whisker.

In place of the cat's-whisker may be another crystal—for example, the well-known Perikon detector, where one of the crystals is composed of zincite and the other of bornite. With such a detector the holding arrangements must be adapted to support the two crystals and provide means for moving the holders in such a way that the sensitive spots on both the crystals may be brought into contact. Other requirements are that the controls shall be perfectly easily worked and stable, that is, when they have once been adjusted they will remain in adjustment for a reasonable length of time and also will not be greatly affected by vibration such as that which might be experienced when the set is standing on a table and the latter is accidentally knocked or shaken.

Innumerable devices have been produced with these objects in view, but it is doubtful if any of them are completely satisfactory. Several typical examples are illustrated as suggestive of what has been done in this way. The crystal detector should be well insulated and be very sensitive, as with such minute currents as are used in wireless reception a small loss in efficiency means a big drop in signal strength. There are various crystals, of which, perhaps, carborundum is the best known, which will only function when a small local current is passed through them. Such current is generally obtained through a small dry battery, or accumulator, and its potential controlled by means of an instrument known as a potentiometer (*q.v.*).

The average experimenter gets perfectly good results with a simple crystal of the cat's-whisker type, using such crystals as hertzite, galena, or silicon. A very simple crystal detector can be made in the manner illustrated in Fig. 1. It consists of a little wooden base about 3 in. long and 2 in. wide, at one end of which is mounted a piece of screwed brass rod set in a vertical position. This is held to the baseboard by means of a nut on either side of the wood. A crystal cup is then screwed to the base by means of a screw passed through the underside of it, at about a distance of 1½ in. from the upright rod. Two telephone terminals are screwed in position as shown, and one connected to the upright rod by means of a piece of copper wire and held firm by soldering, or by means of two small lock nuts screwed on to the ends of the

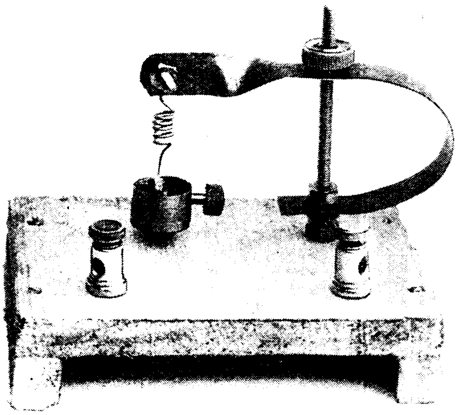


Fig. 1. Rough material may be converted into a neat device of this kind. A strip of spring brass is held on a screwed B.A. rod with an adjustable turning knob

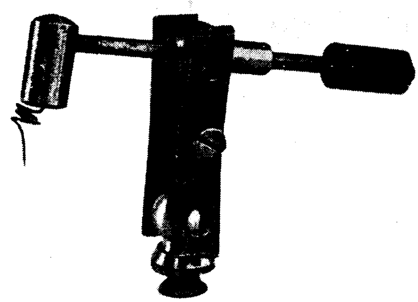


Fig. 2. Universal mounting is a common method of holding a cat's-whisker. The ball-and-socket joints permit a very wide range of movement

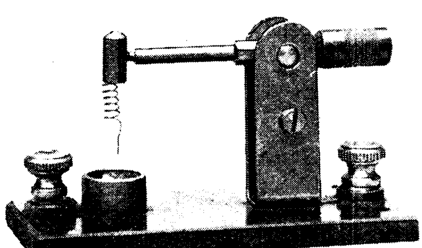


Fig. 3. Another form of ball-and-socket detector has a rigid upright arm holder, otherwise the arrangement is as Fig. 2

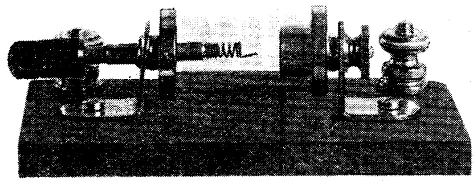


Fig. 4. Horizontal enclosed detectors prevent damp and dust deteriorating the crystal. This is one made by the Economic Electric Co.

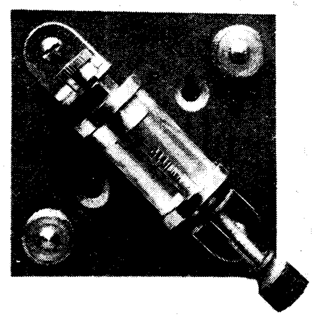


Fig. 5. On the left of this detector will be seen a nut which, when unscrewed, quickly and easily dismantles the whole arrangement

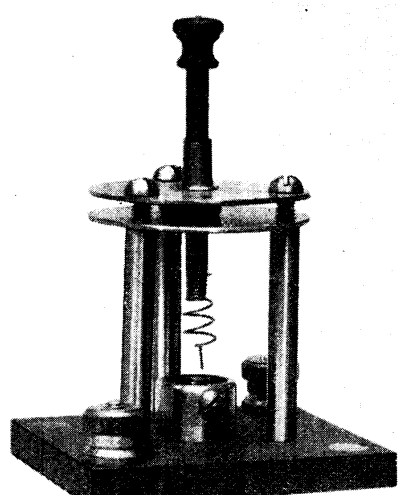
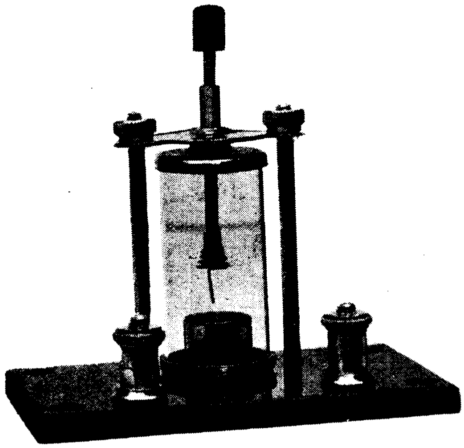


Fig. 6. Vertical detectors are often preferred. The one shown above, made by Will Day, Ltd., works on the ball-and-socket system

CRYSTAL DETECTORS EMPLOYING CAT'S-WHISKERS

spindles. The small cup is similarly connected to the other terminal.

The cat's-whisker is a little piece of fine brass wire, coiled into the form of a spring by twisting it around a 2 in. French nail. The ends should be turned out at right angles to the coils, and the lower end sharpened to a point by filing, and the upper end twisted to form an eye. A strip of copper or brass about $\frac{1}{4}$ in. wide and

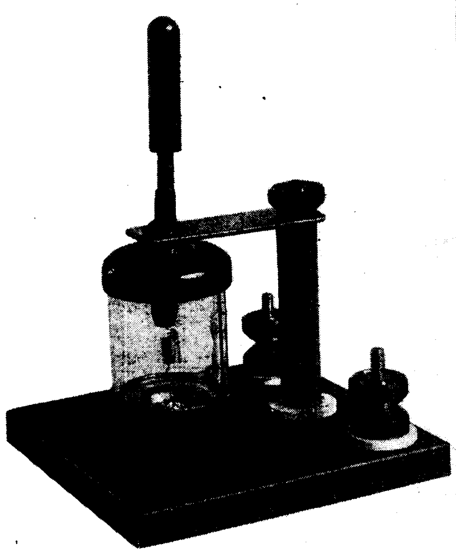


ENCLOSED VERTICAL DETECTOR

Fig. 7. Mounted on two brass posts is a bridge holding a disk into which is fitted a celluloid tube, resting at the bottom in a corresponding disk. By this means the crystal is effectively protected

Courtesy Will Day, Ltd.

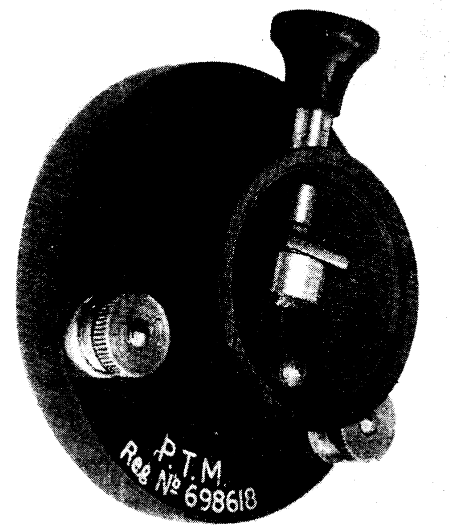
$\frac{1}{32}$ in. thick, is then bent to the shape shown in the illustration Fig. 1, and three holes punched in it. The one on the lower part is to allow it to slip over the upright screwed rod, to which it is attached by



SINGLE POST VERTICAL DETECTOR

Fig. 8. One post only is used in this case. The enclosed crystal is sunk in the cup at the bottom, and the cat's-whisker is adjusted on the ball-and-socket system, the top bar permitting a sideways movement

Courtesy Economic Electric Co.

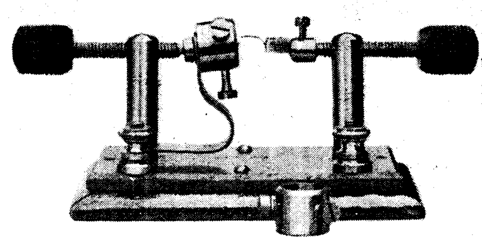


STATIONARY CAT'S-WHISKER

Fig. 9. In this type of fully enclosed detector the cat's-whisker is stationary and the crystal is moved

means of two lock nuts. The second hole is large enough to allow the brass strip to move freely over the particular part of the screwed rod, and is pressed down by means of a knurled nut or terminal nut which screws on the rod. The cat's-whisker is attached to the upper end of the strip by means of a small bolt and nut.

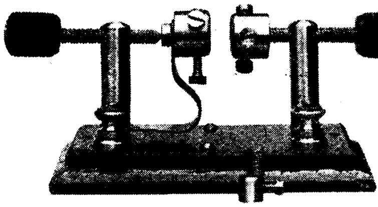
The crystal is placed in the cup and the cat's-whisker adjusted by bending the strip a little and finally adjusting by rotating the knurled nut. Provided the wood be dry, such a simple detector will bring in the signals quite satisfactorily from any near-by station. A better method of adjusting the cat's-



DETECTOR WITH DOUBLE ADJUSTMENT

Fig. 10. Two crystals, or one crystal and cat's-whisker, may be used in this detector. Adjustment may be made on either side of the contact

Courtesy Will Day, Ltd.

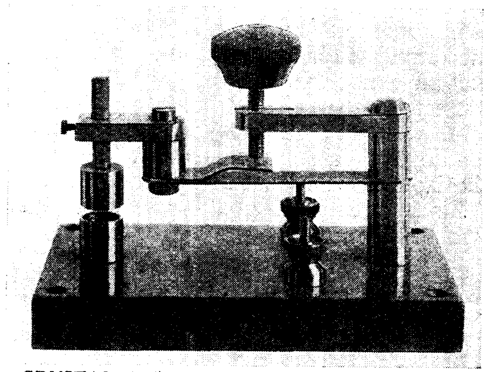


DOUBLE CRYSTAL DETECTOR

Fig. 11. Having substituted a second crystal cup for the cat's-whisker, two crystals may be brought into contact. This detector, made by Will Day, Ltd., is the same as in Fig. 10

whisker is shown in Fig. 2. In this case the cat's whisker is mounted in a brass fitting screwed on to the end of a brass rod about $2\frac{1}{2}$ in. in length, the other end having a small ebonite handle screwed to it. This rod passes through a ball post of brass and is a close sliding fit in it. Two side plates of brass about $\frac{1}{4}$ in. wide and $\frac{1}{16}$ in. thick are provided with holes in each end and secured together by means of a screw passed through them at about the middle of their length. At the lower end a ball-headed screw is provided, which can be attached to the ebonite or other baseboard.

When the parts are assembled as shown in Fig. 2, the whole appliance can be adjusted into practically any position, as it comprises two ball joints which enable the upright to be moved about into various positions, while the cat's-whisker itself can be moved backwards or forwards, or turned sideways by manipulation of the ebonite knob on the end of the arm. Stability is provided by means of tightening the set-screw holding the two upright plates together, until friction is sufficient to keep the whole steady.

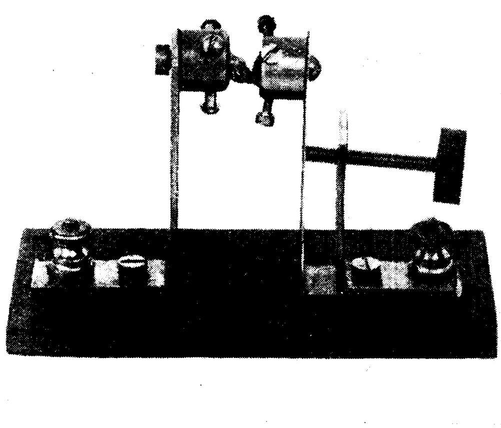


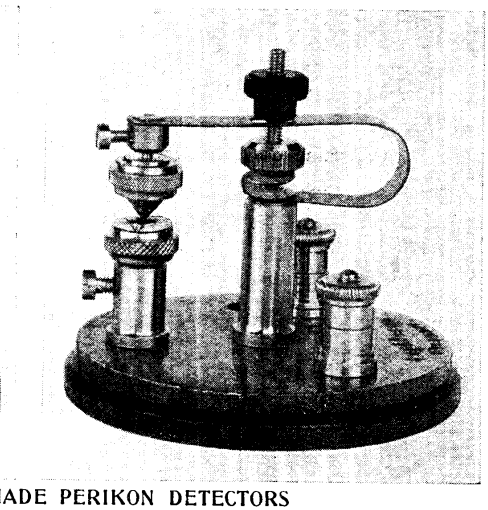
CRYSTAL DETECTOR WITH MICROMETER ADJUSTMENT

Fig. 12 This arrangement provides micrometer adjustment for two crystal cups. The upper cup may be moved with its holder for coarse adjustment, and fine adjustment is made by the screw and knob in the centre

Courtesy Economic Electric Co.

Another type embodying similar principles is illustrated in Fig. 3. In this case the upright is rigid, but the cat's-whisker arm is mounted in a ball-and-socket joint to provide sufficient range of movement.





HOME AND COMMERCIALLY MADE PERIKON DETECTORS

Fig. 13 (left). Two strips of brass bent to shape, a piece of angle brass, and a screwed rod with a turning handle are easily fashioned into the detector here shown. The screw control allows very delicate adjustment. Fig. 14 (right). Standard type of Perikon detector. This is a zincite-bornite combination, with a U-shaped brass strip spring contact device. Delicate adjustment is obtained by turning the screw-knob

One disadvantage of all types of exposed crystal is that dust is liable to settle upon them, and in time there is a loss of signal strength. Although the crystal can be cleaned by dipping it in absolute alcohol, or a fresh surface can be found by lightly scraping it with the blade of a penknife, it is desirable to enclose the crystal in some way to protect it from dust and damp. One method by which this may be accomplished is illustrated in Fig. 4, which shows a good pattern of enclosed crystal detector, of the type where the crystal is embedded in a cup set horizontally at one end of the base and the cat's-whisker in a horizontal position at the opposite end. This type employs a ball-and-socket joint, which permits of easy adjustment, and the whole is protected by means of a tubular glass case, held in position by means of caps at either end.

Fig. 5 shows a variation of the same principle, with the detector set diagonally on to the ebonite base. In this case the whole can be detached by unscrewing the knurled nut at the back, the crystal removed, and a different one substituted.

A neat vertical detector is illustrated in Fig. 6. In this case the crystal cup is rigidly attached to the ebonite base, and three brass columns support a disk of brass, while upon this is a second disk. Between them is arranged a ball-and-socket joint, the tension of which is controllable by means of three set-screws. The cat's-whisker, being arranged in a vertical position, has a natural tendency to remain in adjustment, and, consequently, such a detector is fairly stable in operation.

Protecting Detectors from Dust

A development of the same idea is illustrated in Fig. 7, which shows a somewhat similar detector enclosed by means of a small celluloid tube, which efficiently protects the crystal from dust and dirt. One objection to the vertical pattern is the difficulty of adequately searching the crystal. This is improved in the pattern illustrated in Fig. 8, made by the Economic Electric Co., by mounting the crystal in a cup rigidly attached to the ebonite base. The transparent protective case is comparatively large in diameter, closed at each end by means of metal caps. At the upper part is fitted a ball-and-socket joint held in engagement with the cap on the top of the case by means of a narrow arm, one edge of which is secured by means of a terminal nut to an upright pillar of brass. This arm can be moved slightly in a sideways direction, and this, in conjunction with the ball-and-socket joint, enables the cat's-whisker to be readily adjusted to any part of the surface of the crystal. To compensate for the rocking motion, the transparent case is bedded upon a soft rubber washer at each end, while, to improve the insulation, the terminals and upright pieces are similarly insulated. This type of detector is efficient and stable, and permits of accurate adjustment.

A fully-enclosed type of crystal detector is illustrated in Fig. 9. In this case the cat's-whisker is a fixture, and the crystal itself is moved. The base is composed of moulded ebonite, circular in form, and provided with a flange drilled for holding-down screws, and also fitted with two terminals for connexions. The crystal, which is mounted in a crystal cup, is embedded in it with plastic metal, and is attached to a small rod terminating in an insulating knob.

The whole is enclosed by a circular-shaped glass case not unlike a watch glass. The only adjustment possible is that of rotating the knob, but in practice the device answers admirably.

Combinations of Different Crystals

The experimenter who desires to try the effect of different crystals might use the type of detector illustrated in Figs. 10 and 11. The detector consists of two upright posts provided at their upper ends with screwed rods terminating in ebonite knobs. One of these rods has a removable head, and in Fig. 10 is shown with the cat's-whisker in place, and in Fig. 11 is shown the crystal cup for a double crystal combination.

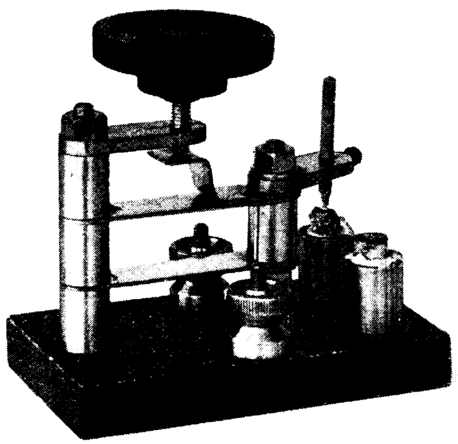
The second cup is held in an ingenious manner by means of a small spring, which keeps the cup pressed against the boss formed on the end of the screwed rod. By its adjustment the crystal held in the cup can be moved into various positions to secure the most sensitive spot..

The amateur can construct a simple Perikon detector in the manner illustrated in Fig. 13. The first requirement is an ebonite base about 3 in. long, $1\frac{1}{2}$ in. wide, and $\frac{1}{4}$ in. in thickness. At one end of this an angle piece of brass strip about $\frac{1}{2}$ in. wide and $\frac{1}{16}$ in. thick is secured by means of screws and terminal nuts. The upper end of this arm is attached to the crystal cup. A second but shorter angle piece is provided for the opposite side, and drilled and tapped to receive the screws and the ebonite knob.

The second crystal cup is mounted in a similar manner to the first, but on a strip of ordinary brass that is clamped in such a way that the set-screw is pressed over as shown in the photograph.

Fig. 14 shows a standard W. & M. type of Perikon crystal detector. In this case the two cups are set so that the faces are vertical and are controlled by means of the ebonite knob screwing on to an ebonite rod. The bearing point is attached to a U-shaped brass strip. The lower end of this is freely fixed on the upright centre piece, and held in position by means of a spring washer and a second terminal nut. Both crystals may be rotated in their holders, so that they can be adjusted to find the most sensitive parts of the crystal.

To provide for finer adjustment a micrometer arrangement can be incorporated into the design somewhat in the manner illustrated in Fig. 12. In this case the strong upright post on the right-hand side of the stout ebonite post carries two arms, the upper having an adjustment screw, the lower a longer and finer

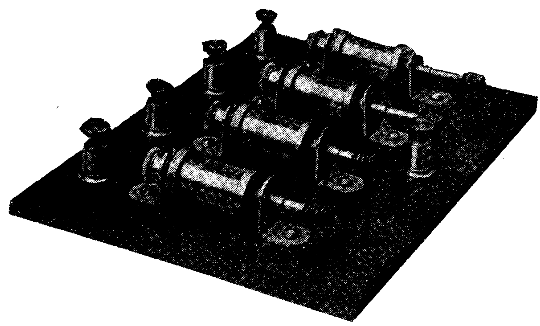


TWO CRYSTALS AND A CAT'S-WHISKER

Fig. 15. In this variety of detector two crystals are used, so that if one fails the second is at once brought into the circuit. The central ebonite knob allows of a micrometer adjustment of the cat's-whisker in a similar manner to that shown in Fig. 12

arm, to the end of which is attached, by means of a short arm, the upper crystal cup. It can be rotated in the arm, and raised or lowered therein, and held in any position by means of a small set-screw.

To the lower cup is attached an ebonite base, and fine adjustment is provided by means of a large ebonite knob. A

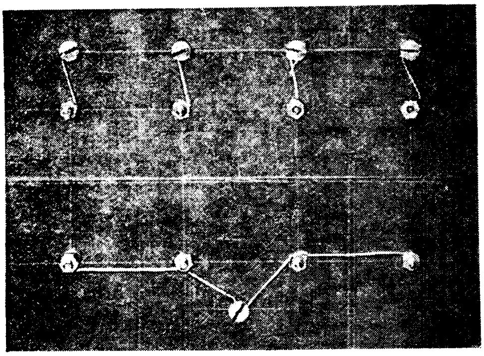


FOUR-CRYSTAL PANEL

Fig. 16. By means of such a crystal panel comparisons may very quickly be made between the sensitiveness of different varieties of crystals

somewhat similar arrangement, but adapted for selective use of two different crystals, is shown in Fig. 15. In this case two separate crystal cups are mounted as shown, and the cat's-whisker is supported by a movable arm in such a way that it can be swung over from side to side and brought into engagement with either of the crystals. This is sometimes of advantage, and is especially helpful for the experimenter in search of the best results in a crystal set, as it enables comparisons to be made between two different crystals by simply moving the arm over from one position to another.

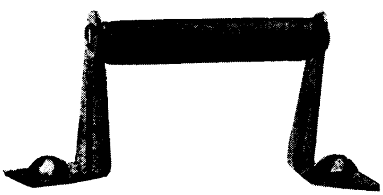
A better plan is to provide a number of separate detectors and mount them all on matted ebonite bases. This arrangement is adapted to four crystals, as shown in Fig. 16, while the wiring inside the panel is shown in Fig. 17. From these it will be seen that one side of the detectors is wired to one terminal and from the other side separate wires taken to four separate terminals. Consequently, by wiring the single terminal to the telephones, and the wire from the aerial tuning device to one of the four terminals, that particular crystal will be brought into the circuit and the others will be cut out. By this arrangement it is possible to tune all four crystals separately, and then compare the results obtained with them.



WIRING OF FOUR-CRYSTAL PANEL

Fig. 17. Compare this photograph with that of the panel in Fig. 16. This is the back of the panel of the four-crystal detector. The backs of the terminals and their wiring are shown

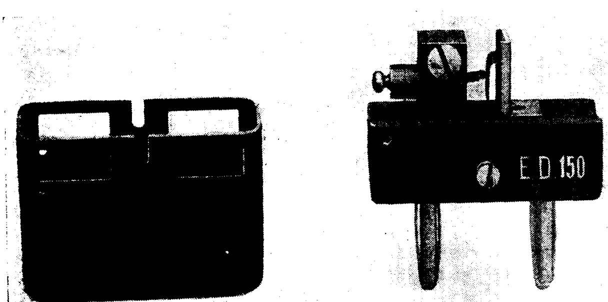
Another advantage is that if it is particularly desired to listen to a long programme and all four crystals are known to be in perfect adjustment, should signal strength be lost with one crystal, it is but the work of a moment to transfer to another.



CAT'S-EYE CRYSTAL

Fig. 18. Cat's-eye or "everset" crystal detectors are always in adjustment. Connexion is made by the two brass end pieces and the brass mounts

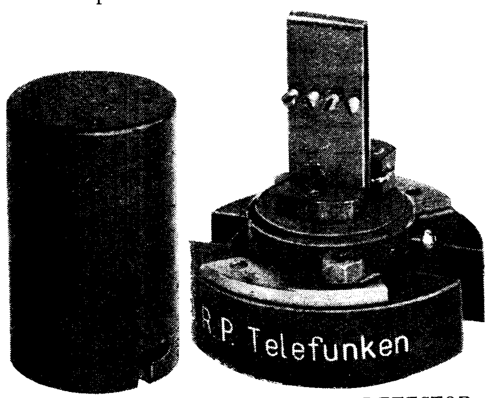
The construction is quite simple, and requires only the drilling and tapping of the requisite number of holes in the ebonite panel and the wiring connexions to be made. The whole can be mounted neatly on to the receiving set in any desired manner.



PLUG-IN CARBORUNDUM DETECTOR

Fig. 20. Contact is made in this detector by means of the spring steel strip. The detector is mounted in a metallic case to protect it from dust and damp

There are many types of enclosed detector of the everset variety, of which an example is illustrated in Fig. 18 and known as the cat's-eye crystal detector. It simply comprises two upright posts or clips, between which is mounted an insulated holder with metallic leads to the interior by brass caps on either end of the insulator.



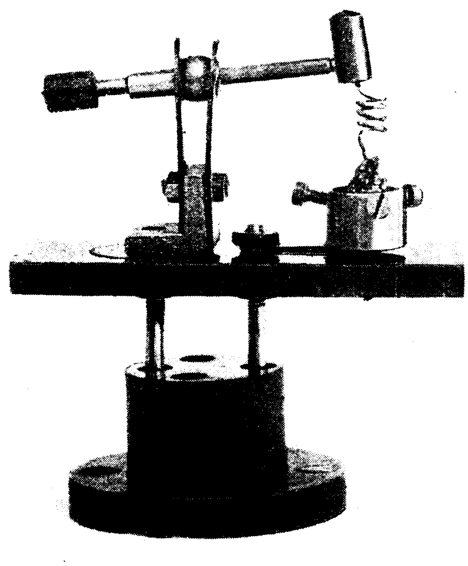
TELEFUNKEN CARBORUNDUM DETECTOR

Fig. 19. Four adjustment screws are provided in the Telefunken type of carborundum detector, which is one of the most stable forms made, resisting very considerable shocks before it is put out of action

The space between the wires is usually occupied by the two elements of the Perikon detector. This class of detector is adjusted by the manufacturers, and is claimed to give uniform and stable results.

Other varieties are made in which the case is mounted to rotate between two supports and contains the crystal, which is connected to one of the terminals. The space in the body of the movable holder may be filled with gold dust or other metallic dust, and arranged so that the wire or other conductor is in engagement with it. Consequently, if the casing is rotated the metallic dust is moved about and finds a fresh point of contact on the crystal.

Carborundum crystal detectors are generally of somewhat more robust construction, and one type is illustrated in Fig. 19, which shows the Telefunken crystal detector. A thin strip of carborundum is rigidly mounted in a stout brass holder, while contact is made by means of an upright U-shaped piece of steel Contact to this is effected with four small adjustment.



PLUG-IN HOME-MADE DETECTOR

Fig. 21. Beneath the base of an ordinary ball-and-socket type of home-made crystal detector valve-leg plugs have been fitted. These are connected to the two sides of the detector. This detector may be used in place of the rectifying valve

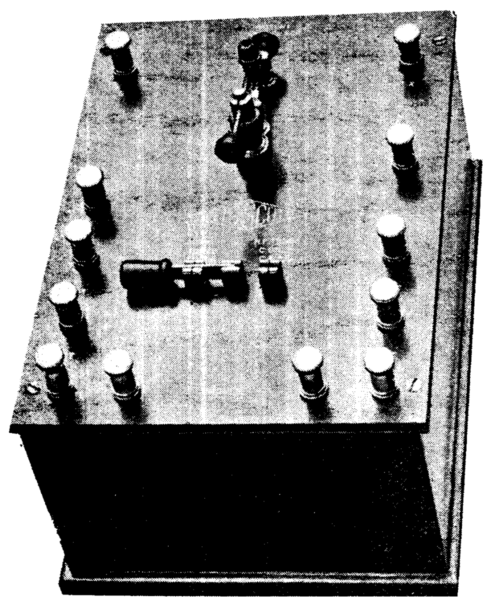
screws which press on the rear or loop of the U. The latter is slotted to form a comb with four prongs. This enables each prong to be separately adjusted by its own screw, and when the requisite degree of tuning has been found, the result is a very stable and sensitive crystal. A pressed metal case is provided to protect it from dust and dirt, and the circular base is slotted to permit of its adjustment or removal from the receiving set. It naturally requires the use of a battery and potentiometer for its control.

Another type of carborundum detector is illustrated in Fig. 20, and shows a pattern adopted to plug into the holder somewhat in the manner of the ordinary valve. In this case a small slab of carborundum is mounted on a circular brass base, which can be attached to the upright of brass and secured there by means of a set-screw. Contact is made by means of a thin, springy strip of steel mounted in an upright brass holder. Connexions are made from the two uprights and the prongs, and the whole is mounted on an ebonite holder and provided with a detachable metallic case to protect it from dust and dirt. It is sometimes desirable to have a crystal detector for emergency fitting to a valve set, and an easily constructed pattern is illustrated in Fig. 21. This comprises a base of ebonite about $2\frac{1}{2}$ in. long and 1 in. wide, to which is attached two valve legs so spaced that they will plug into the anode and grid terminal sockets of the standard valve holder. Connexions are made from these valve legs to the crystal cup and cat's-whisker holder respectively. This may be of any desired pattern, or that shown in the illustration.

Such a detector can be plugged into the holder in place of the ordinary detecting valve, and will give very satisfactory results.—*E. W. Hobbs.*

CRYSTAL DETECTOR UNIT. The unit shown in Fig. 1 forms part of a series described in this Encyclopedia which includes the tuner, condenser and amplifying units. Where a high-frequency amplifying unit is used the crystal detector is attached to the output side. The low-frequency amplifier is attached to the output side of the crystal detector unit.

Crystal rectification has distinct advantages where purity of speech or music are desired. It is commonly thought that a crystal rectifier is only suitable for distances up to 30 miles or thereabouts, but with one or two stages of radio-frequency



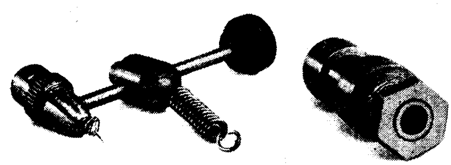
CRYSTAL RECEIVING UNIT

Fig. 1. This unit forms one of the set of unit parts which are all separately described in this Encyclopedia, enabling the experimenter to build up a set step by step

Courtesy Peto-Scott, Ltd.

amplification its range can be extended to 500 miles or more, at the same time keeping the clarity of tone not always possible with a valve. The tuning circuits are in all cases connected on the input side of the crystal detector unit.

Fig. 1 shows the instrument assembled from a complete set of parts supplied by

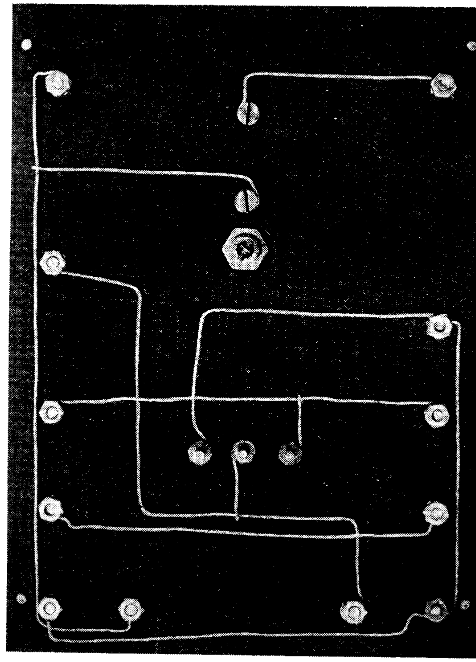


CAT'S-WHISKER COMPONENT DISSEMBLED

Fig. 2. Components of the spring-constructed ball-and-socket type of cat's-whisker used in the set. Note how the spring is fitted to the bottom of the ball-shaped pivot

Messrs. Peto-Scott Co. A spring-loaded arm keeps the crystal firmly attached to a rigid vertical pillar having a cup-like depression at its top into which the crystal is placed. Considerable range of movement is effected on the cat's-whisker arm by a ball-and-socket movement. The socket is arranged at the top of a hollow pillar screwed to the base. The pillar contains a spring connected at its top end to a ball-piece holding the cat's-whisker arm. A pin secures the spring to the pillar at its lower end. These components are shown in Fig. 2.

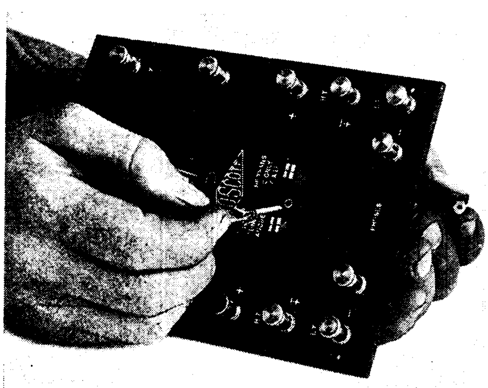
A single pole throw-over switch is provided to meet various circuit requirements, as follows:

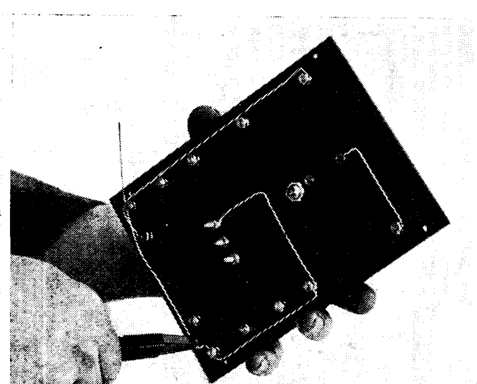


WIRING OF THE PANEL

Fig. 5. Wiring should be carried out by consulting this photograph and the theoretical wiring diagram in Fig. 6

(1) With switch to right (A in Fig. 6)—
- (*a*) Crystal detector only (no high-frequency amplification being used);
- (*b*) Crystal detector followed by low-frequency unit;
- (*c*) Crystal detector preceded by high-frequency transformer coupled unit.





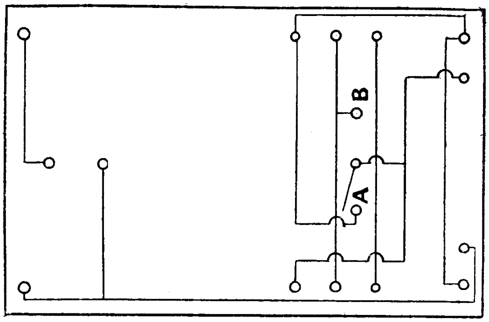
TERMINALS AND SWITCH ON THE PANEL

Fig. 3 (left). Terminals have been fitted to the panel, and the operator has the single pole knife switch in his hand and is about to insert the centre post into the hole for permanent fixing. Fig. 4 (right). Behind the panel are seen the terminal legs and the nut holding the post of the knife switch. The operator is wiring up the terminals. The size of his hand gives an idea of the size of the panel

(2) With switch to left (B in Fig. 6)—
  (*a*) Crystal detector with tuned anode high-frequency coupling;
  (*b*) Crystal detector followed by low-frequency unit, but preceded by high-frequency units.

In assembling the unit the terminals and switch parts are placed in position (Fig. 3) and the nuts tightened up securely. The detector parts are fixed in position by two screws and a nut from underneath the panel. Wiring is carried out with stout-gauge tinned wire, held under the terminals by an additional nut. The experimenter is advised to solder all the connexions when the circuit has been tested for correctness.

It is advisable when soldering to use a paste such as fluxite, as spirits of salts will in time corrode the joints and cause bad contacts. A pair of flat-nosed pliers will be found useful in wiring up. Fig. 4 illustrates their use in bending a wire at right angles.



WIRING OF CRYSTAL DETECTOR UNIT

Fig. 6. Tinned wire of fairly thick gauge is recommended for wiring the panel, the wire being held on the terminal legs by additional nuts. Compare this diagram with Fig. 5

All wires must be kept at least $1\frac{1}{2}$ in. apart, and in Fig. 5 the wiring of the back of the panel is shown completed. Where possible wires should run across at right angles and not parallel to each other.

CRYSTAL RECEIVERS: (1) STANDARD SETS & THEIR USE

How to Obtain the Best Results with the Simplest of All Wireless Receivers

This is the first of a progressive series of descriptive and constructional articles in which the simplest sets are described and then the various forms of tuning, such as variometers and basket coils, up to the addition of low-frequency and high-frequency, enabling the listener to increase the range of his set so that he can listen to all stations. The articles should be read in conjunction with others such as those on Aerial; Amplifier; Coil; Condenser, etc. See also under the names of the various crystals

A crystal receiver is a complete apparatus adapted for reception of broadcast telephony, using a crystal rectifier. It can also be used for reception of spark and other signals, but so far as the ordinary amateur is concerned it is almost entirely restricted to broadcast reception. A crystal receiving set consists essentially of some means of tuning the aerial circuit, a crystal detector, *i.e.* a small piece of crystal which has the power of rectifying the incoming signals transmitted from the broadcast station and virtually converting the high tension current that is intercepted by the aerial into low tension current, which, in conjunction with the telephone, allows the listener to hear speech and music that is sent out from the broadcast station.

The novice in wireless telephony cannot do better than commence with the construction of a crystal set, presuming there is a broadcasting station within some 15 or 20 miles, or preferably nearer. There is nothing difficult or elaborate with a crystal set, but the results obtained from it are noticeable for their purity of reproduction of the tone and inflections of the speaker's voice, and possess the merits that they do not require any batteries or other source of energy than that picked up by the aerial.

To obtain the best results from any crystal set, a good outdoor aerial is generally essential. Those residing within two or three miles of a broadcasting station can get good results from an indoor aerial, but the signal strength will be diminished as compared with the results obtained with a good outdoor aerial and efficient earth.

The apparatus used for this early work need not be discarded. It can form the basis of a complete receiving set, as by adding high-frequency amplification the range of the set is increased, and by adding low-frequency amplification the volume of sound is greatly magnified.

Such sets do not of necessity require any batteries or any other elaborate apparatus. They have the merits of being cheap, easy to handle, cannot possibly cause annoyance and interference to other listeners, and, for the beginner in wireless, are undoubtedly the best sets to commence with, provided they are to be used at a distance of, say, not more than 20 miles from a broadcast station. If the nearest station is more than this distance, crystal receiving sets may still be satisfactorily used, but it will be necessary to use a valve and certain other apparatus to amplify the signals received.

There are many ways of fitting such amplifiers, and these are dealt with at length both in the following pages and under the heading Amplifiers (*q.v.*) Various types of crystal receiving sets are also dealt with at length, as well as their construction, but, practically speaking, any crystal set comprises an inductance coil, a crystal detector, a pair of telephones or headphones, and a condenser, fixed or variable. The latter is not absolutely essential.

How the Required Station is Tuned in

To enable any particular broadcast station to be heard, it is necessary to tune the inductance, and this may be effected either by varying the virtual length of the coils by means of a slider, tapped coil, or various other ways, or by the use of a condenser, which is often spoken of as capacity, shunted across the earth and aerial wires. By shunted across is meant that one side of the condenser is connected to the aerial wire and the other side to the earth wire. The condenser is variable as regards its capacity, and by turning a knob or dial moving plates are turned into or out of engagement with other, fixed, plates, with the result that when the moving plates are wholly in engagement with the fixed plates, the condenser gives its greatest capacity, and when the plates are separated, the minimum capacity. The plates do not touch in any way, but are entirely separated by air, mica, or some other dielectric.

Tuning may be effected by varying the number of turns in the inductance coil and the amount of capacity in the condenser, and it is possible to tune the set to the incoming wave-length and so enable it to detect the signals transmitted by a particular station.

By varying the inductance and/or the capacity the wave-length will be readily found; consequently it is possible to listen to more than one station. The function of the crystal, in non-technical language, is so to affect the high-frequency waves, which are not discernible by the human ear, virtually picking out the audible or low-frequency waves or rectifying them. This current passes on to the telephones with such character that they are able to respond to it by setting up vibrations in the diaphragm, which, in turn, set up sound waves appreciable to the human ear, in the form of music, speech, or anything else that is being transmitted by the broadcast station on the wave-length to which the set is tuned.

Details of many forms of crystal detector are separately dealt with under that heading (*q.v.*) but, briefly, the crystal is held in a little metal cup or other device connected to the aerial wire, and a fine wire, known as a cat's-whisker, is supported on an adjustable arm connecting with the wires communicating to the telephone. Upon the adjustment of the contact between the cat's-whisker and the crystal depends to a very large extent the success of the set, presupposing it to be used within reasonable range of the broadcast station, and to be properly tuned to the desired wave-length.

Finding Sensitive Spots on the Crystal

The point of contact between the cat's-whisker and the crystal should be as small as possible. Consequently, the cat's-whisker should be sharpened to a very keen, fine point. To locate the most sensitive part of the crystal this point has to be moved about all over the surface until the loudest signals are heard on the telephones, this process being known as searching the crystal, and the pressure exerted by the cat's-whisker on the crystal should not be greater than that necessary to secure the desired effect.

If it is too slight, the least vibration will throw it out of engagement, and the signals will be lost ; but if a too heavy pressure is exerted the signal strength will suffer. Experience and practice alone can determine the best position. The crystal is not uniformly sensitive over the whole of the surface, and, consequently, it is necessary to find the best position by the method already briefly described. The crystal should be protected from dust for good results.

Some particular crystal receivers are made with two different sorts of crystal. In this case the second crystal takes the place of, and is used in the same manner as, the cat's-whisker. After some experience has been gained by the use of a crystal set, the amateur will do well to tune for the loudest signals by first tuning the set to the correct wave-length, adjusting the crystal so that clear signals can be heard, and then slightly detuning—that is, losing signal strength by readjustment of the inductance or capacity tuning arrangements until the signals are barely audible in the telephones, and then proceeding to search for the most sensitive part of the crystal. This having been found, the tuning may be readjusted to its fullest strength, and by this method it is possible to get extremely good results.

Working a Loud Speaker from a Crystal

Extraordinary claims are sometimes made for crystal sets. For example, it is often stated that it is possible to use a loud speaker with a simple crystal set anywhere within a radius, say, of five miles from a broadcast station. This can undoubtedly be accomplished, and the set illustrated and described on pages 593–598 has, in fact, accomplished this result. It should be appreciated, however, that very efficient aerial and earth connexions are used, that the set itself is extremely efficient, all connexions very well made and soldered, and extremely sensitive telephones are used. Naturally, the crystal itself and all the adjustments must be of the finest to secure such results.

Generally, the amateur will find it best to use amplification if it is intended to use a loud speaker. In one respect crystal detectors are preferable to valves, and that is, they give far more perfect rectification and reproduction. The sounds are more pure, enunciation is much better, and there is a marked absence of hissing noises often to be heard with some valve sets. Like most other things, there are good and bad crystal sets, and the same may be said of valve receiving sets, but recent experiments show that a good crystal as a detector will give entirely satisfactory results and perfect reproduction for all concerts broadcasted in Great Britain.

Types of Crystal Sets. One of the simplest crystal sets is the single-slider set illustrated in Fig. 1. It comprises a wooden baseboard to which is attached a cardboard tube upon which has been wound a coil of insulated wire. Mounted on top of the two uprights or end pieces, shown in Fig. 1, is a square brass bar, whereon slides an ebonite knob, the lower part of which has a brass spring plunger attached to it. One end of this plunger bears against the inside of the brass bar upon an exposed part of the winding. To the front part of the baseboard is attached a crystal detector. The one illustrated is of the totally enclosed type, and is known as the Penberthy.

The connexions, which are made with insulated copper wire about No. 16 gauge, go from one end of the winding on the inductance coil to one side of the detector, and by another wire from the other side of the detector to the telephone terminal. The third wire connects the second telephone terminal to the terminal attached to the slider bar. The aerial lead-in is connected to the terminal on the end piece to which the end of the inductance winding and the wire to the detector is connected, the right-hand end in the photograph. The opposite end of the inductance coil is not connected to anything. The terminal of the slider bar is connected to earth.

How the Simplest Crystal Set is Used

To use the set, a pair of high-resistance telephones is connected to the telephone terminals, and the aerial and earth connexions to their respective terminals. The slider is moved along the bar to vary the tuning of the coil, which expression simply means that when the slider is put in a certain position, the coil will have the correct inductance to enable the set to receive signals on the wave-length of the broadcasting station it is desired to hear. The only other adjustment is to move the knob of the end of the detector to vary the position of the cat's-whisker until the loudest signals are heard.

Another type of crystal receiver, also with a simple inductance coil and sliding contact for tuning purposes, is illustrated in Fig. 2. In this case the connexions are carried beneath the base, which is made hollow for that purpose, and, in addition, a condenser is shunted across the telephone terminals. Opinion varies as to the merits or advantage of this condenser, but generally it is an advantage when the set is to be used subsequently with an amplifying device of some kind.

Instead of having the inductance coil exposed, it can be enclosed in a simple cabinet made from hardwood and the top constructed of ebonite, and then known as a panel. An example of this class, made by the Economic Electric Co. Ltd., is illustrated in Fig. 3, and shows a knob which, when rotated, controls the tuning. The detector is of the cat's-whisker type. The four terminals are respectively for the aerial and earth connexions and for the telephones.

With simple sets of this kind, broadcast concerts can generally be received under favourable conditions for distances up to about 15 to 20 miles from the broadcasting station, provided the aerial and earth are good and the set is well adjusted. The tuning, however, is necessarily very broad. By this is meant it is difficult, if not impossible, to eliminate interference from undesired stations, and a frequent experience is to hear two or three stations simultaneously, one much more loud than the other. The interference is not necessarily from another broadcast station, but may be from a telegraphic or spark station, or from amateur transmission. To overcome this difficulty a more selective tuning arrangement is necessary.

Sets with Tapped Tuning Inductances

A development of the enclosed inductance type of receiver is illustrated in Fig. 4, and is known as the Oracle. This comprises a cabinet with a hinged lid and an enclosed type of detector mounted on an ebonite panel between two tuning inductances. These are of the tapped variety—that is to say, instead of having a sliding contact, wires or leads are taken from the inductance at various distances along its length and these wires are connected in serial order to contact studs attached to the ebonite panel.

Two sets of studs are arranged in this way, one having tappings at relatively long distances apart and used for coarse tuning. That on the left is for fine tuning, and the tappings in this case are one from each turn in the inductance coil at one end. By moving this fine tuning knob very accurate tuning is possible, because only one turn of wire is brought into or taken out of the inductance circuit at a time. This gives very accurate tuning and has the great merit that the contact arm makes a more reliable connexion to the studs than is practicable with the sliding type of contact. Wear is eliminated, as there are no moving contacts to rub on the windings, as is the case with the slider bar system.

The Sterling No. 1 crystal set, illustrated in Fig. 5, is a somewhat similar arrangement in general principles, but has a very wide range, as means are provided for plugging in a standard inductance coil of the honeycomb or slab type, such as that seen in the illustration immediately behind the crystal detector. A coil of this character is used when the set is to be tuned for reception of signals of high wave-length, as, for example, the time signals which are radiated from the Eiffel Tower in Paris every day on 2,600 metres.

This has the advantage of avoiding the necessity of having a very large inductance coil of sufficient size to tune to such a wave-length, as for ordinary broadcast reception such a large coil would be unnecessary. Consequently, greater efficiency is obtained by the use of a loading coil employed in this manner. The same principle is also adopted in many other sets when it is desired to receive on special wave lengths.

The Cosmos crystal set (Fig. 6) supplied by the Metropolitan Vickers Electric Co., Ltd., is another example of a crystal receiver of the cabinet type. A compartment is in this case arranged on one side of the cabinet wherein to store the headphones. The tuning is effected by means of a variometer, the dial and control lever for which are clearly visible on the panel. The detector is of the cat's-whisker type with a special arrangement for accurate tuning.

Advantages of Variometer Tuning

Loading coils may be used if necessary, and in the lid of the set are given the necessary instructions for connexion to earth and aerial, and for handling the set. The variometer provides a convenient and practical means of accurately tuning the crystal set, and has the advantage that there are no sliding contacts, nor are there any contact arms, studs, or anything of that nature, the whole of the tuning being effected by moving one part of the variometer, the rotor, over the other part, the stator. The principle and action of the variometer are more fully described under that heading.

Another example of a variometer-tuned crystal set, known as the Gecophone, is made by the General Electric Co., Ltd., and is illustrated in Fig. 7. Provision is made here for the use of a loading coil for reception of Paris time signals, and one very neat fitting is the plug-in arrangement for connecting it to telephones, earth

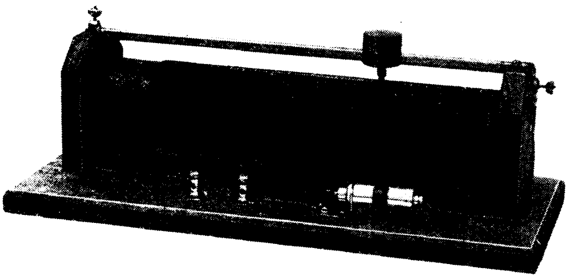


Fig. 1. One of the simplest possible receiving sets. It consists of an inductance coil, crystal detector, and single-slider tuner, mounted on a wooden baseboard

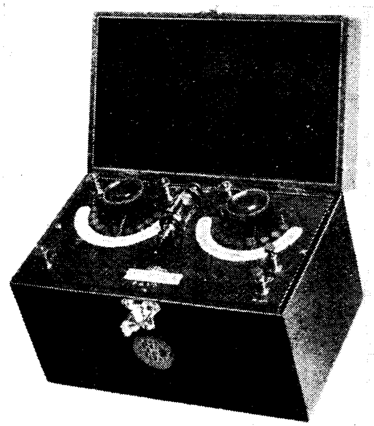


Fig. 4. Two tapped inductances are included in the "Oracle" set
Courtesy Bassett Lowke, Ltd.

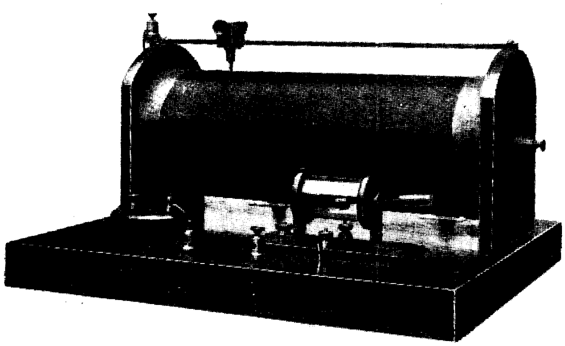


Fig. 2. Across the telephones a fixed condenser is shunted, otherwise this set is similar in principle to that in Fig. 1, though its construction is better
Courtesy Economic Electric Co.

Fig. 5. Plug-in loading coils may be used in this variety of receiver
Courtesy Sterling Telephone and Electric Co.

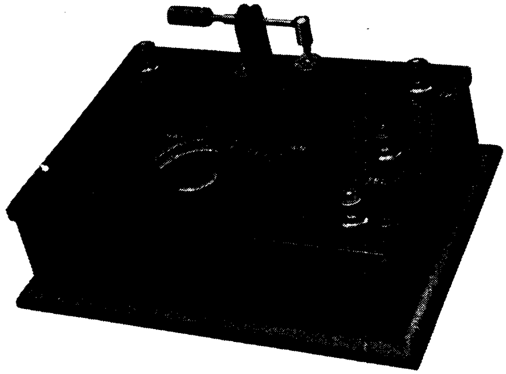
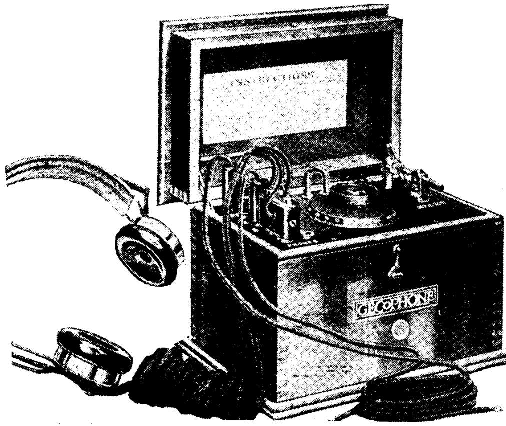


Fig. 3. Receiver enclosed in a cabinet with tapped inductance and coarse and fine tuning switches
Courtesy Economic Electric Co.

Fig. 6. Cosmos crystal sets have a compartment for telephones when not in use
Courtesy Metropolitan Vickers Electrical Co., Ltd.

STANDARD TYPES OF CRYSTAL RECEIVING SETS

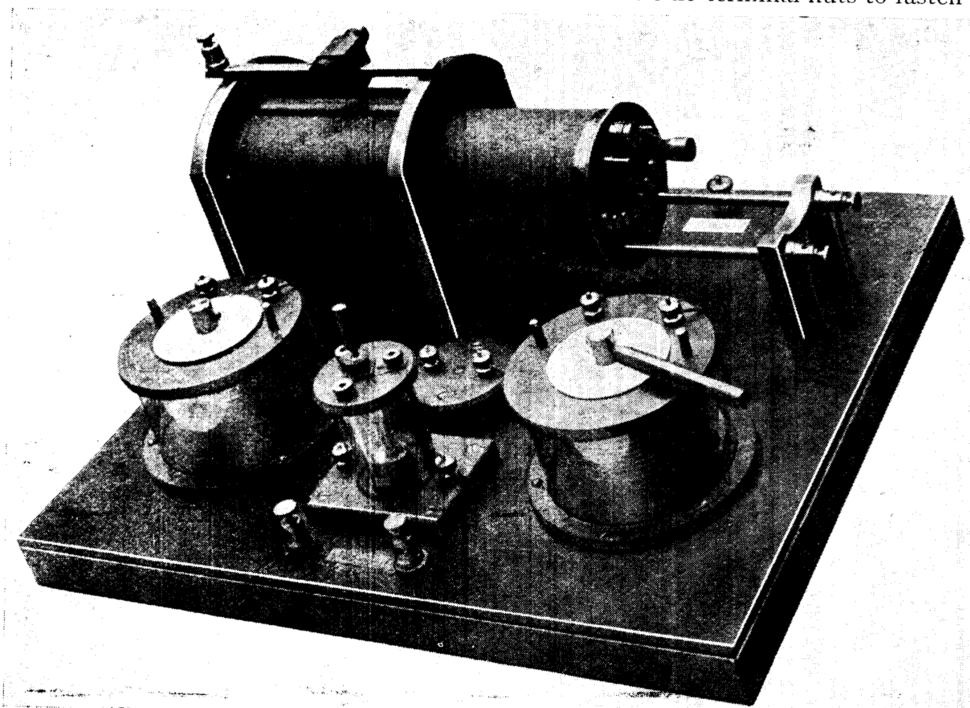


GECOPHONE CRYSTAL RECEIVING SETS

Fig. 7 (left). With this set a variometer is used for tuning, and a loading coil may be added for reception of certain wave-lengths. Aerial, earth, and telephone connexions are plugged in. Fig. 8 (right). This set has a tapped aerial tuning inductance and plug-in connexions for aerial, earth and telephones

Courtesy General Electric Co.

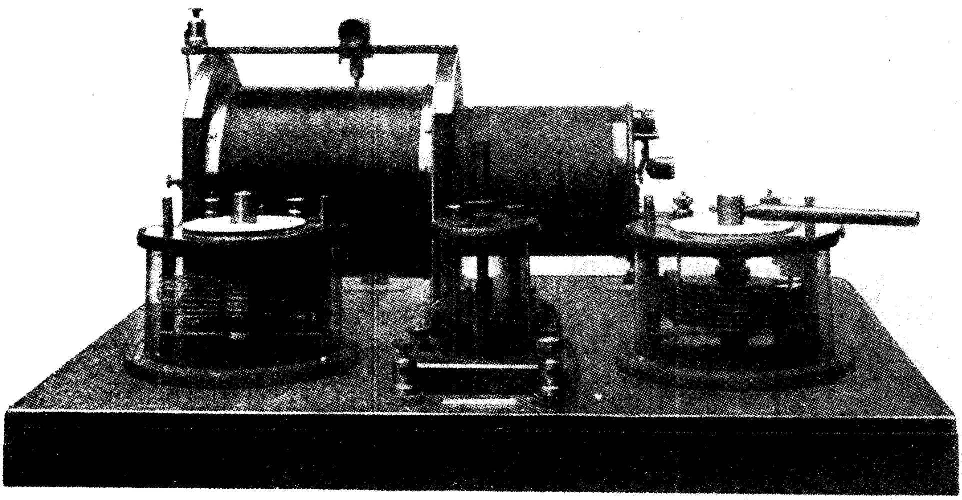
and aerial connexions. Wires for this purpose can be obtained ready prepared with well-braided insulation, and provided at one end with an eye for attachment to the terminal of the lead-in tube and to the earth connexion. The other ends have ebonite blocks with metal plugs which simply have to be pushed into sockets on the ebonite panel. The telephones are treated in the same way. The result is a connexion which can be made in a moment, and there are no terminal nuts to fasten or



LOOSE COUPLER WIDE RANGE CRYSTAL RECEIVING SET

Fig. 9. Reception of wave-lengths between 400 and 2,400 can be obtained by this arrangement. A set of this kind is suitable for receiving ship and spark stations, Paris time signals in London, and signals of a like nature

Courtesy Economic Electric Co.



SIDE VIEW OF LOOSE COUPLER CRYSTAL RECEIVING SET

Fig. 10. Another view is given here of the crystal receiver employing a loose coupler. In this photograph the fixed or blocking condenser, variable condensers, and enclosed type of crystal are clearly shown

Courtesy Economic Electric Co.

unfasten. All necessary connexions are automatically made within the case itself.

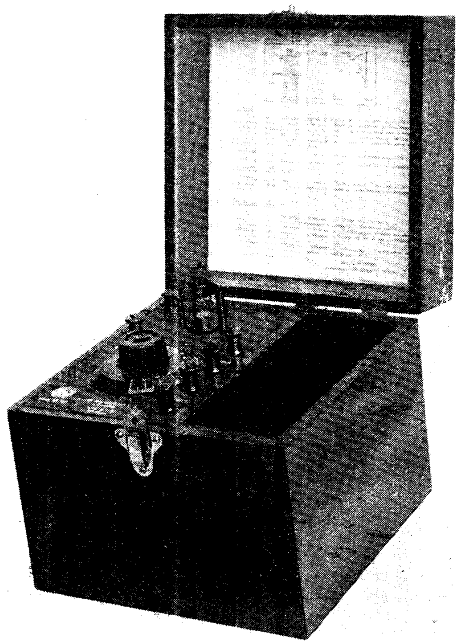
In the Gecophone set shown in Fig. 8 the condenser is used in addition to the other features, which include a tapped aerial tuning inductance. The set has the same type of plug-in connexion for the aerial and telephones.

Figs. 9 and 10 show a loose-coupler crystal receiver. Loose-coupled receivers are usually very selective, and generally more efficient than those having a single circuit. The wave-length range of the set illustrated is from 400 to 2,400 metres, and is designed, therefore, to receive ship and spark Morse stations rather than broadcast telephony.

The primary or aerial coil is of the slider type, with a ·00035 mfd. condenser connected in parallel. The secondary or closed circuit inductance is tapped for coarse adjustment, and is also fitted with a variable condenser. An enclosed type detector fitted with a Rectarite crystal, and a blocking condenser for the telephones complete the instrument.

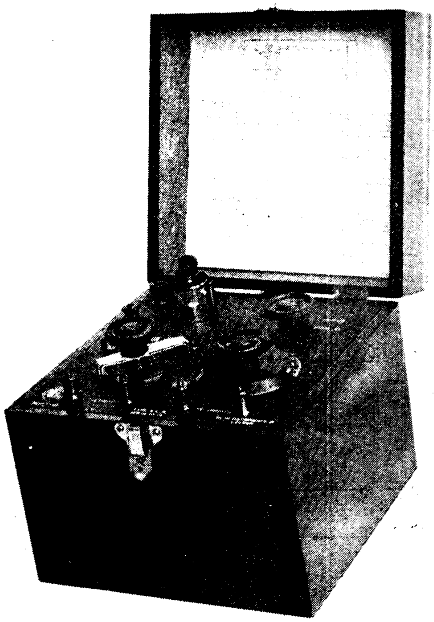
The crystal set shown in Fig. 11 is of the simplest possible construction. It has a variometer covering the whole broadcast wave-length band for tuning and the detector is of the standard enclosed cat's-whisker type.

A rather more elaborate set of the same make is shown in Fig. 12. An identical detector is fitted, but the tuning is



RADIO INSTRUMENTS, LTD., CRYSTAL SET

Fig. 11. Variometer and cat's-whisker detector are employed in the set above, which is tunable to all the wave-lengths used by the British Broadcasting Company



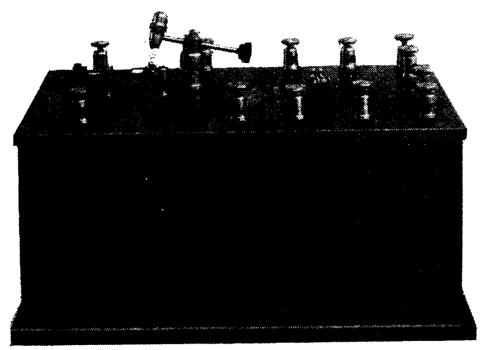
TAPPED INDUCTANCE TUNING

Fig. 12. Tuning in this crystal receiving set is accomplished by means of a tapped inductance and variable condenser, which, by a switch, may be placed directly across the aerial tuning inductance or in series with the aerial

Courtesy Radio Instruments, Ltd.

accomplished by a tapped inductance and variable condenser. A switch is fitted, enabling the latter to be placed either directly across the A.T.I or in series with the aerial. A set of this description enables a greater wave-length range of signals to be tuned in.

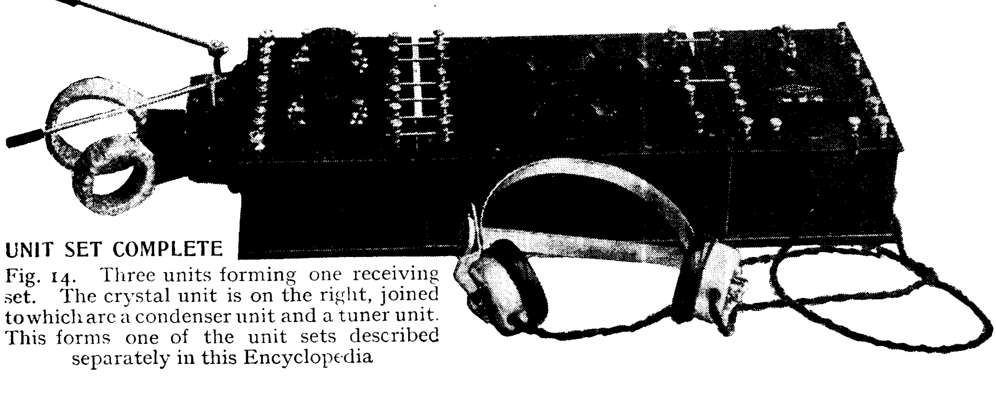
The foregoing may be considered as simple self-contained crystal receiving sets, but there are others which form an element or unit, and are used in conjunction with other units, which, when properly connected together, form a complete comprehensive whole. Such an example is that shown in Fig. 13, made by Peto-Scott Co., Ltd. It comprises a polished wood cabinet with an ebonite panel, and mounted upon it are the detector, change-over switch, and a series of terminals, the connexions being made to them in accordance with the markings on the panel. The connexions are varied according to the position which the crystal set occupies in any particular circuit. For example, in Fig. 14 the detector is shown on the right connected to a condenser unit (*q.v.*) and the tuner unit. The whole, with the telephones seen in the front, comprises a complete crystal receiving set.



UNIT CRYSTAL RECEIVER

Fig. 13. Receivers on this system include one or more units added to a detector unit as the above. This is a crystal detector unit to which may be added high- or low-frequency units to extend the range of the crystal to take all the broadcasting stations in England and Scotland

Arranged in this way it becomes a particularly good two-circuit crystal set. Its wave-length range is practically unlimited, as coils of any desired value may be plugged into the holder on the left of the tuning unit. Moreover, the change-over



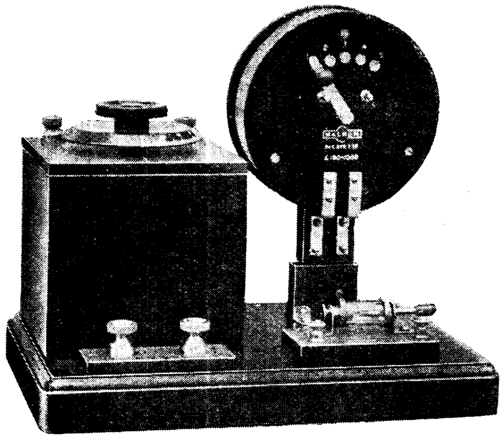
UNIT SET COMPLETE

Fig. 14. Three units forming one receiving set. The crystal unit is on the right, joined to which are a condenser unit and a tuner unit. This forms one of the unit sets described separately in this Encyclopedia

switches on it provide for series or parallel connexion between the aerial tuning inductance and the condenser unit, thus giving a maximum range. In addition to the controls already mentioned, tuning is effected with the aid of two of the condensers in the condenser unit, and also by varying the degree of coupling between the two plug-in coils on the tuner unit shown on the left of the photograph.

If it is desired to increase the strength of the signals, an audio-frequency amplifying unit can be attached to the right of the crystal detector unit, and when energized with batteries of proper value, signals are brought in with many times the volume that is possible with the simple crystal, and generally enough power is provided to actuate a loud speaker.

When it is desired to hear concerts broadcasted from some considerable distance which is normally beyond the power of the set, another unit, known as the high-frequency or radio-frequency amplifier, is added between the condenser unit and the crystal unit. This has the effect of increasing the strength of the signals before they are rectified on the crystal detector, and enables concerts to be clearly heard from considerable distances. The change-over switch of the crystal detector panel is provided to complete the connexions either to the high-frequency amplifier, or with the low-frequency amplifier as desired. The crystal set shown in Fig. 15 is made from a number of individual components mounted upon a baseboard. The square cabinet on the left contains a variable condenser of ·001 mfd. maximum capacity. Aerial and earth terminals are in front of this. An enclosed type of detector is used and a plug to take coils of any desired



CRYSTAL RECEIVER WITH PLUG-IN COIL

Fig. 15. On the left is shown a cabinet containing a variable condenser On the right is a plugged-in coil with tappings and switch, by means of which a wide range of wave-lengths can be received

wave-length. A tapped inductance coil is shown which permits of listening on the higher wave-lengths. It can be used for spark signals as well as the lower wave-lengths for broadcasting and amateur transmission.

CRYSTAL RECEIVERS: (2) HOW TO MAKE SIMPLE SETS

Construction and Use of Twelve Easily Made Crystal Receiving Sets

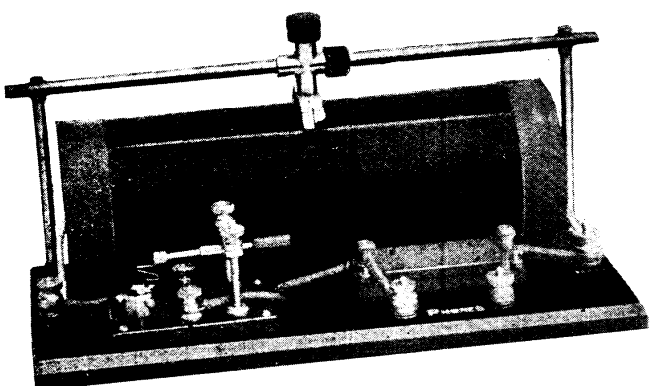
In this section home-made sets of straightforward design for ordinary reception are fully described and illustrated. They represent all varieties, including tuning by basket, spider and other coils and variometers and a unique set working a loud speaker without a valve. The section which follows deals with the addition of valve amplification to crystal receiving sets

The novice to wireless cannot do better than begin by the construction of a simple crystal set, provided there is a broadcasting station within, say, twenty miles. The cost, apart from the telephones, is trivial, but the experience gained is the most practical introduction to the subject. Results should be equal to the professionally made sets if care be taken to make all joints perfect, and generally to exercise common sense in the construction.

In those cases where a broadcasting station is a greater distance away, the receiver can be a crystal set with a stage of high- or low-frequency amplification.

The choice of a set to make at home will be to some extent governed by the constructive powers of the maker, the geography of the place where the set is to be used, and the results desired. For example, if the builder is resident in a town near to a broadcasting station, say within a few miles, an ordinary single circuit set of the simplest character will give satisfactory results, even with two or three sets of telephones, because the signals will be very strong and interference will be at a minimum.

It would, however, be more difficult to listen in to other stations, as the proximity of the local station makes it difficult to tune it out, and therefore if it is intended to listen to the other stations a selective set is needed, and preferably one with a stage of high-frequency amplification. Such a set would allow of the use of a loud speaker for the signals from the local station, and should permit of good signals from the others that are within reasonable distances of, say, fifty miles or so. It should be remembered that when desiring to listen to all the stations in Great Britain a selective set should be used, with one stage of high-frequency amplification and one or two stages of low-frequency amplification.



EASILY MADE CRYSTAL RECEIVER

Fig. 16. One of the simplest crystal sets to make is designed as above. It consists of a single-slider inductance coil, crystal detector and fixed condenser

The choice, therefore, is governed first by the location of the station that it is generally intended to listen to. When this is near at hand, a very simple set will suffice. If a loud speaker is wanted for the set, add a stage or stages of low-frequency amplification. If interference is expected or is heard, as is often the case when a coast or commercial station is not far away, have a set with a selective tuning arrangement such as a loose coupler or a two-circuit device. For long-range reception choose a set with a stage of high-frequency amplification and with low-frequency amplification, and, above all, one with a selective tuning arrangement.

As a start it is generally quite practical to begin with a simple single circuit set, and when results have been obtained to add the various stages of amplification and amend the tuning system. By progressing in this way the principles are better understood and successful results are more likely, as it is far more difficult to get satisfaction when the first set has a multiplicity of controls and tuning arrangements, all of which have to be properly adjusted before any signals can be heard.

Spark stations are heard over much greater distances than the broadcasting stations, and if the Morse code is learned there is much interesting news to be picked up on the signals, which will be easily read on a simple crystal set. For this work the tuning system must be capable of tuning to a sufficiently long wave-length. Ordinary broadcasting is carried out on a wave-length band of some 300 to 500 metres, amateur stations work on wave-lengths of 200 and thereabouts, as well as up to 400, but as many of them are of low power, they are not so easily picked up on a crystal set.

The beginner will do well to commence with the reception from the local station and increase the range of the set after acquiring a measure of proficiency in the use of the simplest devices. The longer the range of a set the more complicated it becomes, as a rule, to tune, and it is far wiser for the beginner to proceed in easy stages from the crystal than to buy a seven-valve set in an effort to listen to America the first night.

One of the easiest sets to make is illustrated in Fig. 16, and consists of an ebonite base, which may measure 8 in. long and 4 in. wide. A cardboard or ebonite tube is then attached to it by means of two screws and nuts, with a block of ebonite between the tube and the base, as described under the heading Cardboard Tube. These screws should be located at the ends of the tube.

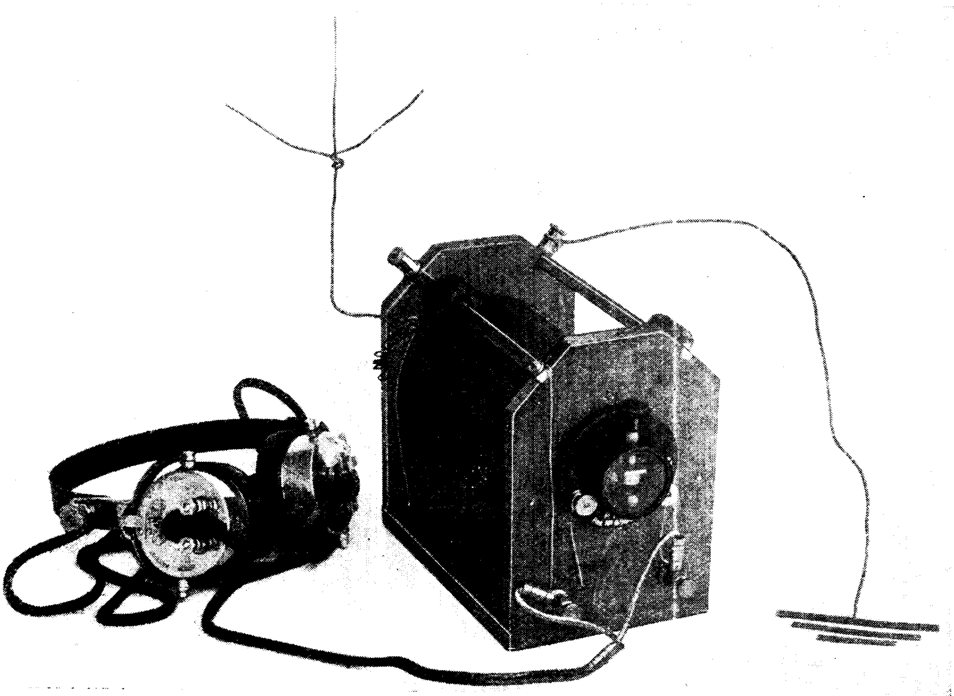
Two uprights of brass rod are provided to support a cross bar of brass rod about $\frac{1}{4}$ in. diameter. Joints are effected by means of screws and nuts. A cross-shaped brass fitting, as sold for use on small model engines, is arranged to slide on the top bar, and two ebonite knobs fitted as shown. To the bottom of the cross piece is attached, by means of a small screw, a laminated contact arm, the ends of which are adjusted to bear on the surface of the tube. The width of the arm from contact point to contact point is about 1½ in.

A simple detector and a low-value condenser are fixed to the front part of the base, and wired as shown under Crystal Circuits (page 557). The ebonite or card tube is now removed from its place and the wire wound upon it. This may be No. 24 gauge S.C.C. or enamelled wire, and should be wound evenly on to the tube. It is replaced in position when wound and the insulation removed from it at the two points where the contact arm will pass. With cotton-covered wire the better plan is to well paint it with insulating varnish prior to replacing it.

The contact arm will need a slight adjustment, and the path on the coil winding may need touching up here and there to ensure perfect contact over the whole of its length. The set is wired to the aerial and earth, and the sliding contact and the crystal adjusted until signals are heard. Fine tuning is obtained by tuning with the contact arm on the front contact path, and getting the closer tuning by rocking the arm over so that it makes contact with the path at the back of the coil. This in effect adds or reduces the inductance value by an amount equal to only a length of about 1½ in. of wire. When properly adjusted, the contact arm should make contact at the front or back, as the case may be, and not touch the other path or contact strip on the coil winding. This set should tune from about 200 metres to 600 metres on the average aerial.

A simply made double-slider tuning set is illustrated in Fig. 17, which shows the whole of the connexions and the parts needed for reception of broadcast concerts. The aerial and earth connexions are shown as symbols.

The telephones should be of high-resistance type, very sensitive, and at least 2,000 ohms. and preferably 4,000 ohms resistance. An enclosed type of detector is used, and this can be purchased at low cost from most dealers in wireless apparatus. Any other type can be substituted if desired.



SIMPLE DOUBLE-SLIDER CRYSTAL RECEIVING SET

Fig. 17. Fixed to the cheek of the coil in the foreground will be seen a crystal detector of the circular enclosed type. The method of wiring is easily followed by the symbols made in wire for illustration purposes. The theoretical diagram of this set is given in Fig. 18, and the method of construction in subsequent figures

The wiring is given in the form of a theoretical diagram in Fig. 18, which shows the sliders on the two slider bars are connected respectively to the leads from the telephone and to earth. The aerial is attached to the commencement of the coil winding.

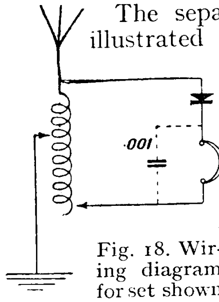
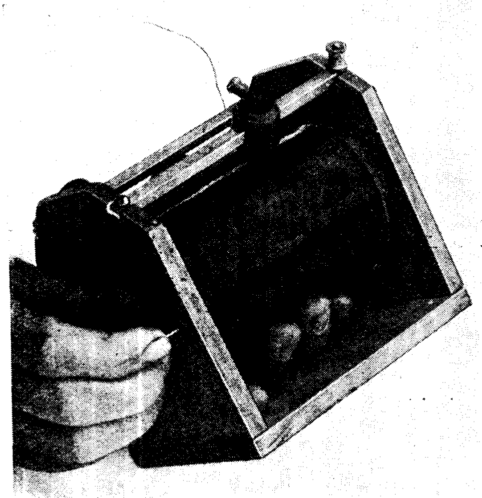


Fig. 18. Wiring diagram for set shown in Fig. 17. The fixed condenser is optional

The separate components are illustrated in Fig. 19, and this shows how the stand is made from three pieces of hardwood measuring about 4 in. wide and ½ in. thick. The ends are shaped at the upper part and screwed at the lower to the base with fine countersunk screws. The sliders and bars can be bought ready for use and cut to length ; about 6 in. long will be suitable for ordinary broadcast reception. The tube whereon the coil is wound should be about 3¾ in. diameter and 6 in. long, and is wound with No. 22-gauge enamelled copper wire.

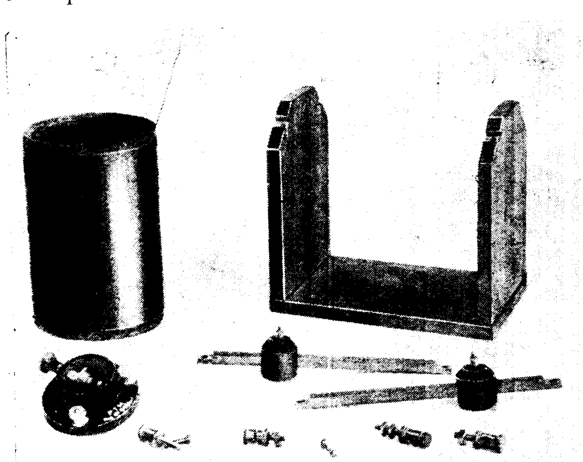
The method of fitting the sliders is clearly shown in Fig. 20, where one is in place and the other in the act of being fitted to the slots cut in the end pieces to receive the ends of the slider rod. The rods are filed to about half their thickness to form an edge for the inner faces of the end pieces to abut. The coil, when wound, is fixed between the two uprights with the aid of ordinary fine pins that are driven through fine holes drilled in the end pieces. The operation of fixing them is shown in Fig. 21, and illustrates how the coil should be held with the upper part in close contact with the two plungers in the sliding contacts.

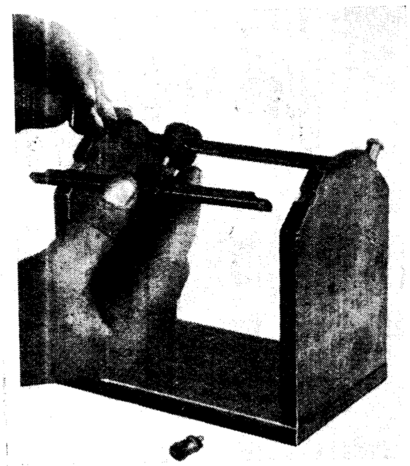
If placed into position in this way the two contacts are readily worked into proper engagement as the coil is pressed up towards them, so that it bears evenly



METHOD OF FIXING INDUCTANCE COIL

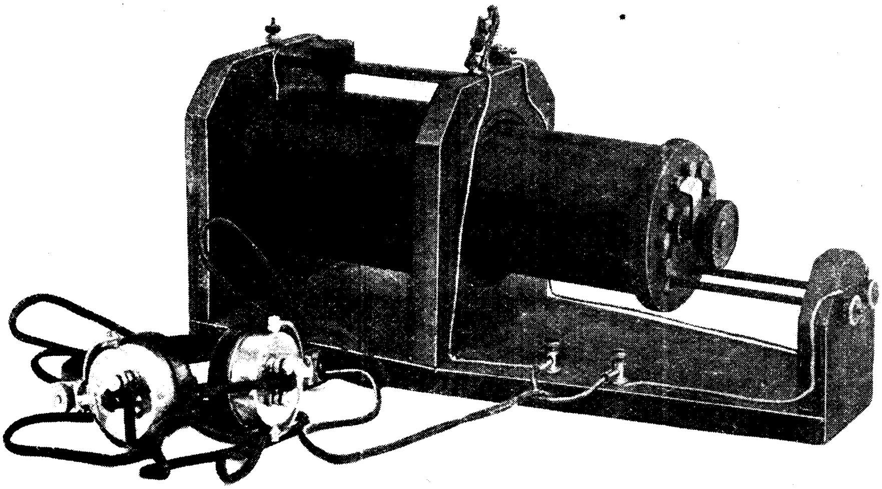
Fig. 21. Fine pins are driven through the end pieces and the cardboard tube as a means of holding the inductance coil





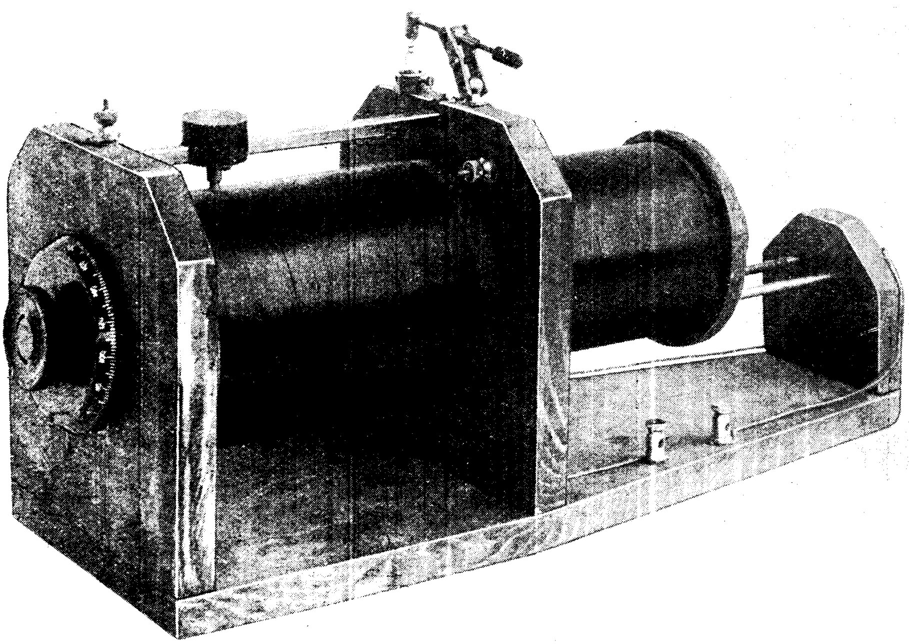
CONSTRUCTIONAL DETAILS OF TWO-SLIDER CRYSTAL RECEIVER

Fig. 19 (left). Components of the crystal set with double-slider inductance coil are laid out. How simply the set is arranged is well seen. Fig. 20 (right). Wood-screw terminals hold the slider bars in position. Here the operator is shown fitting the slider bars temporarily, to make sure that they fit before assembling the coil



CRYSTAL DETECTOR MOUNTED ON A LOOSE COUPLER

Fig. 22. Greater selectivity can be obtained in a loose coupler set than in the single or double slider tuner sets. The crystal detector is mounted on the centre support of the loose coupler. One coil of the coupler is varied by a slider, and the other by tappings taken internally and wired to an end switch. In this photograph the complete apparatus is shown



VARIABLE CONDENSER OF LOOSE-COUPLER CRYSTAL DETECTOR

Fig. 23. Mounted on the left cheek of the loose coupler will be seen a calibrated disk. This is the disk of the variable condenser, which is accommodated within the former of the coil. By this arrangement the condenser is well protected and out of sight. Tuning can be carried out by operating the switch and movable coil with the right hand and the condenser at the same time with the left

on them. When one end has been fixed the sliders are pushed to the other end and the pins driven into the end of the tube. The insulation is then scraped from the coil to form a path for each slider to make contact with.

The detector is screwed to the end piece, and the terminals screwed into place, as shown in Fig. 17, and the connexions made with No. 18-gauge tinned copper wire, which may be left bare or protected with Systoflex or rubber tubing, as desired.

The construction of a loose-coupled set gives a little more trouble, but the selectivity is much greater than in a single circuit set. Hence it is preferable for many purposes where accurate and selective tuning is needed. The appearance of the complete set is shown in Fig. 22, with the connexions made to the telephones. The back view of this set, Fig. 23, shows the location of the condenser, and Fig. 24 gives the theoretical circuit diagram.

The base is made of hardwood for preference, but soft wood, if dry, will answer fairly well. The primary winding is made with No. 22-gauge D.C.C. wire wound for a distance of 6 in. on the card or ebonite tube former, which should be 4 in. diameter. The secondary is similarly wound on a former $3\frac{1}{2}$ in. diameter, with No. 26-gauge wire and tappings taken at regular intervals to studs fixed in the outer end plate. The wires should be painted with insulating varnish or shellac.

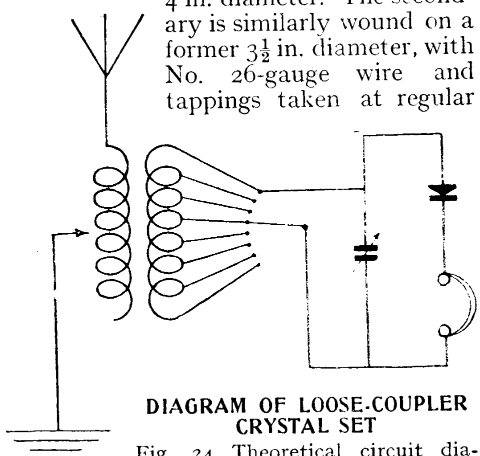


DIAGRAM OF LOOSE-COUPLER CRYSTAL SET

Fig. 24. Theoretical circuit diagram is given here by means of which wiring of the set shown in Figs. 22 and 23 can be carried out

The two uprights for the support of the primary winding are screwed to the baseboard, and the tube fixed by fitting it into a recess in the end piece and into a hole cut through the outer end piece. The secondary coil slides on two brass rods stretching from the short outer end piece to the opposite end. Connexions are made with these rods by means of brass tube bushes from the bush for the central arm by means of a strip of copper, and the other from the commencement of the winding. A condenser is mounted just within the end upright, and is shunted across these two brass rods, the connexions being made internally.

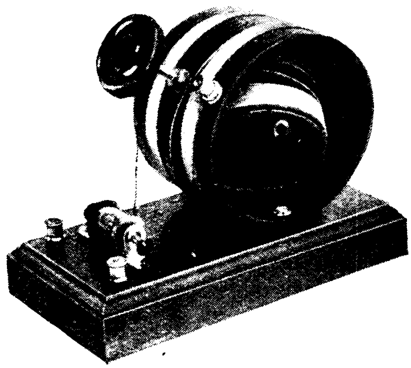
A simple crystal detector is mounted on the top of the middle upright, and connexions made with the usual terminals and insulated copper wire. The primary coil is tuned by means of the slider contact, the secondary by the contact arm and tappings in conjunction with the condenser. When tuning for the first time the two coils should be closely coupled—that is, the secondary should be pushed into the primary as far as it will go. The slider on the primary is now adjusted until signals are heard, after which the signal strength is increased to a maximum by tuning the secondary coil. This will necessitate retuning the primary. Some practice is necessary before the signals can be tuned in quickly and to the fullest strength, but when the knack has been acquired the set is fairly selective.

Variometer and Crystal Broadcast Receiver. Fig. 25 shows a simple variometer crystal set which gives good results up to 20 miles from a broadcasting station with the ordinary single or twin wire outdoor aerial. The set has the advantage of being very compact, the overall dimensions being $6\frac{1}{2}$ in. by $3\frac{1}{2}$ in., and cheap to make.

The materials required are:

Baseboard, $6\frac{1}{2}$ in. by $3\frac{1}{2}$ in., by $\frac{1}{2}$ in; large cardboard tube, $2\frac{3}{4}$ in. wide, $3\frac{1}{2}$ in. diameter; small cardboard tube, $2\frac{1}{2}$ in. wide, $1\frac{3}{4}$ in diameter; one glass-enclosed detector; one ebonite knob; 3 in. of 2 B.A. screwed rod; 45 ft. 28-gauge S.C.C. wire; four terminals, nuts and screws and washers.

The baseboard should be made first, as when varnished it can be put aside to dry while the remainder of the set is being constructed. The board is made from any suitable dry wood, oak, mahogany, or beech being specially recommended. When cut to size and edges squared, a bevel is made on the top edge, or if a moulding plane is available, a better finish can be given by its use. Four strips of wood,



SIMPLE VARIOMETER CRYSTAL RECEIVER

Fig. 25. Apparatus of this design is very simple to construct, and can be made quickly by the amateur. It consists of a variometer and enclosed crystal detector, and costs but a few shillings

½ in. square, are glued flush with the sides on the underneath of the base. This brings the base to 1 in. thick, giving a very substantial appearance and obviating the necessity of recessing the nuts and channelling grooves for connexions under the base. When these strips are quite firm the whole base is planed up, sandpapered, and varnished.

A variometer consists essentially of two parts, an outer inductance and an inner one In the large majority of cases, and owing to natural ease of construction, the inner inductance is capable of rotation inside the larger one, which is stationary. For this reason they are respectively called rotor and stator.

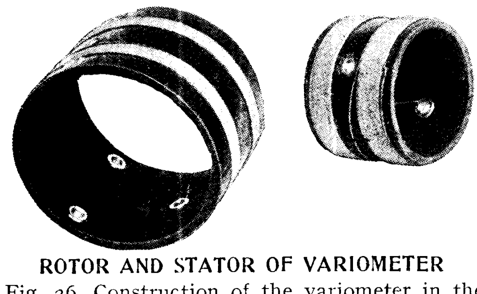
The stator is cut from cardboard tube of 3½ in. diameter and a width of 2¾ in. The only process demanding exact workmanship is in drilling the two holes in both rotor and stator so that the former will readily rotate inside the latter without touching it. The process adopted for both is exactly the same, so that only one need be described in detail. Drill a $\frac{3}{16}$ in. hole centrally in the stator. This will be 1⅜ in. from centre to either edge.

A strip of paper is cut about ½ in. wide and a little over half the length of the circumference of the stator. One end is applied to the outside of the hole just drilled and the paper then wrapped round. At a point judged as half-way round, a pencil mark is made from the paper to the stator. The same process is carried out on the opposite side of the stator. The stator is marked adjoining the pencil mark on the paper. It will be seen that the two pencil marks made on the stator represent an equal distance from the centre of the hole, and the midway point between the two marks gives the centre of the hole to be drilled. Proceed in this way with the rotor, both holes again being $\frac{3}{16}$ in. diameter. In order to give a more pleasing appearance and to make the cardboard look like ebonite, the rotor and stator may be painted with a black enamel inside and out before winding.

The stator is wound with 26 turns of No. 26 S.C.C. wire. Commence winding ⅝ in. from the edge. When thirteen turns have been put on, the wire is taken straight across, not fouling the holes drilled, and rewinding commenced 1 in. from this edge. The 13 layers occupy about ⅜ in., so that this measurement will make the two half-coils balance. When all the wire is on, two terminal holes near each edge are drilled in line with the centre hole.

The rotor has 26 turns of the same wire on each side of the central holes. Winding is commenced $\frac{3}{16}$ in. from one edge and finished off the same distance on the other side. The outsides of both rotor and stator are given two coats of white hard varnish to fix the windings permanently into position. Two more holes are required in the stator to hold the complete variometer in position, and are drilled in line ⅜ in. from each edge at a distance of 3¾ in. along the circumference from the terminal holes. All the holes in rotor and stator are bushed with brass eyelets. They should have a central hole of $\frac{1}{16}$ in.

These are shown on the rotor and stator in Fig. 26. The $\frac{3}{16}$ in. holes already drilled will need to be slightly enlarged for the eyelets to fit. The tang of a file will be sufficient to open the holes out. The eyelets are then pushed through the holes with the rounded side on the inside. Both ends of the rotor connexions are fastened under



ROTOR AND STATOR OF VARIOMETER

Fig. 26. Construction of the variometer in the set shown is Fig. 25 is not difficult. Note how the holes are bushed with brass eyelets

their two eyelets before bending over the tag ends. In the stator one wire is fastened in the central eyelet opposite to the three holes in line.

The remaining stator wire is held under the right eyelet of the three in line. This terminal is seen on the stator in Fig. 25 of the complete instrument. The central eyelet is connected to that on the left by a short length of wire. For assembling the rotor to the stator two lengths of 2 B.A. rod will be required, $1\frac{3}{4}$ in. and $1\frac{1}{4}$ in. respectively. The longer piece is slipped through the hole between the terminal holes and a 2 B.A. spring washer pushed on from the inside. This washer is followed by a 2 B.A. lock nut, after which the rotor is slipped on.

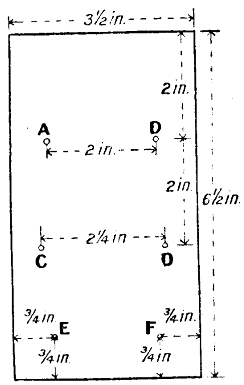


Fig. 27. Measurements for the panel shown in Fig. 28

Another 2 B.A. lock nut screwed on from inside the rotor will bind up the spindle tight with the rotor. Do not allow any spindle to project inside the rotor, or it may be too short to take a nut and knob which will be fitted later. Exactly the same procedure is carried out on the opposite side with the shorter length of screwed rod. A spring washer and nuts are fitted in the same order. Each spindle now receives a nut on the outside. They must be tightened up to bring the rotor in the middle of the stator, so that the distance separating both is the same all the way round. When this is so another lock nut is screwed on each spindle.

The base is drilled as shown in Fig. 27, and is shown completed in Fig. 28. A glass-covered detector is fitted as in Fig. 29. The holes for mounting the detector are not shown in Fig. 27, as they must vary according to the type of detector purchased. Mount the variometer in position with two 2 B.A. screws with nuts 1 in. long. An ebonite knob is screwed on to the longer stemming and tightened up

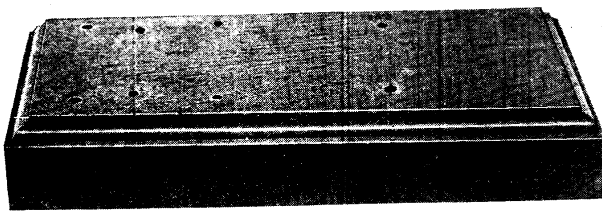


Fig. 28

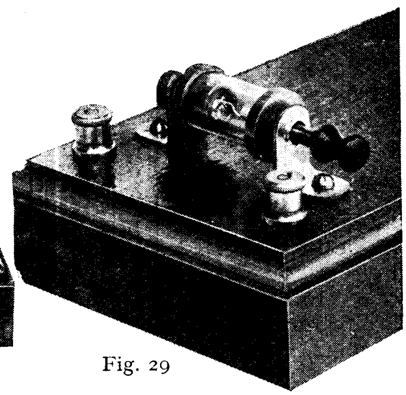


Fig. 29

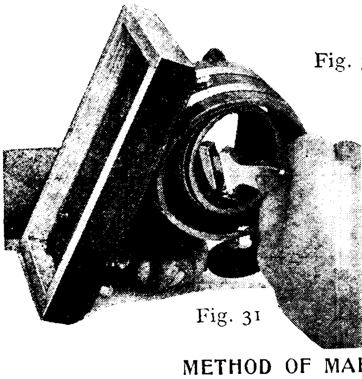


Fig. 31

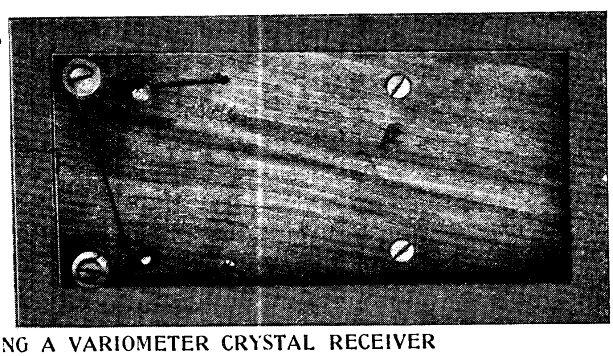
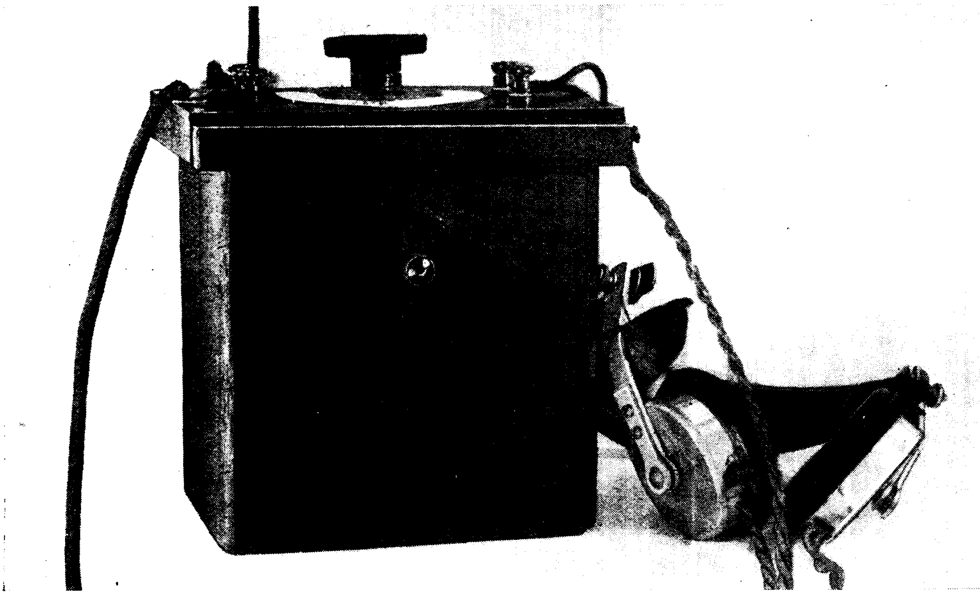


Fig. 30

METHOD OF MAKING A VARIOMETER CRYSTAL RECEIVER

Fig. 28. How the base for the set shown in Fig. 25 is made, sizes being given in Fig. 27. Fig. 29. Mounted near the edge of the base are two terminals and an enclosed detector. Fig. 30. Under the crystal detector connexions are taken through the base and wired on one side to one of the terminals, and on the other to the variometer. The other terminal is also wired to the variometer through the base. Fig. 31. With the aid of a spanner the nut holding the longer spindle is firmly tightened up, as it bears all the strain of the rotor's movement



CIGAR BOX CRYSTAL RECEIVING SET

Fig. 33. Compare the size of the headphones, the ear-pieces of which are close together, and the dimensions of the box containing this set will be appreciated. This small home-made set is constructed with a cigar box for cabinet, the hinged lid making an excellent falling front. The contents are by no means cramped, as their simplicity requires little space

by a lock nut screwed on first. Two terminals are fitted to the adjoining holes, wires clamped under the bases going through two small holes immediately underneath them.

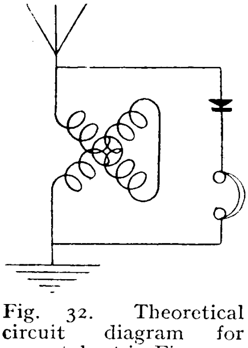


Fig. 32. Theoretical circuit diagram for crystal set in Fig. 25

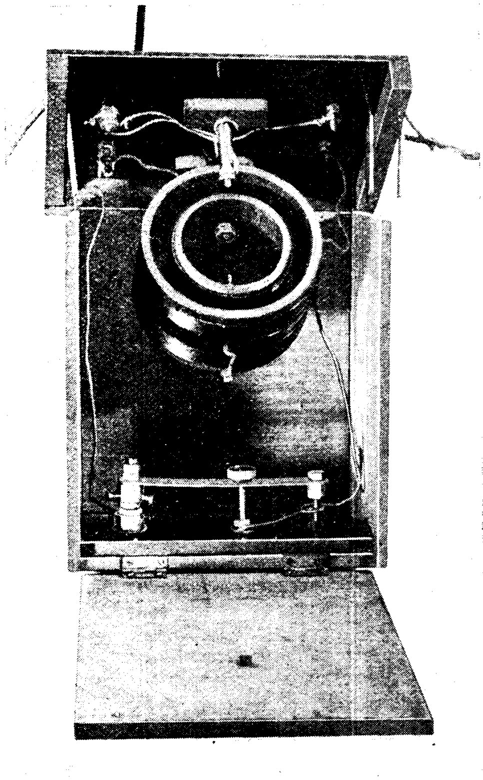
The wire on the left goes directly to a terminal on the left of the baseboard, E in Fig. 27. The wire on the right goes to the terminal F on the right of the baseboard (Fig. 27) after passing through the crystal detector. The wiring under the base is shown in Fig. 30. Before the set is finally finished the nut under the rotor, where the longer spindle is held, should be given another tightening with a small spanner. This nut bears all the strain of the rotor's movement, and it is important it should be quite tight. Fig. 31 illustrates this operation. The terminals on the variometer, from left to right, are, respectively, aerial and earth. The terminals on the base are telephone terminals.

Fig. 32 shows the theoretical circuit diagram for the crystal set.—*W. Whiffen.*

Cigar Box Crystal Set. The set shown in the photograph Fig. 33, although extremely simple in construction, is compact and easy to operate and of better appearance than the previous set. It gives good results up to ten to fifteen miles from a broadcasting station.

The case is a cigar box about $3\frac{3}{4}$ in. by $5\frac{1}{2}$ in. by 6 in., with hinged lid, such as may be obtained for a few pence from any tobacconist. It is arranged to stand on one end with the hinged lid falling downwards. The other end is removed and its place taken by an ebonite panel, which is cut $\frac{1}{4}$ in. larger each way than the end of the cigar box, *i.e.* if the cigar box is $5\frac{1}{2}$ in. by $3\frac{3}{4}$ in. the ebonite panel is cut 6 in. by $4\frac{1}{4}$ in.

Strips of wood $\frac{1}{4}$ in. wide and about $\frac{1}{2}$ in. deep are screwed underneath the two short sides and one long side of the panel, so that it fits over the end of the box without the necessity of hinging or other fastening. This permits easy access to the underside of the panel for wiring or any adjustments, as seen in the photograph Fig. 34. The lay-out of the panel is shown in the diagram Fig. 35, and the wiring diagram is given in Fig. 36.

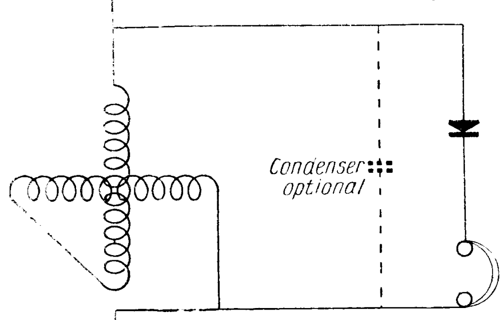


INTERIOR OF CIGAR BOX SET

Fig. 34. Inside the cabinet or cigar box the variometer and crystal detector are housed. The wiring can also be seen. Note that the lid or panel is not fixed to the box

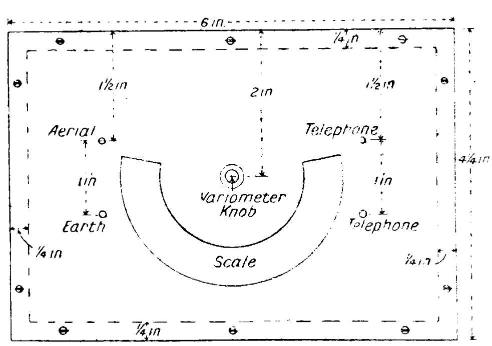
Inductance is provided by a variometer, which may be constructed according to the directions given under that heading or may be purchased for a few shillings. It is conveniently fixed by passing its two uprights through the ebonite panel and fastening them with nuts on top. A neater way is to cut two strips of ebonite or hardwood $1\frac{1}{2}$ in. by $\frac{1}{2}$ in., at least $\frac{1}{4}$ in. thick, fastening them by means of nuts to the two uprights, the nuts being countersunk flush with the top of the strips. The strips are then fastened to the panel by countersunk screws.

The detector is seen at the bottom of the photograph Fig. 34. The crystal to crystal arrangement is particularly satisfactory in this type of set, since, if good bornite and zincite crystals are obtained, the adjustment, once made, need hardly ever be interfered with. The detector is mounted on a piece of ebonite about $1\frac{1}{2}$ in. wide, the crystals being wrapped in silver foil and held in the ordinary type of cup. The upper crystal is fastened on a fairly stout piece of springy steel. Pressure is adjusted by means of the milled nut working on the threaded screw about $1\frac{1}{4}$ in. long, seen in the centre. The end of the piece of springy steel is supported on another $1\frac{1}{4}$ in. screw between nuts.



CIGAR BOX RECEIVER CIRCUIT

Fig. 36. Wiring of the cigar box type of crystal receiving set may be carried out with or without the optional condenser shown in dotted lines

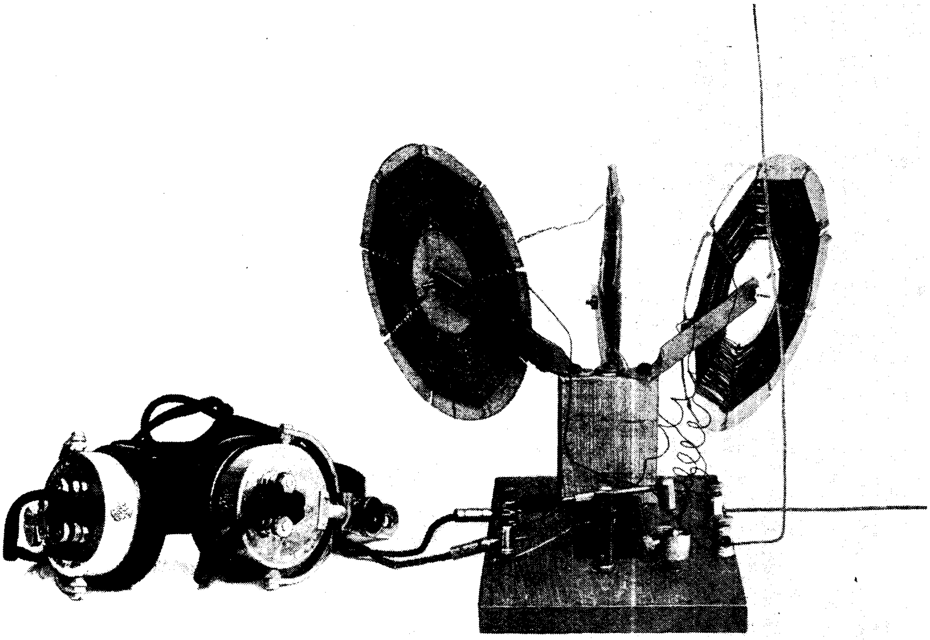


DIMENSIONS OF PANEL

Fig. 35. Measurements and the lay-out of the top or panel of the cigar box set

Either 2 B.A. or 4 B.A. screws will answer the purpose. Both the holes in the flat steel through which these two screws pass should be $\frac{1}{8}$ in. larger than the diameter of the upright screws to allow a certain amount of play for the upper crystal so that the most sensitive spot may be found. The case is finished off with a strip of wood on the top of the hinged door of the same dimensions as the strips underneath the three edges of the panel, and fixing a terminal head as a button, as seen in Fig. 33.

The appearance is improved by lightly staining the cigar box, finished off with a wax polish.—*S. G. Stubbs.*

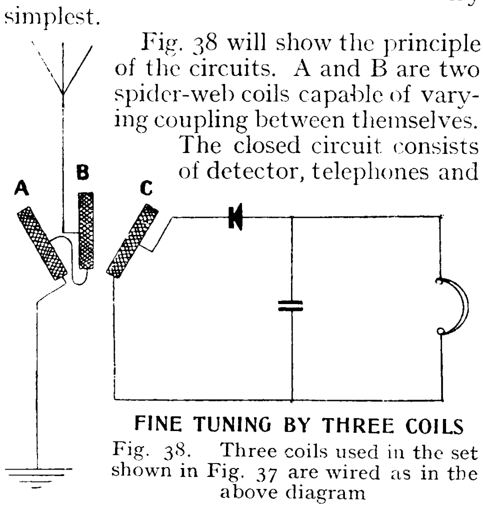


SPIDER-WEB COILS FOR TUNING A CRYSTAL RECEIVER

Fig. 37. Fine tuning can be carried out in a very simple crystal receiving set by the use of three spider-web coils arranged as shown as this photograph. In this receiver the detector is of the ball-and-socket type, employing the usual cat's-whisker. The set is very easily made by the amateur

Spider Coil Set. The crystal set shown in Fig. 37 is specially suitable in a locality where jamming from shipping or other transmissions on a broadcast wave-length are prevalent. It has the advantage of greater selectivity than an open circuit type of receiver. The materials required for its construction are of the very simplest.

Fig. 38 will show the principle of the circuits. A and B are two spider-web coils capable of varying coupling between themselves. The closed circuit consists of detector, telephones and spider-web coil C, with a fixed condenser shunted across the telephones. This coil is inductively coupled to the primary circuit.



FINE TUNING BY THREE COILS

Fig. 38. Three coils used in the set shown in Fig. 37 are wired as in the above diagram

The experimenter is allowed considerable licence regarding constructional details, but care should be taken to see the spider-web coils are made to the sizes given. The amateur generally has little scraps of material to hand, and if these can be modified to suit requirements there is no need to follow slavishly a set design where it can make no difference to the efficiency of a set. The following dimensions and particulars should be taken as a guide only.

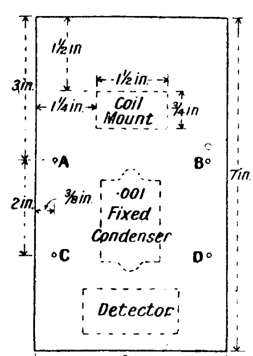
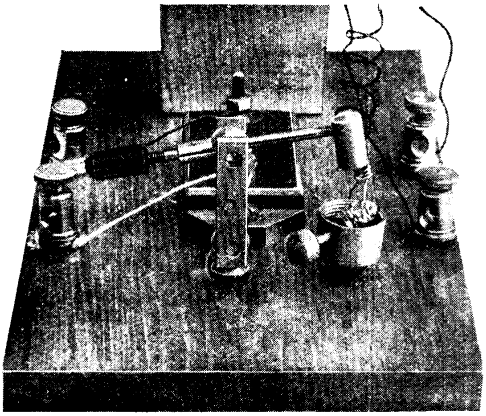


Fig. 39. Dimensions of panel and general layout of set shown in Fig. 37

The base of the receiver is constructed of any hard dry wood. Beech, oak or



DETECTOR FOR THREE-COIL RECEIVER

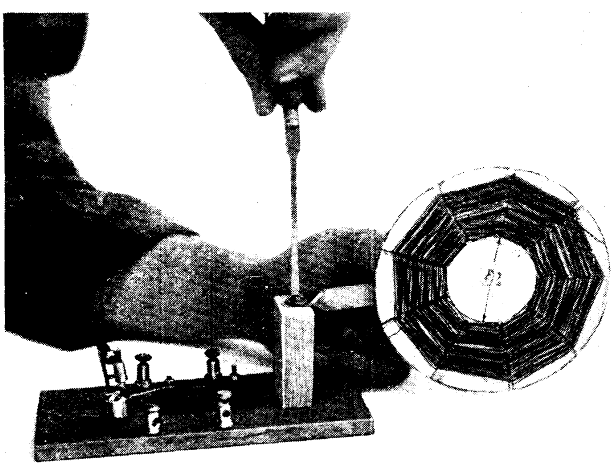
Fig. 40. Details of the crystal detector for the three spider-web coil set are seen here. The two parts of the detector are mounted direct on the base of the set

mahogany are recommended. It is of paramount importance that the timber used should be perfectly dry. Baseboard sizes and the position of fixed condenser, crystal detector and coil-mounting block are shown in dotted lines in Fig. 39. The thickness of the base is $\frac{1}{2}$ in. The coil mounting block is a piece of wood 2 in. high, $1\frac{1}{2}$ in. wide and $\frac{3}{4}$ in. thick. It is mounted in the position shown by the dotted lines in Fig. 39 by two No. 5 by 1 in. countersunk wood screws screwed from underneath the base. The holes must be countersunk, to make the screw heads flush with underside of base. Four terminals are fixed in position at A, B, C, D in Fig. 39. These should be left loose and only tightened up when wiring is completed. The positions of the condenser and detector are only roughly outlined,

FIXING SPIDER-WEB COIL TO ARM

Fig. 41. Nuts and screws hold the spider-web coils to the metal arms on which they are mounted. Here the operator is seen screwing up tight one of the nuts

as the experimenter must be guided by their actual sizes. The condenser is not at all necessary, and it is left to the choice of the experimenter whether or not it is included.



ATTACHING THE COIL ARMS TO THE SUPPORT

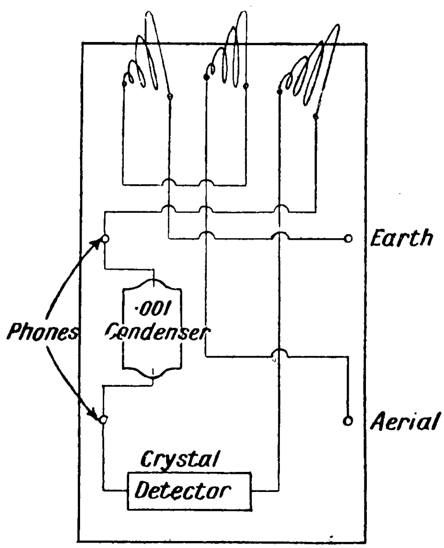
Fig. 42. Contact is not made through the brass strip coil arms, and these may be screwed with ordinary wood screws and washers to the upright wooden mount

The wiring diagram, Fig. 38, shows how it is connected. A convenient size for such a condenser is ·001 mfd. So many different and efficient crystal detectors are on the market, and at such a low price, that it is better to buy a suitable pattern and mount it in the position outlined for it in Fig. 39. Fig. 40 shows a common and efficient type of crystal detector, that can be bought ready for mounting for the cost of a few pence. If it is desired to construct the whole set, several constructive articles will be found under Crystal Detectors.

The spider-web coils are constructed from three 4 in. circles of stout cardboard.

Nine evenly-spaced radial slots are cut $\frac{1}{8}$ in. wide round the circumference to a depth of 1 in. each. The wires are wound alternately on each side of the cardboard, No. 26 enamelled wire being used on each.

A contains 30 turns, B, 60 turns, and C has 45 turns. Fairly long leads are left for attachment to the instrument. The coils are attached to the mounting block by three identical $\frac{1}{16}$ in. brass strips $4\frac{1}{2}$ in. long and $\frac{1}{2}$ in. wide. At one inch from one end of each the brass is turned at a right angle. A small hole at the twisted end and another $\frac{1}{4}$ in. from the other end completes these strips.



SPIDER-WEB COIL SET CIRCUIT DIAGRAM

Fig. 43. Three spider-web coils are wired to the crystal receiver in accordance with the above diagram

Mount the coils to the brass strips by a small nut and bolt, as shown in Fig. 41. The coil and strip B is attached rigidly to the centre of the mounting by a screw block, as shown in Fig. 42. The other two coils pivot on screws $\frac{5}{8}$ in. from the central one on either side. A brass washer on either side of the movable strips will assist in making their action smoother. If it is found that the ends of the strips foul each other they may be rounded.

The aerial terminal is connected to the beginning of coil B, the end of which joins the beginning of coil A. The end of this coil is attached to the earth terminal. The beginning of coil C goes to one side of detector, and from this to one telephone terminal. The other telephone terminal connects back to the end of coil C. If the condenser is inserted it is joined straight across the telephone terminals. A neater result is obtained if the connecting wires are carried to their terminals in grooves made on the underside of the base.

Fig. 43 shows the theoretical circuit diagram for the set.

Enclosed Set with Basket-Coil Tuning. The set illustrated in Fig. 44 has basket coils as the tuning arrangement, and by the simple expedient of changing them the set can be tuned over a wide range of wave-lengths.

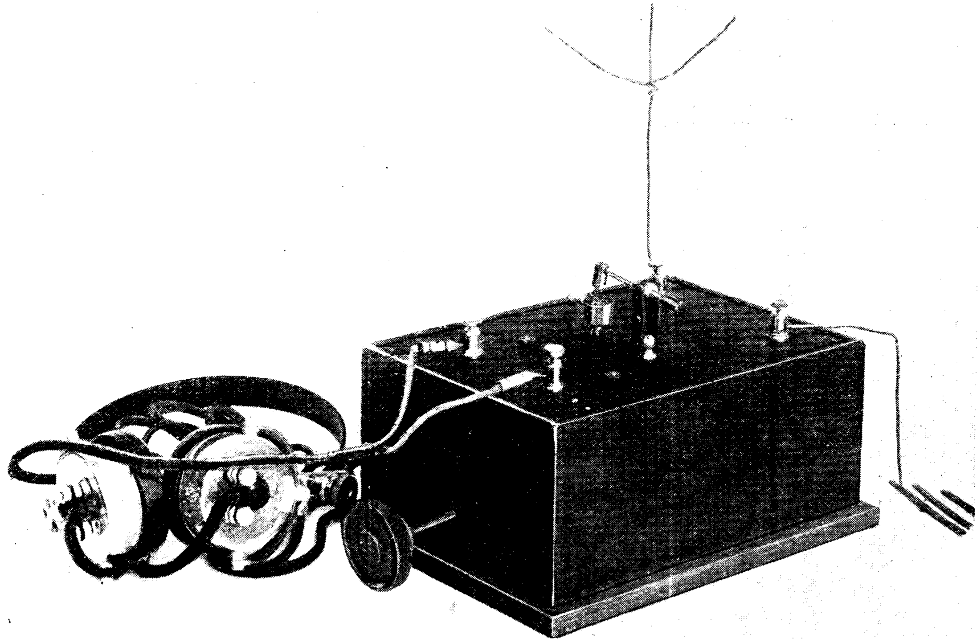
The set is enclosed in a cabinet and has the usual ebonite panel, whereon is mounted the crystal detector and four terminals. Those at the back, as shown in Fig. 44, are connected respectively to the aerial and earth leads, shown in the illustration by the customary symbols. The other terminals are for the telephones.

The theoretical circuit diagram is given in Fig. 46; all the wires are connected beneath the panel. An interior view of the case is given in Fig. 45, and shows one basket coil fixed to the bottom of the case with two round-headed wood screws. The second coil is mounted to the underside of a piece of ebonite, or hardwood, that is arranged to slide in guides attached to the sides of the case. This part is further shown in Fig. 47, and illustrates how the second coil is attached to the underside of the sliding member.

The tuning of this set is accomplished by sliding the secondary coil over the primary, for which purpose the slider plate carrying the second coil has a long brass rod attached to it, and this terminates in an ebonite knob. This is located at the front of the case, and can be seen protruding from it in Fig. 44.

Suitable sizes for the case are 7 in. long and 5 in. wide, but if some other case of approximately the same dimensions is available it could be substituted. Having made or procured the case, the panel is cut to fit into a recess in the upper part of the framework, or can be screwed direct to the top of it.

Holes are then drilled for the terminals and the crystal detector, which can be purchased ready for use, or made as described in the article on crystal detectors. The basket coils are readily obtainable in sets, or separately, and the ordinary concert sizes are correct for the set if listening to broadcasting. One of the coils is

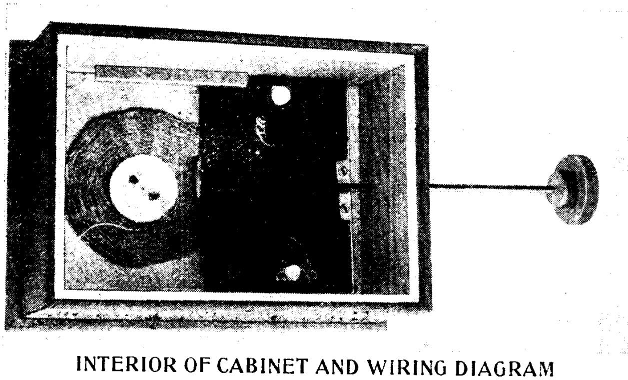


BASKET-COIL CRYSTAL RECEIVING SET

Fig. 44. Enclosed in the cabinet are two basket coils arranged on the principle of the variometer, except that they are flat instead of tubular. One coil slides over the top of the other, and is operated by means of a brass rod and ebonite handle, thus varying the inductive value of the combination. The crystal detector is mounted on the panel, and the terminals for aerial and earth are indicated by means of symbols made in wire

attached to the bottom of the case, and the wires from that coil connected one to the aerial terminal and the other to the terminal on the slider plate.

The slider plate is cut from ebonite or wood, and should have two side pieces attached to it on the underside and measuring about ¾ in. deep. These are to raise the slider above the level of the coil on the bottom of the box. The other coil, attached to the underside of the slider, should just comfortably clear the lower one. To keep the slider in place two guide pieces of wood are screwed to the inner sides of the case, as shown in Fig. 45. Two terminals are fixed to the top of the slider, and these



INTERIOR OF CABINET AND WIRING DIAGRAM

Fig. 45. One of the basket coils can here be seen at the bottom of the cabinet, and the wooden guide piece is also visible. The moving platform of ebonite on which the second coil is mounted moves on these guides, and is seen with the second coil connecting wires joined to the terminals

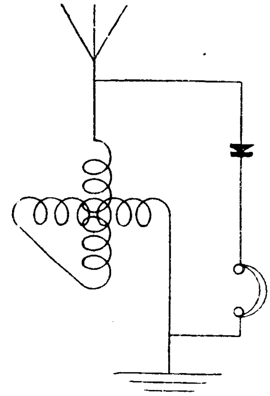
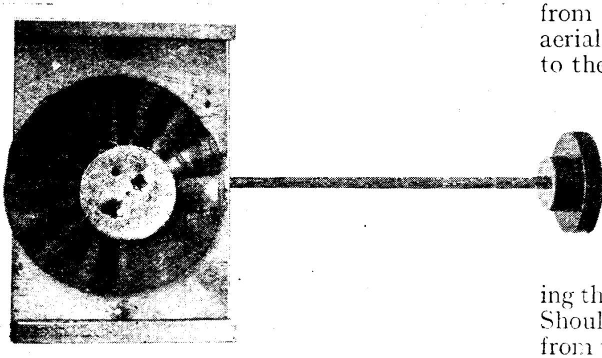


Fig. 46. Although the symbol is the same as for a variometer, the coils are, of course, different in shape



BASKET COIL ON EBONITE PLATFORM

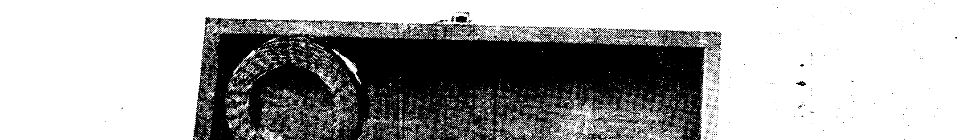
Fig. 47. Mounted on the underside of the ebonite moving platform is the second basket coil. The long rod is of brass, and the handle an ordinary ebonite knob

are connected to the two ends of the secondary coil. The other sides of the terminals are connected respectively to the first coil and to the earth terminal.

The crystal has now to be connected from one terminal of the crystal to the aerial, and from the second terminal to the telephones.

From the other telephone terminal a wire is connected to the earth terminal. On connecting to aerial and earth, adjusting the crystal, and listening with the telephones, signals should be heard and their strength adjusted by sliding the knob of the slider plate in or out. Should nothing be heard the connexions from the second coil should be reversed.

Crystal Set with Loud Speaker. The crystal set shown in Figs. 48 and 49 is described in detail and a full set of working drawings given, because with this set, if the instructions are carefully followed, it is possible to use a loud speaker within five miles of a broadcasting station. With the set illustrated, Manchester, Birmingham, Newcastle, and the Eiffel Tower have been heard in the north of London



CRYSTAL RECEIVER DESIGNED TO OPERATE A LOUD SPEAKER

Fig. 48. It is claimed for this crystal receiving set that it will operate a loud speaker within five miles of a broadcasting station. On the headphones continental and provincial stations have been heard in London. In order to obtain the results the set is capable of, the greatest care must be taken to adhere rigidly to the dimensions and details given for construction. A selection of crystals is kept with the set

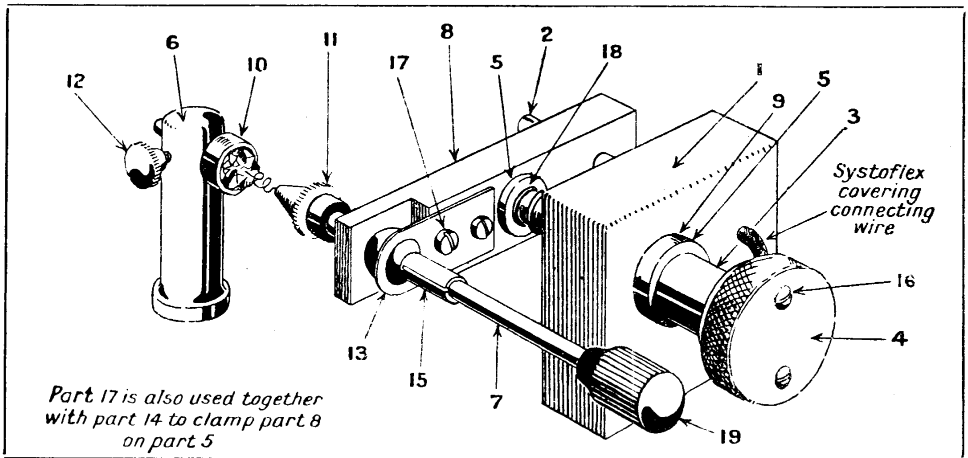
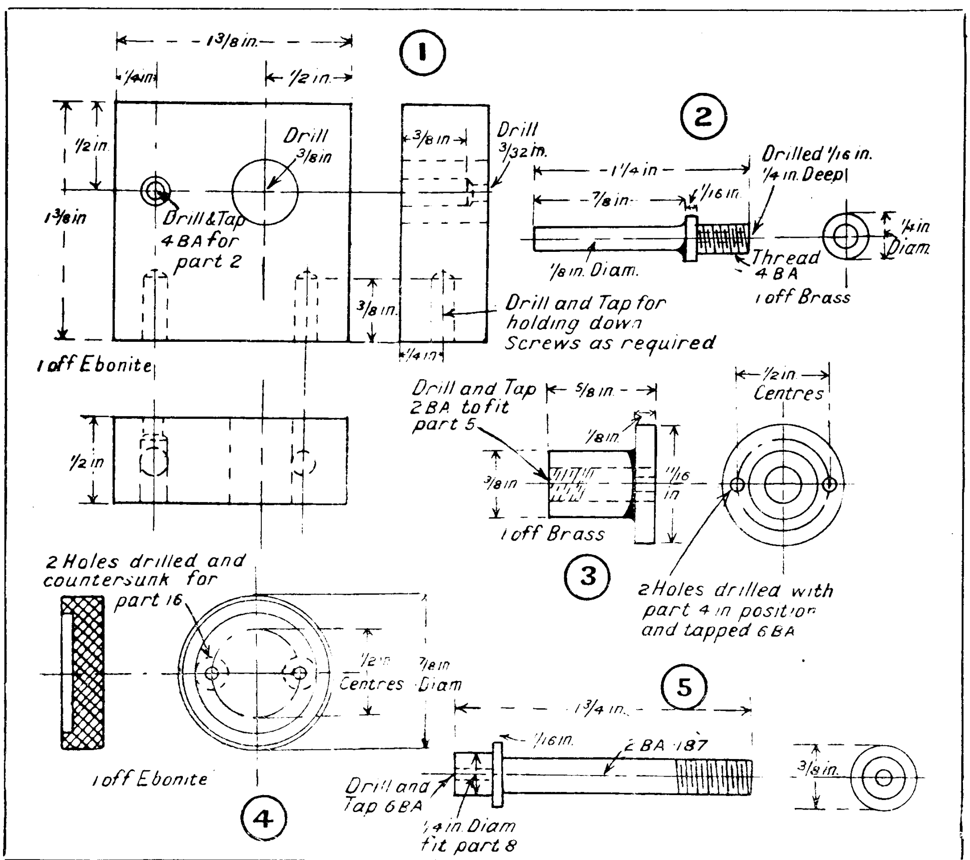
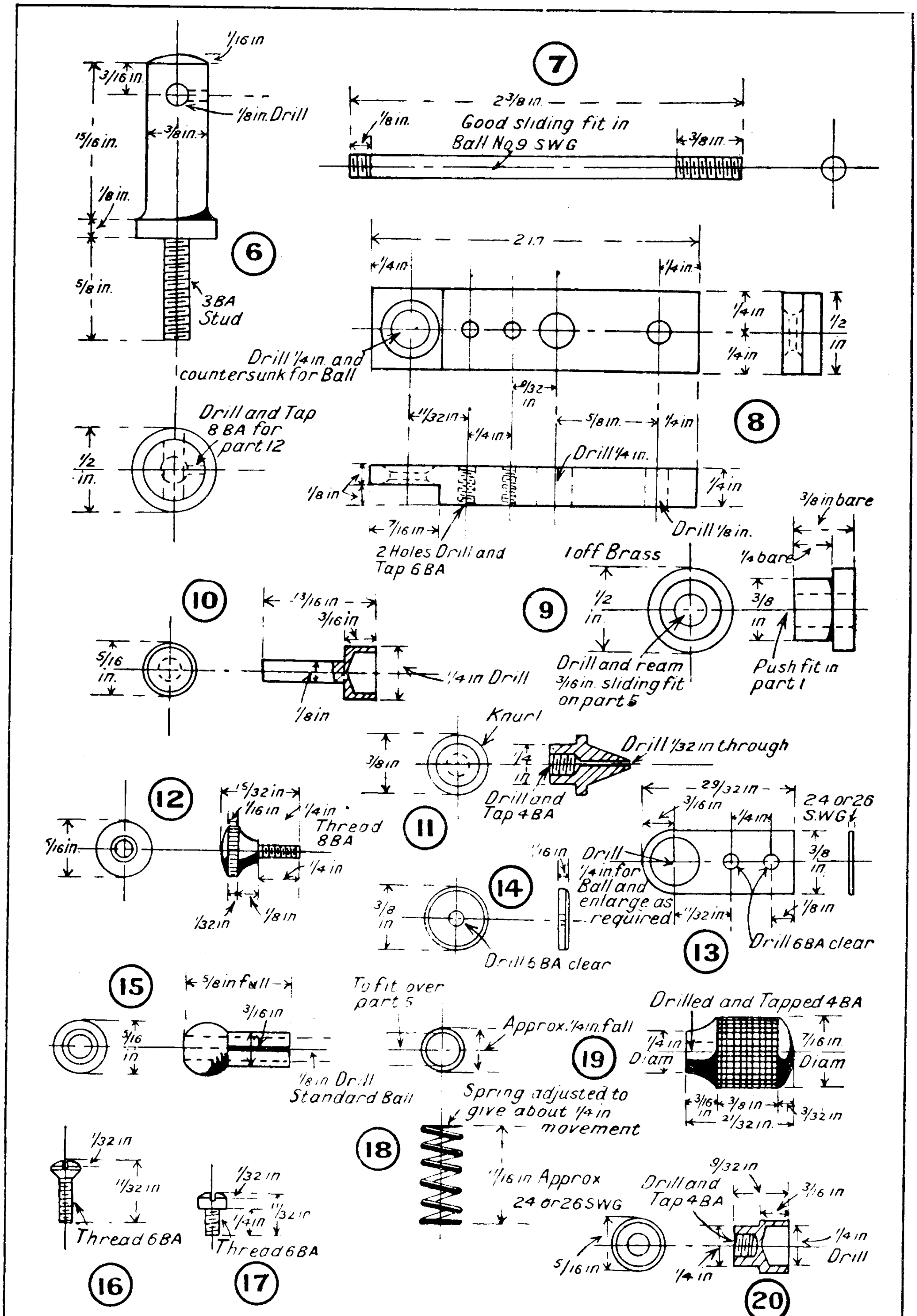


Fig. 49. Complete crystal detector with all parts numbered. The numbers refer to the detailed sketches in Fig. 50



CONSTRUCTIONAL DETAILS OF DETECTOR FOR LOUD SPEAKER CRYSTAL SET

Fig. 50. In these detailed and exactly-dimensioned diagrams every part of the detector shown in the numbered diagram, Fig. 49, is given. Parts No. 1 and 4 are of ebonite, all other parts are of brass. The hole in part 2 is threaded with a short length of 22 S.W.G. copper wire, and this should be soldered in. In Fig. 51 this wire is covered with systoflex. The guide pin must be absolutely parallel to the axis of parts 5 and 8. Further details are given on the opposite page



CONSTRUCTIONAL DETAILS OF DETECTOR FOR LOUD SPEAKER SET

Fig. 50. This is a continuation of the series of diagrams of the details of the special detector shown in Fig. 49. Part No. 19 is of ebonite, No. 18 is of steel; parts 16 and 17 are of steel or brass. Parts 7 and 15 should, if at all possible, be nickelled. Part 8 can be made from ½ in. by ¼ in. brass bar

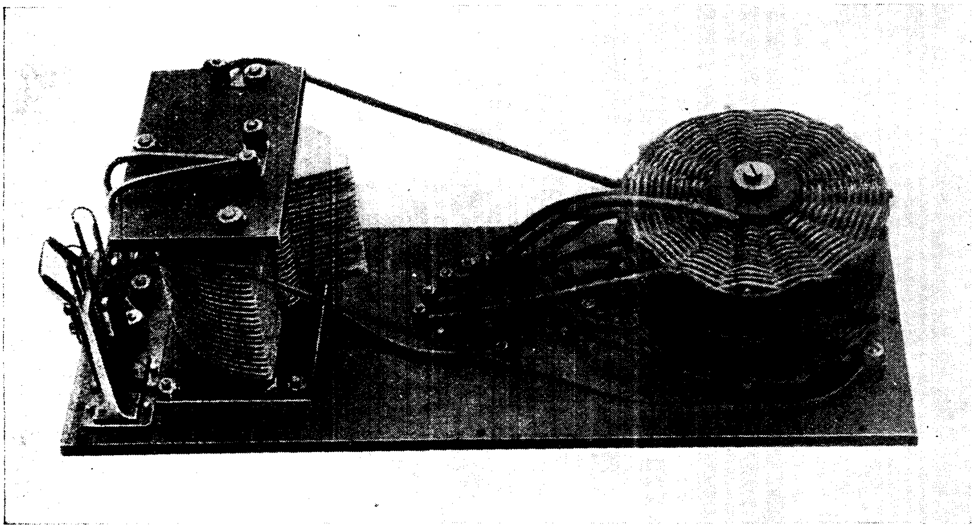
It must be impressed on the experimenter, however, that all joints must be most carefully made, wires cleaned up and properly soldered, and the instructions and diagrams followed absolutely closely to obtain these results. The set has worked regularly five miles from 2 LO (London) with eight pairs of headphones.

One of the important parts with which to begin is the crystal detector itself. This is an improvement on the usual ball-and-socket joint, with which, to obtain the really best results, it is extremely difficult, if not impossible, to adjust the cat's-whisker to its most sensitive state. The detector described allows very sensitive adjustment to be made and kept.

Fig. 49 shows the general arrangement of the crystal detector. The ebonite support should be made first, and, after drilling and tapping to take the control knobs, it should be matted all over by rubbing with fine emery cloth and oil. Fig. 50 shows the complete necessary drawings for making the detector, and each part is numbered to agree with the general arrangement shown in Fig. 49. The crystal detector is the most important part of the set, and every care should be taken in making it, otherwise the necessary fine adjustments to hear distant stations clearly cannot be made. Figs. 49 and 50 make the whole of the necessary steps quite clear, and a long detailed description has been purposely avoided.

In the making, however, there are one or two points that may be noted. For part 8 a piece of $\frac{1}{2}$ in. by $\frac{1}{4}$ in. brass bar can be filed, drilled, and tapped to the dimensions shown. Part 5 is fitted into part 8 and fixed by a 6 B.A. screw and washer. The position of the hole in the ebonite support for the guide pin, part 3, can be located when parts 8 and 5 are in position. The guide pin must be absolutely parallel to the axis of 8 and 5. Before finally screwing the guide pin in the ebonite support, a short length of 22 S.W.G. copper wire should be soldered in the hole in part 2. The wire must be left long enough to pass through the panel and make the connexion where necessary. When assembling the detector on the panel, a piece of systoflex may be threaded on the wire and pushed neatly into the $\frac{3}{32}$ in. hole in the ebonite support. The spring, part 18, must be adjusted to give about $\frac{1}{4}$ in. movement and not push part 8 off the guide pin.

The ball-and-socket movement is standard, but care must be taken to make the rod slide sweetly in the ball. If possible, parts 7 and 15 should be nickelled to lessen the possibility of these two parts sticking through the varnishing. The pressure of the spring brass plate,



UNDERSIDE OF PANEL OF SET WORKING LOUD SPEAKER

Fig. 51. On the underside of the panel three well-made basket coils are mounted. These are very carefully tapped, each wire being well insulated and as short as possible, being taken direct to the stud of the switch. A variable condenser, with its leads also well insulated, is seen on the left. Jacks for telephone, or, alternatively, loud-speaker plugs are seen at the side of the condenser

Fig. 52. Searching the crystal can be carried out by drawing the cat's-whisker across the surface and by rotating the crystal cup. For flat crystals the fine adjustment is used to alter the tension of the cat's-whisker point upon the crystal without shifting its position

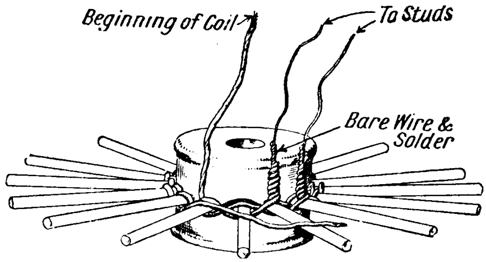


Fig. 53. Tappings are taken from the basket coil in this manner

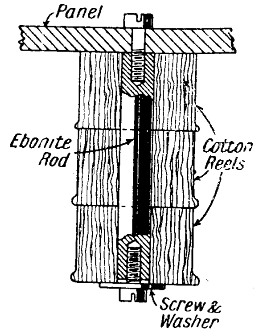


Fig. 54. Cotton reels can be used in this way as a means of attaching the basket coils to the underside of the panel

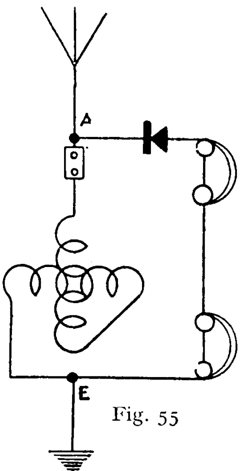


Fig. 55

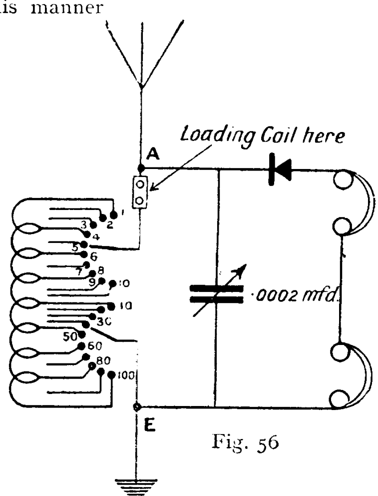


Fig. 56

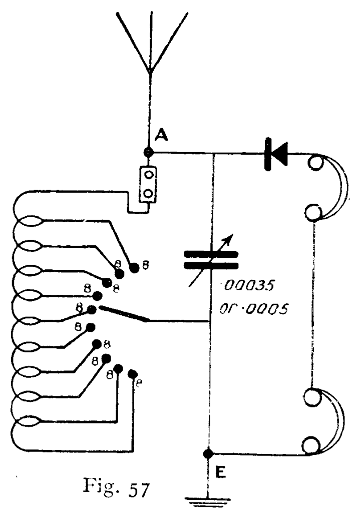


Fig. 57

Fig. 55 is a circuit employing a variometer, Fig. 56 has a coil tapped in units and tens, and Fig. 57 is a circuit using a coil tapped every eight turns and larger condenser. These variations can be applied to the same type of apparatus. In all three cases it will be noticed the loading coil remains. The condenser in Fig. 57 is larger than in Fig. 56

CRYSTALS AND COILS FOR THE LOUD SPEAKER SET

part 13, upon the ball can be adjusted by the screw nearest to it.

A number of crystal cups and cat's-whisker holders can be made as required and mounted with crystals to suit individual choice. Cat's-whiskers, whether of copper, silver, gold, or tordinodium wire, should be of not more than 36 S.W.G. The most useful cat's-whisker can be made from a strand of 40 S.W.G. wire from a piece of electric-light flex. Fig. 52 shows how such whiskers should be made and mounted for different types of crystal.

A gramophone needle can be mounted in part 11, and a piece of lead from a pencil can be fitted with Wood's metal in part 20. These will be found of use with silicon or carborundum.

To allow the detector to be used most efficiently, a good tuning arrangement must be used. For broadcasting, perhaps the most efficient and simple arrangement would be a well-made variometer of the moulded ball-and-shell type, like the Igranic or Edison Bell variometers. Fig. 55 shows the circuit diagram.

Fig. 56 shows the crystal circuit for a coil tapped in tens and units, and Fig. 57 the circuit when using a tapped inductance coil. "A" in all three circuits is a plug for a plug-in loading coil. In the circuit shown in Fig. 56 a ·0002 mfd. variable condenser is used, and in Fig. 57 a ·00035 or ·0005 variable condenser.

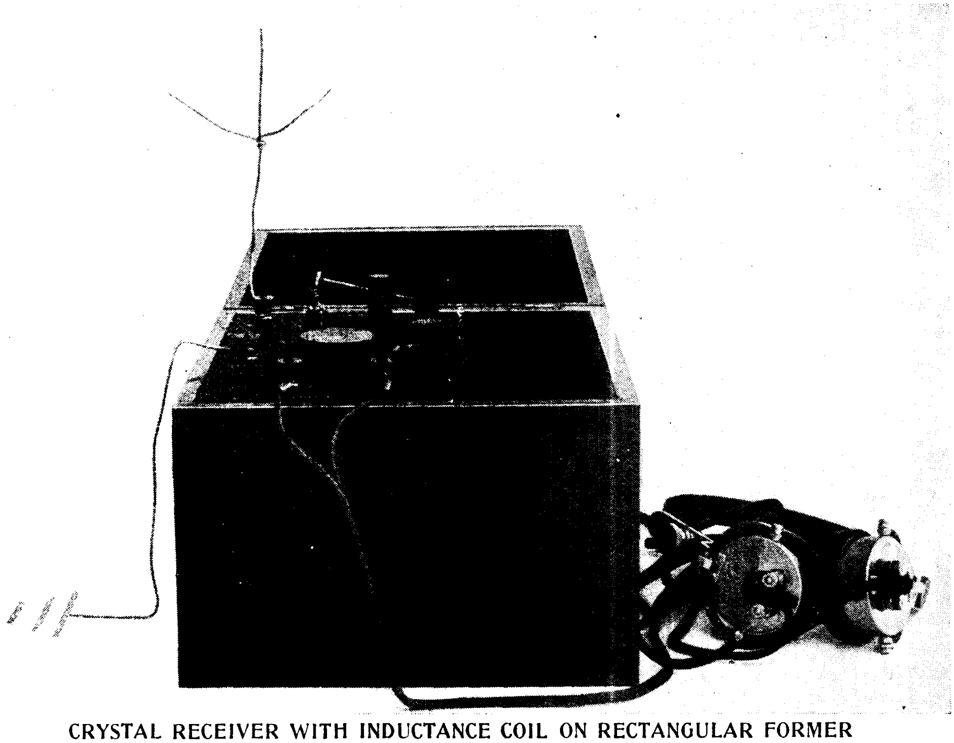
For a tuner for short broadcasting wavelengths, basket coils wound with 25 to 30 turns each and three or more coils connected to make up the required number of turns will be most convenient. The coils should be mounted on the panel as shown in Figs. 51 and 54, taking care that all the windings run in the same direction and that the inside end of one coil is connected to the outside end of the next coil, *i.e.* in series. It would be best to make the first ten turns wound on a basket coil the unit taps in a tens and unit system. In wiring up, care should be taken to make good connexions by soldering wherever possible. Fig. 53 shows the method of tapping.

Slider and Coil Tuned Crystal Set. The set shown in Fig. 58 is one of the simplest types of receiving sets, and gives excellent results within ten miles of a broadcasting station.

The set is enclosed in a mahogany case with a hinged lid. A baize-lined partition permits of storage of the telephones when not in use. An ebonite panel is used, and this is fitted on the exterior with four terminals and a plain type of cat's-whisker detector, and tuning is controlled with a knob. The set is shown complete in Fig. 58, and a detail of the underside of the panel in Fig. 59, which shows how simple is the set.

The inductance is a coil of No. 22 gauge enamelled wire wound around a rectangular former made from a piece of hardwood. This is well impregnated with hot paraffin wax both before and after the winding to ensure perfect insulation and to render the wood less susceptible to atmospheric influences.

The former, when it has been wound, is attached to the underside of the panel by means of four screws passed through from the exterior and through hollow



CRYSTAL RECEIVER WITH INDUCTANCE COIL ON RECTANGULAR FORMER

Fig. 58. No. 22 gauge enamelled wire is wound on a rectangular hardwood former for this crystal receiving set. Simple though it is, excellent results can be obtained within ten miles of a broadcasting station. The compartment for the telephones is lined with baize. A deep lid enables the whole set to be closed up when not in use

ebonite bushing about ½ in. high. This is to raise the windings above the level of the panel, to allow of the free movement of the contact arm. The latter is attached at one end to the spindle, which passes through the panel and is attached to the control knob at the outer end. The contact arm is a strip of brass about ½ in. wide and tapered a little at the outer end. It is then bent over to form a contact face, and this bears on a path formed on the winding by holding a piece of emery paper on the end of the contact arm and then moving it to and fro until the emery paper has rubbed the insulation from the wire. The path ought to be perfectly clean when this has been done, as otherwise there will be a considerable loss of signal strength. The contact arm is secured to the spindle with two nuts and then soldered.

Connexions are simple, and made with No. 18 tinned copper wire covered with systoflex or rubber tubing. One wire goes from the aerial terminal to the inductance winding, and another from the same terminal to the crystal. Another wire is taken from the other terminal of the crystal to one of the telephone terminals, and from the second telephone terminal to the earth terminal. A wire is also connected from the contact arm near to the spindle and taken to the earth terminal.

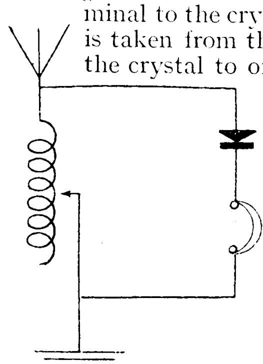
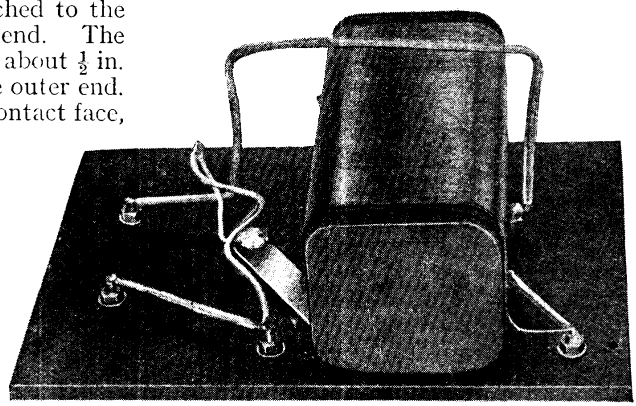


Fig. 60. Theoretical wiring diagram for simple crystal set with rectangular inductance coil. *See also* Fig. 59.

All these connexions should be properly soldered. When the wiring is complete the panel is screwed to the case, the aerial and earth connexions made and the telephones connected to the two telephone terminals. The crystal should then be adjusted so that the cat's-whisker is just touching the crystal, and the knob is then turned slowly until signals are heard.

A pointer can be fitted to the knob and the panel graduated so that the best setting can be noted for future use. Two stop pegs are fitted to the top of the panel to limit the travel of the pointer and thereby to limit the stroke of the contact arm. If it is not so protected the arm might be



RECTANGULAR INDUCTANCE COIL

Fig. 59. Fized to the underside of the panel of the set shown in Fig. 58, is the rectangular coil shown above. The former is a solid piece of wood. It is easy to follow the wiring in this photograph

turned beyond the length of the coil, and this would necessitate removal of the panel and a readjustment of the contact arm, as this has to make a good contact at all points on the coil. Fig. 60 shows the wiring diagram for the set.

Crystal Set with Variometer Tuning. The set shown in Fig. 61 is built up into a hinged lid cabinet, and makes an effective and fairly selective unit. The tuning is carried out with a plain variometer of a type that can be purchased ready for use at most dealers in wireless appliances. The complete set, wired up ready for use, is shown in Fig. 61, the aerial and earth terminals being represented as connected to the aerial and earth by the standard symbols.

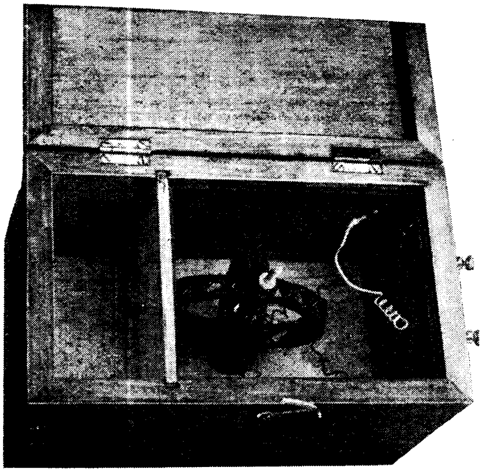
It will be seen that the connexions are all made to terminals on the end of the cabinet, the lower two for the telephones and the others for the aerial and earth leads.

The cabinet can be made as described under the heading Cabinets. The telephones should be of at least 2,000 and preferably 4,000 ohms resistance.

A partition is left in the cabinet for the reception of the telephones; the other part is enclosed with an ebonite panel. This has to be drilled to accommodate the enclosed type of crystal detector, which is shown screwed to the top right-hand side of the panel with round-headed brass screws tapped into holes in the panel. The lower ends of the screws have wires soldered to them, and they are connected to the aerial and one of the telephone terminals respectively. The variometer is simply placed in the case (Fig. 62) and the lower end of the spindle arranged to turn in an ebonite bush screwed to the bottom of the case.

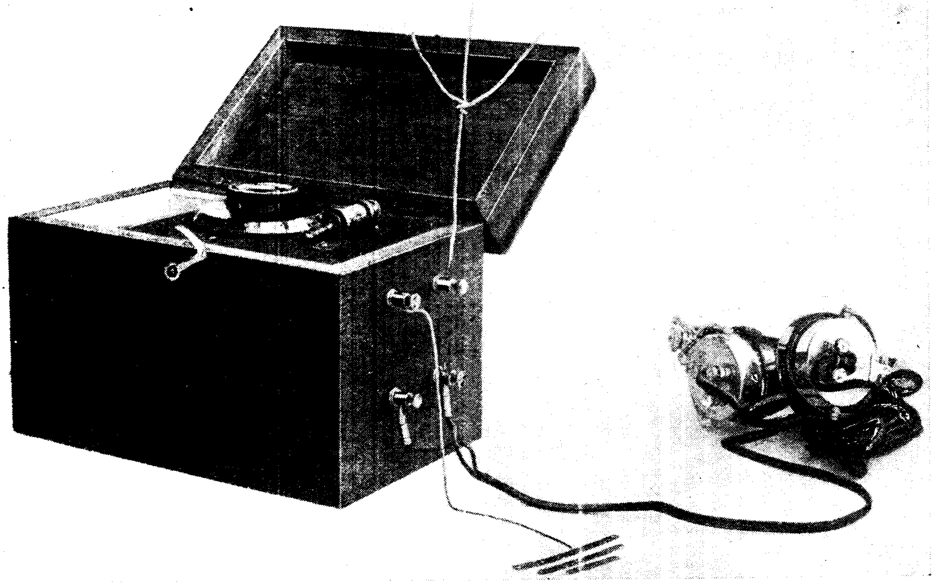
The side of the variometer winding is steadied by means of two blocks of wood screwed to the inner side of the case. These blocks are only to keep the windings from moving when the rotor is turned. On some makes of variometer there is no need to do this, as the appliance is made up with a stand or special fixing which will only have to be secured in place in the case.

The protruding spindle is then passed through a hole drilled for the purpose in the panel. The hole is preferably bushed with a brass tube to prevent undue wear on the panel. A knob and dial should be fitted to the outer end of the spindle. The wires should then be fitted to the remaining terminals, and if they be long enough the panel can be turned up on one side of the case, as shown in Fig. 63, in order to facilitate the making of the connexions. The wires can be secured with nuts as shown in the illustration, or the connexions made by soldering, which is by far the best plan, the resulting signals being louder.



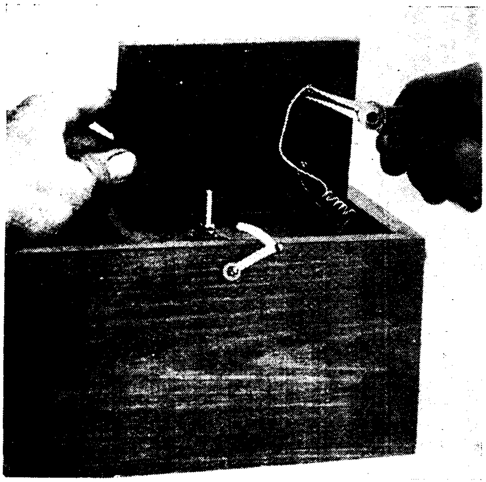
LATTICE-WOUND VARIOMETER

Fig. 62. Inside the cabinet is mounted the lattice-wound variometer, which is fixed between the bottom of the chamber and the panel. The rotor is operated by the turning knob seen in Fig. 61



COMPLETE LATTICE-WOUND VARIOMETER CRYSTAL RECEIVER

Fig. 61. Four terminals for the aerial and earth and telephone connexions are placed on the side of the cabinet in this set. The lid is sufficiently deep to accommodate the variometer turning knob and disk and the crystal detector, which are mounted on top of the panel. A compartment is provided for the telephones when not in use



WIRING VARIOMETER TO PANEL

Fig. 63. Inside the cabinet is the variometer. The panel is raised, and the nut which holds the connecting wire to the variometer terminal is being tightened. Sufficient length of wire is allowed to enable the panel to be moved without straining the wire

The connexions are completed by attaching one wire from the variometer to the aerial terminal and the other wire to the earth terminal. The remaining telephone terminal is connected to earth also.

The theoretical circuit diagram is the same as that shown in Fig. 46.

Crystal Set in a Cabinet. A very neat arrangement is shown in Figs. 64 and 65, where the whole of the apparatus is enclosed in a vertical cabinet. The interior is illustrated in Fig. 65, which shows the appearance of the set when the door is opened, while a back of panel view is given in Fig. 66, which shows the disposition of the parts. A shelf is fitted to the cabinet to form a division for storage of the telephones when not in use.

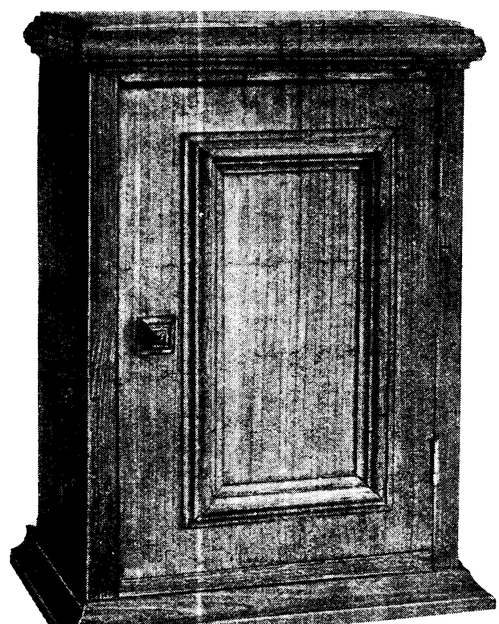
The cabinet can be made from hard or soft wood as desired, and on the lines described in the article on cabinets. The general lines on which it can be made are to make it as if it were a plain box and then apply the mouldings to the top and the base.

The back of the case is screwed to the sides with brass wood screws, so that it can be removed whenever necessary without much trouble. The door can be a plain piece of timber, or may be framed up as desired, but quite good results are obtained from the simpler method, especially when relieved with a moulding as shown in Fig. 64.

An ebonite panel is cut to fit closely into the cabinet in the space above the shelf, and on this is mounted the aerial tuning inductance, in this case a tapped inductance coil. Fine tuning is accomplished by the aid of a variable air condenser shunted across the aerial tuning inductance in the usual way. An enclosed type of crystal detector is screwed to the face of the panel at the right of the inductance. The circuit diagram is given in Fig. 67.

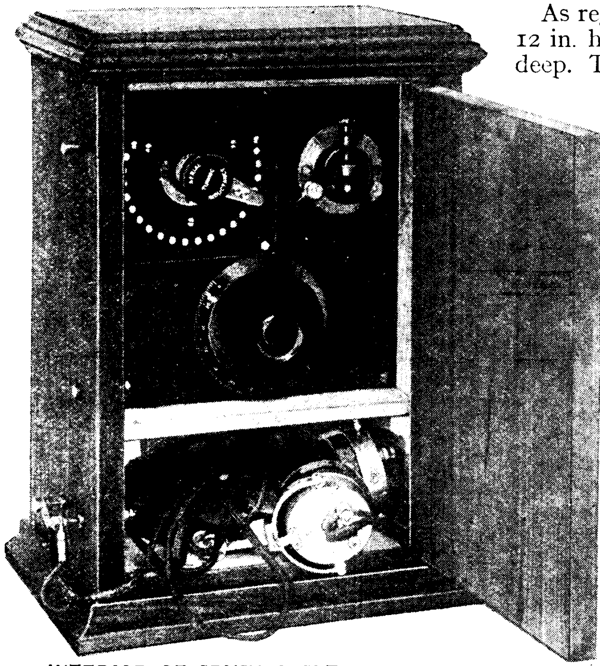
One special feature is the use of plug-in contacts for the aerial and earth connexions and for the telephones. These are made from ordinary valve legs, and the latter are embedded into the sides of the cabinet and connexions made to the screwed shanks in the usual way. The telephone leads are attached to the valve legs by a pair of lock nuts, and the exterior preferably covered with insulating tape. This has been omitted in the illustration, Fig. 65, to permit the details to show.

To tune the set, the aerial tuning inductance is turned until a signal is heard, then the crystal is adjusted until the loudest signals are heard, and final tuning accomplished with the condenser, which may have a value of ·0005 mfd.



UPRIGHT CABINET FOR CRYSTAL SET

Fig. 64. Plain deal is used in making this cabinet, which opens on the cupboard principle. The applied mouldings and staining give it an excellent appearance



INTERIOR OF CRYSTAL SET CABINET

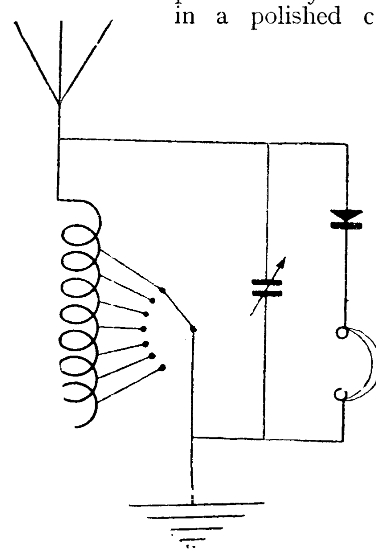
Fig. 65. Inside the cabinet is the panel with crystal detector, A.T.I. switch in left top corner, and condenser dial in centre. Note the plug-in sockets on the side of the cabinet

BACK VIEW OF CABINET

Fig. 66. Behind the panel are the aerial tuning inductance and the variable condenser, with their wiring. Note the panel supports

As regards size, the cabinet can measure 12 in. high and $7\frac{1}{2}$ in. wide and some 6 in. deep. This will permit of easy accommodation of all the parts, but these sizes may have to be modified to suit any existing apparatus. Naturally, the tuning arrangements can be altered to suit any special conditions. The set can be closed up when listening-in has finished without the need of detaching any vital connexions or altering the setting of the crystal. The set once tuned to a particular broadcasting station need not be touched, as the aerial and earth leads are simply plugged in to their respective sockets, and the same applies to the telephones.

Carborundum Set. The construction of a carborundum set is recommended where the set is liable to vibrations which would disturb the adjustment of the ordinary cat's-whisker or double crystal type. Such a set will be one well worth experimenting with by the amateur. The set complete is shown in Fig. 68, mounted on a baseboard, and the lay-out allows of complete accessibility. When the principles and the working of the set are well understood, the components may be housed in a polished cabinet



CIRCUIT USED FOR CABINET SET

Fig. 67. Above is given the theoretical circuit diagram of the apparatus used in the cabinet seen in Fig. 65

with ebonite panel, according to the ideas of the experimenter. Materials required comprise:

Carborundum detector and crystal.
Potentiometer of 250 ohms resistance.
Variable air condenser, ·0005 mfd. capacity.
Igranic or similar coil, and coil-holder.
Pocket flash-lamp battery of $4\frac{1}{2}$ volts and switch.
Four terminals.
Baseboard 17 in. by 6 in. by $\frac{5}{8}$ in.

The components are arranged on the board as shown in the plan view of the completed set in Fig. 69. The coil-holder is mounted on the baseboard by two right-angle brass brackets, and the battery is secured by a brass strip held down to the case by two wood screws, as shown in Fig. 70. The method of mounting the detector must be left to the experimenter, as the method employed depends on the instrument itself. The detector used in the set described has a round base $1\frac{1}{2}$ in. in diameter. This is dropped into a corresponding hole cut into the base. The aerial and earth terminals are seen in Fig. 69, between the tuning coil and tuning condenser.

It is the object in wireless work to make all wiring as short and as straight as

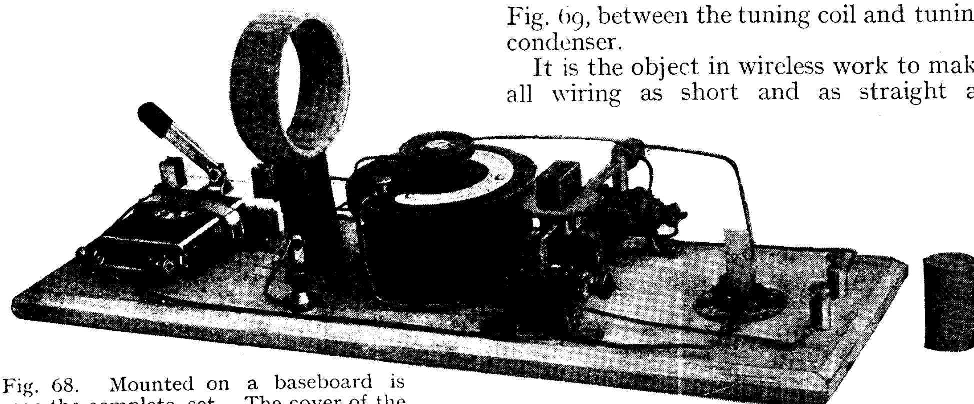


Fig. 68. Mounted on a baseboard is seen the complete set. The cover of the carborundum crystal detector is removed

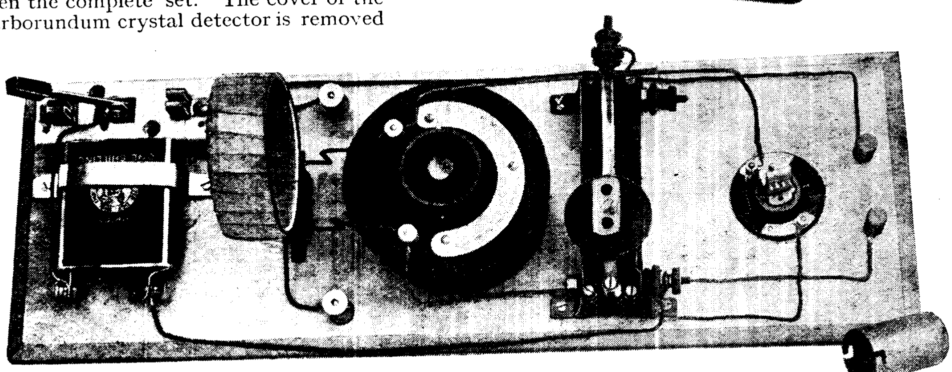


Fig. 69. On the left will be seen the dry battery which provides the potential required for the carborundum detector

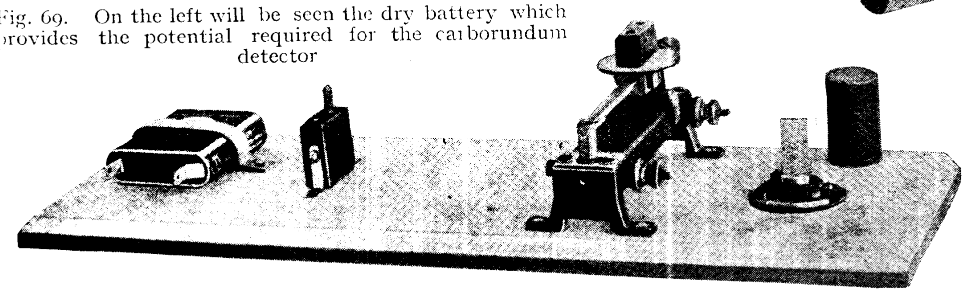
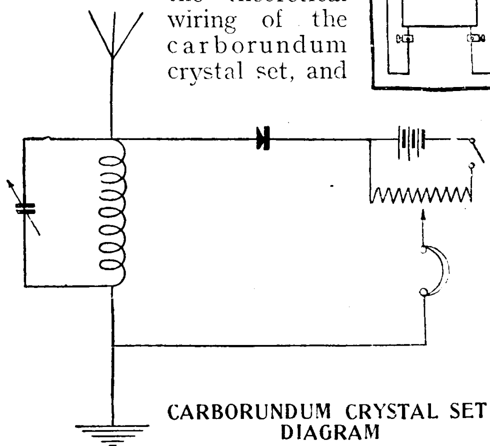


Fig. 70. Some of the components removed to show clearly the potentiometer used, with the carborundum detector, seen on the right with cover removed. Near the flash-lamp battery is the plug-in holder for the inductance coil, seen mounted in the top photograph

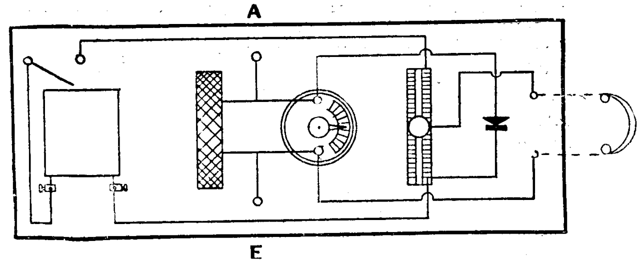
CARBORUNDUM CRYSTAL SET WITH BATTERY AND POTENTIOMETER possible. It is for this reason the terminals mentioned are placed as near as possible to the components to which they are connected. Fig. 71 shows the theoretical wiring of the carborundum crystal set, and



CARBORUNDUM CRYSTAL SET DIAGRAM

Fig. 71. Circuit arrangement of the carborundum crystal set is here shown diagrammatically

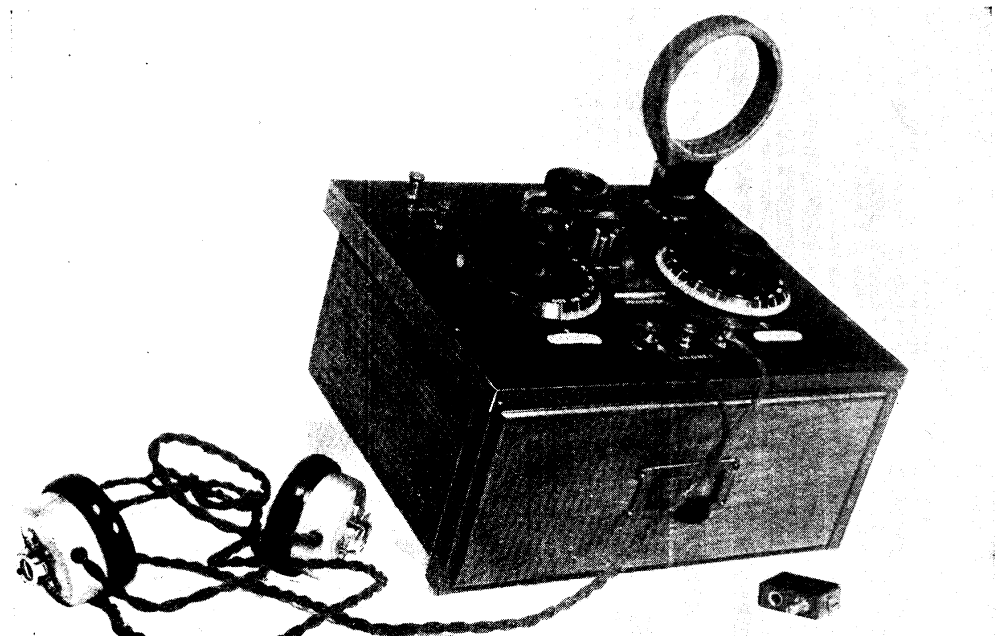
in Fig. 72 this wiring is shown diagrammatically. Unless a switch is inserted, the battery will run itself down through the windings of the potentiometer. The



WIRING OF CARBORUNDUM CRYSTAL SET

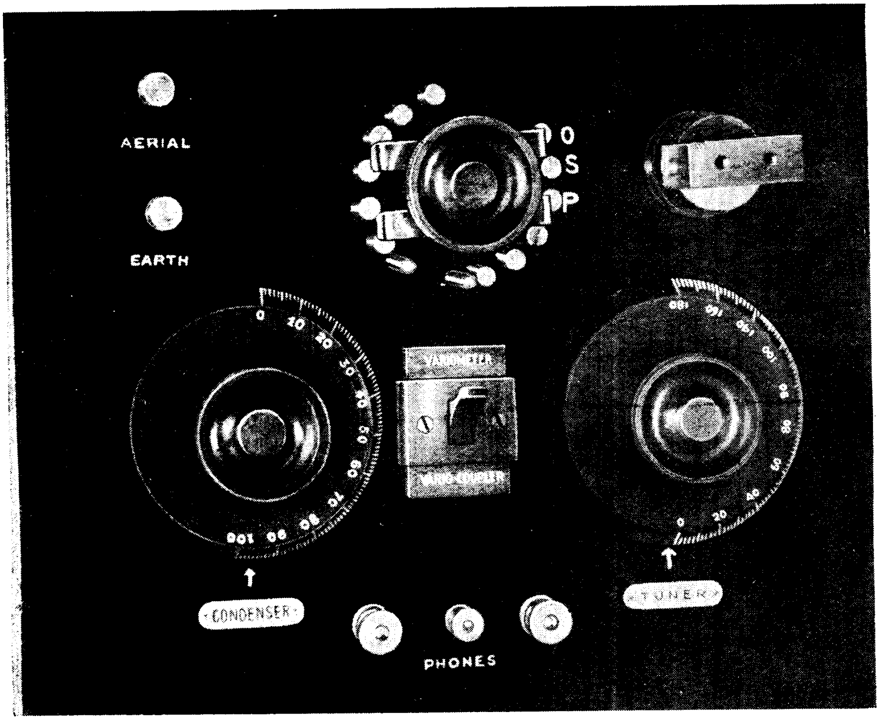
Fig. 72. Laid out on a baseboard are the details of the set, with the flash-lamp battery indicated by a square with terminals at the leads. A and E are aerial and earth terminals

aerial tuning coil used depends on the wave-length it is desired to receive. For British broadcasting a Burndept No. 2½ coil is suitable, or a No. 35 or 50 Igranic coil, shunted by the ·0005 condenser. In operating the instrument it should be first made certain that the steel arm of the detector is firmly pressed on the crystal. Aerial, earth, and telephones are connected up, and the correct duo-lateral coil for the wave-length of the station to be received is inserted in the coil holder. The battery switch is closed, and sweeping, or searching for signals is commenced.



COMBINATION CRYSTAL RECEIVING SET FOR EXPERIMENTERS

Fig. 73. This set, by means of a series-parallel switch for the condenser, Dewar switch for variometer or vario-coupler, and plug for loading coils, enables the circuit to be rearranged in twelve different ways without altering the wiring



PANEL OF EXPERIMENTAL CRYSTAL SET

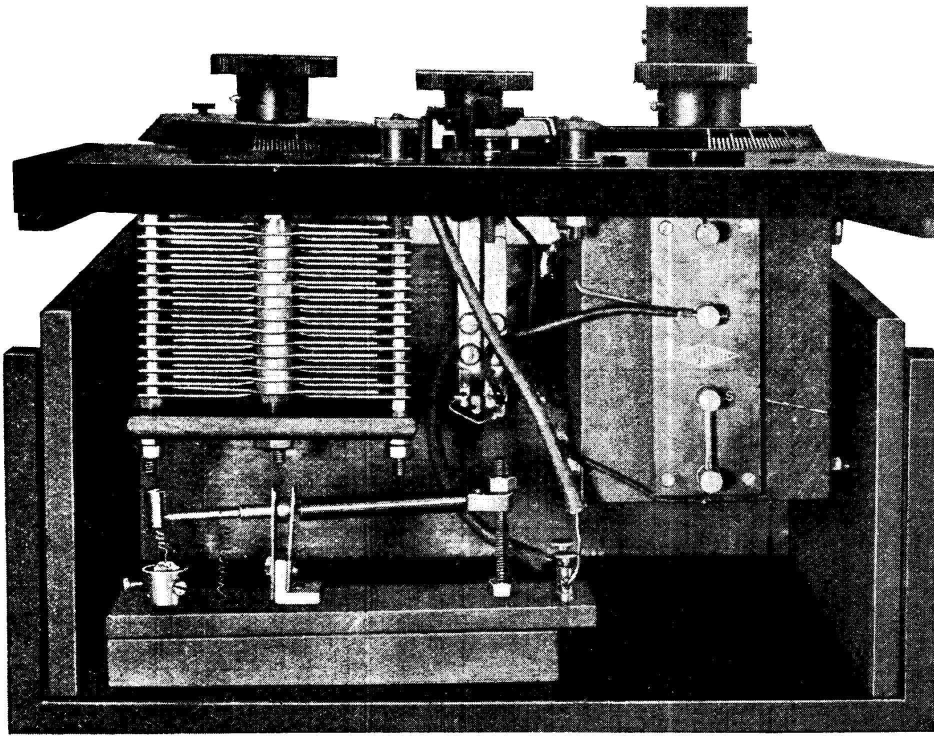
Fig. 74. The series of controls mounted on top of the panel are clearly seen in this photograph. The rotary switch gives three positions for the condenser. O = condenser out, P = parallel, and S = series. A Dewar switch gives variometer or vario-coupler tuning. The shorting plug is in place, cutting out coils

This consists of slow rotation of the variable condenser, and possibly the substitution of plug-in coils, for a slightly higher or lower wave-length. When a signal has been received the condenser setting should be left, and attention concentrated on finding the best voltage for the particular piece of carborundum in use. This is effected by slow movement of the potentiometer slider knob. The position of the slider knob shown in Figs. 68 and 69 indicates roughly the correct setting when a battery of $4\frac{1}{2}$ volts is used in conjunction with a potentiometer resistance of 250 ohms. An adjustment of the detector itself is now made to ensure a good spot, and to find the correct pressure of the steel spring on the crystal. The battery switch must be left open after use, to avoid running down the battery.

Combination Set for Experimenters. The combination crystal set shown in Fig. 73 gives, by means of two switches and a plug for loading coils, the possibilities of twelve different arrangements of the circuit without any rewiring. The panel, with its switches and terminals, is seen in Fig. 74, and its lay-out in Fig. 77.

By means of the series-parallel switch the variable condenser can be: (1) cut out altogether; (2) placed in series with the earth lead; (3) placed in parallel with the earth and aerial leads. The three positions are marked O, S, and P respectively on the panel (Fig. 74). The Dewar switch, seen in the centre, controls the inductance either as variometer or vario-coupler. Any other form of double-pole, double-throw switch can, of course, be used. A barrel switch or an anti-capacity switch (the making of which is described on page 115) would be suitable. If the set is to be used as a tuning unit in connexion with an amplifier it will be well to use an anti-capacity switch, the extra space required being allowed for on the panel. When a loading coil is not required a shorting plug is used (Fig. 74).

These different arrangements, with suitable loading coils, permit the experimenter to cover a very considerable range of wave-lengths, from 150 metres upwards.



INTERIOR VIEW OF EXPERIMENTAL CRYSTAL SET

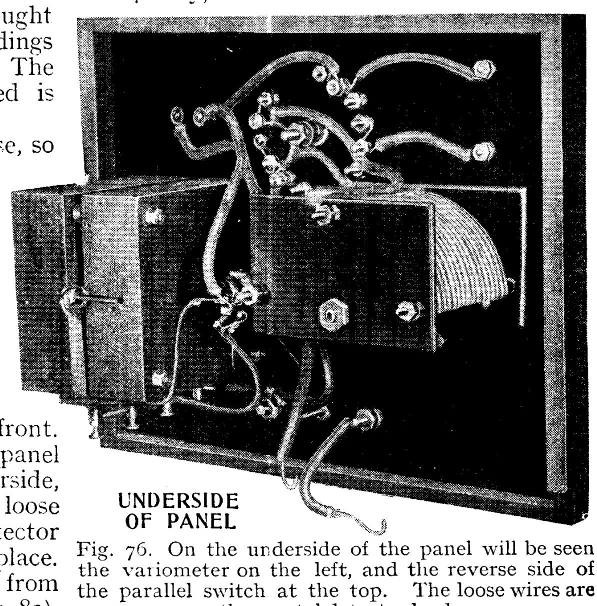
Fig. 75. Front removed to show the interior. The panel is also raised, and the way in which the components are accommodated in the space available will be seen. In the foreground is the crystal detector. The method of securing the panel without screws, which facilitates easy inspection or alteration of the interior, is seen more clearly in Fig. 76

Underneath the panel (Fig. 76) are fixed a variable condenser, ·0005 mfd., and a variometer, with its four leads brought to outside terminals so that its windings can be used in series or parallel. The one used in the set photographed is made by the Peto-Scott Co.

The panel is not fixed to the case, so that it can not only be wired up with ease, but can be removed at any time without disturbing the wiring. It is kept in place by means of $\frac{3}{8}$ in. wood strips screwed or nailed through the panel at the edges of the two sides and the back, the panel being cut $\frac{7}{16}$ in. wider than the case on each side to allow for these strips. The detector is fixed to the bottom of the case in front.

Dimensions and lay-out of the panel are given in Fig. 78, and its underside, with the wiring, in Fig 77, the two loose leads being connected to the detector terminals when the panel is in place. The wiring can also be followed from the theoretical circuit diagram (Fig. 81).

Connexions to the Dewar (or the anti-capacity) switch should be soldered, but



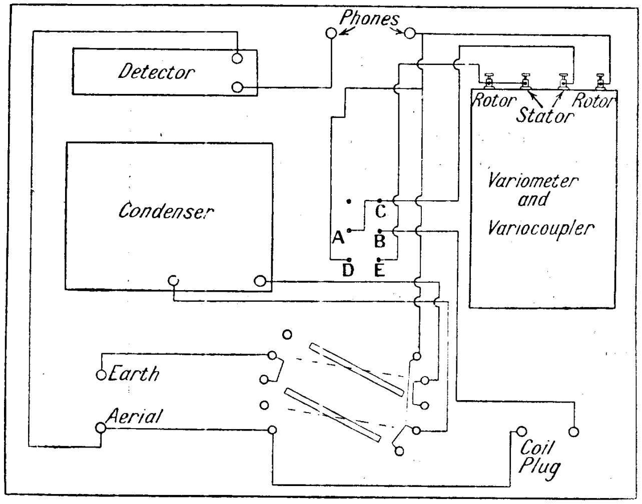
UNDERSIDE OF PANEL

Fig. 76. On the underside of the panel will be seen the variometer on the left, and the reverse side of the parallel switch at the top. The loose wires are the crystal detector leads

others can be made in the ordinary way if a fairly heavy gauge wire is used and the nuts screwed down dead tight on the terminals with pliers or a small spanner.

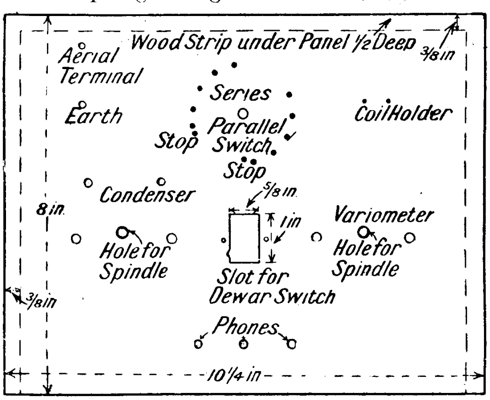
Any type of detector can, of course, be used. That shown in the photograph (Fig. 80) has advantages in simplicity of construction and adjustment. A detector arm, with a ball-bearing upright and an ebonite tube handle, is purchased together with a cup. Into the free end of the ebonite tube a small screw eye is fastened. The eye should be just large enough to slide loosely over a 4 B.A. or 6 B.A. threaded rod. The parts are assembled on a strip of ebonite, as shown in the photograph, a coiled spring being attached at the whisker end and adjustment provided by means of a nut or terminal on the upright rod on which the screw eye slides.

By this means one of the principal objections to the cat's-whisker is overcome. The fine adjustment which is so important is more easily obtained than by the ordinary hand method, and, once adjusted, the whisker is not disturbed by vibration, as is usually the case. The loose fitting of the screw eye on the upright rod, with the universal ball-bearing movement, allows



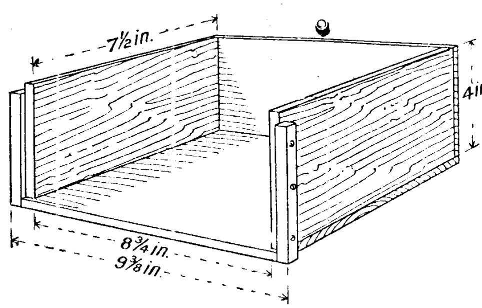
HOW THE PANEL IS WIRED

Fig. 77. Underside of panel, showing all leads. The aerial lead is taken in two directions, one way to the crystal detector, and the other to one stud of the switch and then to the plug-in coil, so that the condenser may be in series or parallel. A, B, C, D, E are Dewar switch connexions



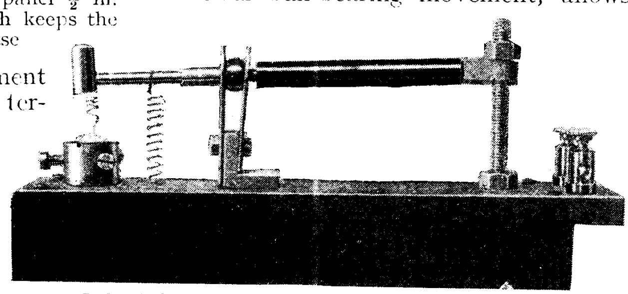
DIMENSIONS OF PANEL

Fig. 78. Dimensions are given as for the top of the panel, not as it is represented in Fig. 77. There is a wood strip under the panel ½ in. deep, shown in this diagram, which keeps the panel in position on the case



CASE DETAILS

Fig. 79. The case consists of the three sides, bottom, and extra pieces at the open edges. They are screwed together



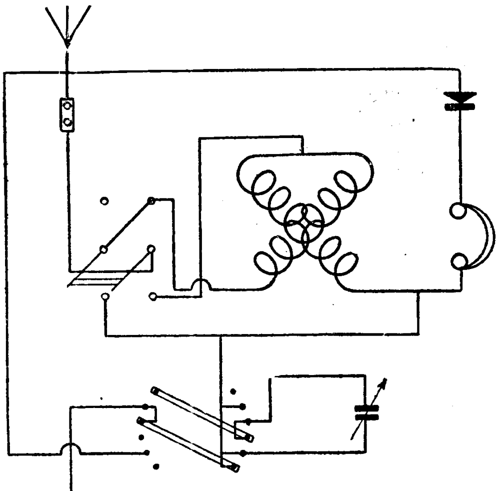
CRYSTAL DETECTOR OF EXPERIMENTAL SET

Fig. 80. Adjustment is easily made in this form of detector. A spring is fitted to the arm, and a nut on the control pillar. By this means the cat's-whisker is maintained in delicate but firm contact. Once set, it is not easily disturbed

all parts of a crystal to be searched. Adjustment will be finer if the ebonite rod is kept short and a 6 B.A. threaded rod used. The coiled spring should be fairly light. If its tension is too great it will not allow sufficient side play in searching for sensitive spots on the crystal.

The detector is wired on the underside of the ebonite strip and, to keep the wires clear of the bottom of the case, it is mounted on two ⅜ in. wood strips.

The case is very simply made, and consists of three sides and a base, screwed together, the dimensions being given in Fig. 79. The panel fits on to the case without any fastening (Fig. 75). The case is completed with a front panel made to fit in the front of the case (Fig. 73), kept in position by being made a fairly tight fit. If desired, it can be held in place by one screw, but as easy access to the detector is necessary for occasional adjustment, it is better to make it friction-tight.



EXPERIMENTAL SET CIRCUIT

Fig. 81. In the aerial lead is a plug-in coil base in which a loading coil or shorting plug can be inserted. The condenser may be cut out or put in series or parallel, and the variometer or vario-coupler is available by switching

CRYSTAL RECEIVERS: (3) ADDING AMPLIFICATION

How to Make Crystal Sets with Valve Amplifiers

In the following pages methods are described for adding high- and low-frequency amplification to crystal sets. The reader is also advised to consult the articles on High Frequency, Low Frequency, and Amplifiers if he wishes to construct any set not described in these pages. To obtain a thorough grasp of the subject he should also consult such cognate articles as Capacity, Condenser, Inductance, Transformer, Valve

Amplification to some extent is always possible by the simple addition of a valve, with the necessary tuning arrangements, batteries, etc., the circuit being ultimately connected to the aerial and earth sides of the crystal set. This method will function if the crystal set is well insulated so that the high-tension current cannot leak across the surface. When adding high or low frequency, but especially the former, polished ebonite should not be used, but must be matted. If wood be used, it must be dry or the parts separately insulated from it by ebonite or other suitable means. The crystal set should be able to tune independently on wave-lengths about 30 per cent higher than may be required.

H.F. amplification is also possible with inductively coupled circuits in which the tuning arrangements of the crystal set are coupled to those of the H.F. set. This will almost always mean altering the constructive arrangements of the crystal set.

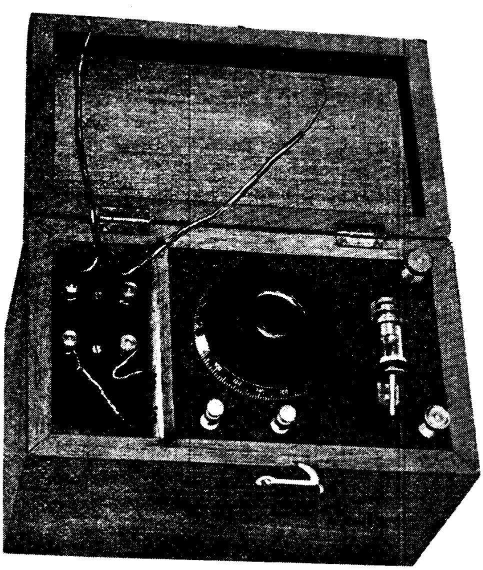
L.F. amplification is applicable to any crystal set. If the crystal set is to be combined with H.F. and L.F. it should have two entirely and completely separate circuits, one for the H.F. and the other for the L.F., preferably each with its own batteries. This appears the most practical method for the amateur.

It is a common practice in many types of commercially made crystal receiving sets to include a space at the side or at the bottom of the panel for the insertion of the telephones when the set is not in use. This space may very conveniently be used for the addition of a low-frequency amplifier when it is desired to increase the strength of signals or to place a larger number of telephones in the circuit. The alteration may be carried out without any fear of upsetting the working or structure of the crystal set itself.

Unscrew the panel from the cabinet and remove it from the box. The two wires connected to the telephone terminals are disconnected and another foot of wire added to each. This is best done by soldering, but if this is not convenient, clean the wires and twist them very tightly together with a pair of pliers to ensure perfect contact. They are covered with cycle valve rubber or insulated sleeving, and carried through two holes drilled in the side partition. An iron core low-frequency transformer is screwed to the base of the cabinet at the back. The wires projecting through the partition are subsequently connected to the primary terminals of the transformer.

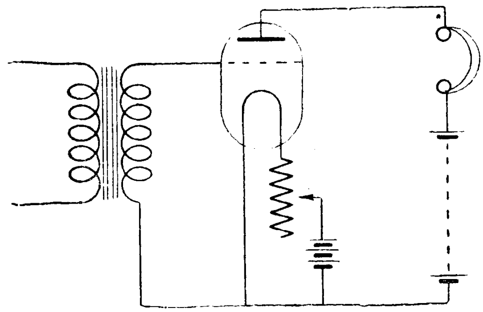
Fig. 82 shows the construction up to the present stage. A panel of ebonite is cut and filed to fit the space. This is held in position by four strips of wood glued and tacked to the walls of the cabinet so that the new panel will come flush with the other. Four small countersunk holes are drilled, one at each corner, for screwing in position when completed. A filament resistance is attached to the panel on the underside, and behind this a valve holder is mounted. At any convenient position three terminals for connexion to high and low tension battery are screwed to the panel.

All the components are now assembled, and wiring should preferably be carried out with a stranded flex wire, as there is a possibility of a single wire being broken off in fitting or removing the panel top. Two more holes are drilled in the side partition and two short lengths of wire



LOW FREQUENCY AND CRYSTAL DETECTOR

Fig. 82. Fitted into the telephone recess of the cabinet of this crystal receiver is a low-frequency transformer. The primary winding of the transformer is connected to the original telephone output. The two free wires of the transformer secondary are joined to the grid and low-tension negative terminal

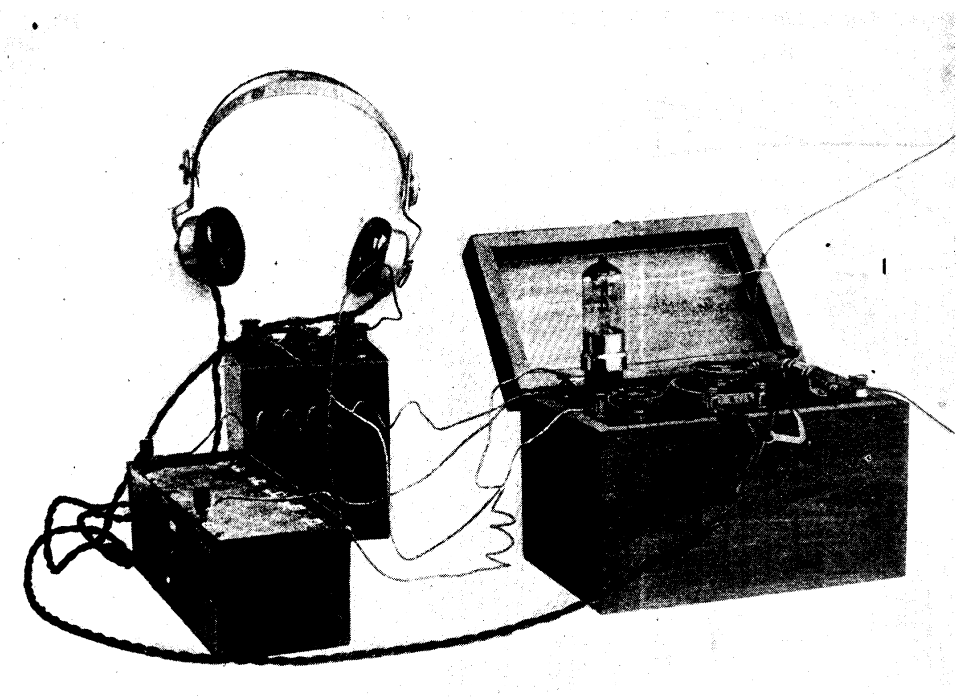


TRANSFORMER-COUPLED CRYSTAL DETECTOR

Fig. 83. By the employment of a transformer, as here shown, the crystal receiver can be joined to a valve amplifier. Such a set is shown in Figs. 82 and 84

attached to the now disconnected telephone terminals of the crystal receiver. These terminals still remain for the same purpose as telephone terminals. The free end of the one wire is connected to the anode leg of the valve holder, and the other wire to the predetermined high-tension terminal. Of the two disconnected terminals of the transformer, the one marked " OS " or " S_2 " is joined to the grid leg of the valve holder and the other terminal to the high-tension negative terminal. The same terminal is used for low-tension negative, and is connected to either valve holder leg of the filament. The remaining leg is joined to the moving arm of the filament resistance, the circuit being completed on connecting the end of the resistance coil to the low-tension positive. This wiring should be checked by the wiring diagram shown from the back of the panel in Fig. 85, and also from the circuit diagram shown in Fig. 83.

The risk of burning out a valve by wrongly connecting the batteries is minimized by marking the terminals. The following method of engraving the lettering gives a well-finished appearance. Procure an old screwdriver, or similar blunt-ended tool, and file up to the size of the engraving on the crystal set. If it is not engraved, the experimenter may judge his own size. The screwdriver is warmed a little and pressed into the ebonite, causing a slight depression, the depth being dependent upon the heat of the tool and the pressure applied. The groove thus made is shown up by filling in with white wax, chalk, or white enamel. Fortunately, all the letters and signs required consist of straight lines and can easily be made. A little practice on

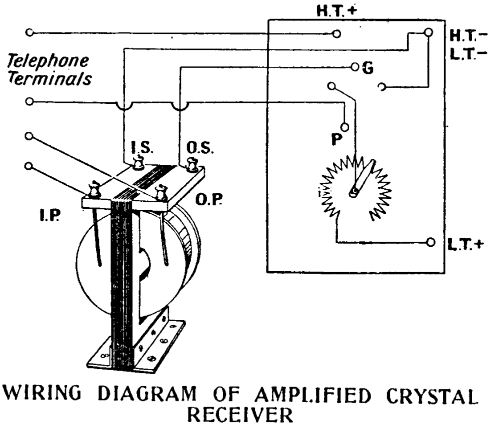


COMPLETE CRYSTAL RECEIVER WITH LOW-FREQUENCY AMPLIFICATION

Fig. 84. In the telephone recess of the original crystal receiver is fitted a low-frequency transformer and a panel on which is mounted a valve and filament resistance. The complete set is here shown joined up with the low-tension accumulator and a high-tension battery with wander plugs. The crystal detector circuit remains unchanged

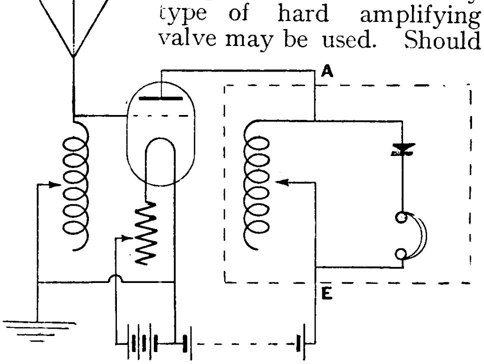
scrap ebonite will soon discover the amount of heat and pressure required.

Both the new unit panel and the crystal set panel are now screwed down into position and the set is then ready for operation. This is shown in Fig. 84. Telephones of high resistance are required, and those used in conjunction with the crystal set will be found quite suitable. The tuning of the set will be found exactly the same as before. The signal strength will be increased from three to four times the previous volume. Any type of hard amplifying valve may be used. Should



WIRING DIAGRAM OF AMPLIFIED CRYSTAL RECEIVER

Fig. 85. Wiring of the panel on which the valve in Fig. 84 is mounted is here shown. Beneath the telephone terminals will be seen two other terminals, which originally were the telephone terminals of the crystal set



ADDING HIGH-FREQUENCY AMPLIFICATION

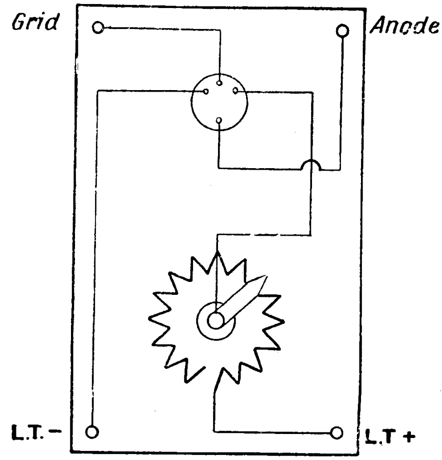
Fig. 86. High frequency is employed in this circuit, with the aerial tuning system to tune the anode of the valve. In this case no alteration is made to the crystal set, shown within dotted lines

extra loud volume be required sufficient to operate a loud speaker, if near enough to a broadcasting station, a power valve taking a large anode current may be used in conjunction with extra high and low tension voltage.

Adding High-Frequency Amplification. The range of a crystal set can be very much increased by the addition of high-frequency amplification.

It will be seen from the circuit diagram in Fig. 86 that two entirely separate tuning circuits exist. The inductance coil on the left is the aerial tuning circuit, and the wiring shown in the dotted square shows the anode tuning coil with crystal and telephones. This wiring is exactly the same as a crystal receiver, and by using its aerial tuning system for tuning the anode of the high-frequency valve no alterations whatever are needed to the crystal set. The aerial tuning connects to anode, and the earth to high-tension positive.

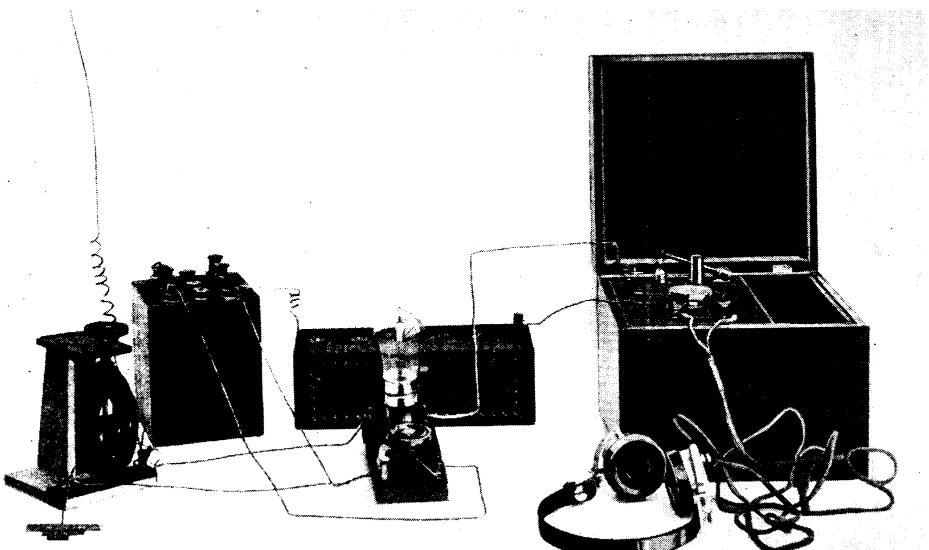
An ebonite panel is cut about 6 in. by 2½ in., on which are mounted a valve holder, a filament resistance, and four terminals. The anode valve leg is connected to the top right-hand terminal, and the grid to the left-hand top terminal. Low-tension negative joins one filament valve leg direct, while the positive low-tension terminal goes to the remaining valve leg through the filament resistance. Fig. 87 shows the wiring of the panel from the top side, on which side also, for the sake of simplicity, is put the filament resistance. Any type of hard valve would be suitable, but best results are obtained from a valve specially designed for high-frequency amplification, such as the Cossor Red Top.



VALVE WIRING FOR CRYSTAL AMPLIFIER

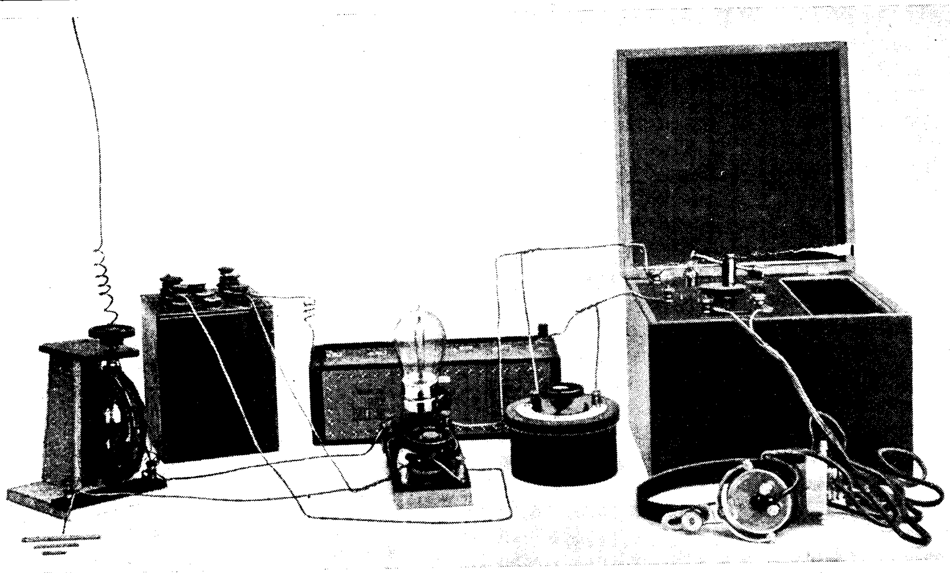
Fig. 87. The four connexions of the valve are shown in this diagram. One filament lead is connected in the usual way to a rheostat

Fig. 88 shows the lay-out of a set comprising a variometer for aerial tuning from



ADDING HIGH-FREQUENCY AMPLIFICATION TO A CRYSTAL RECEIVER

Fig. 88. Added to the original standard B.B.C. crystal circuit is another circuit employing the lattice-wound variometer seen on the left, high- and low-tension batteries, a rheostat, and one valve. The original aerial and earth connexions of the crystal set are, in this case, joined to the plate or anode of the valve and the high-tension positive respectively

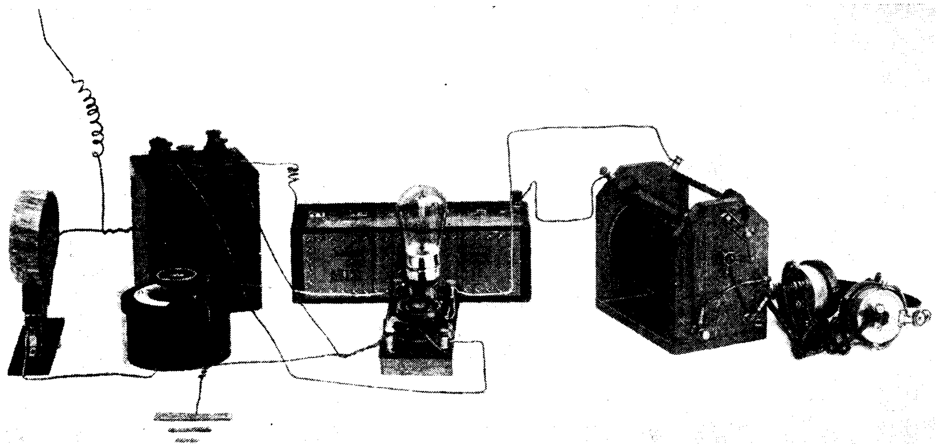


HIGH-FREQUENCY CRYSTAL AMPLIFIER WITH CONDENSER ADDED

Fig. 89. In this illustration a ·0005 variable air condenser is seen shunted across the anode inductance to bring up the wave-length to equal the combined wave-lengths of the aerial tuning inductance and the fundamental aerial wave-length. In other respects this circuit is the same as in Fig. 88

the aerial terminal of which a wire is taken to the grid terminal of the valve. The earth terminal of the variometer connects to low-tension negative terminal of panel and accumulator, and also to high-tension negative. The filament circuit is completed by wiring the low-tension positive to its correct terminal on the panel. Telephones are joined to the terminals they occupied when the crystal set was used by itself. Aerial and earth terminals are connected respectively to anode of valve and high-tension positive.

The operation of tuning presents some difficulty at first, as there are two circuits to tune at the same time. The anode tuning will be for a higher wave-length than the aerial tuning inductance, as it must equal in wave-length the combined wave-lengths of the tuning inductance and the aerial itself.



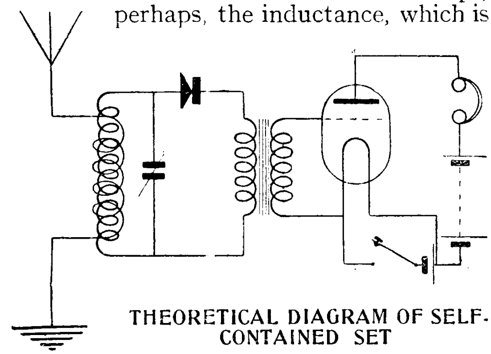
ANOTHER CRYSTAL RECEIVER WITH HIGH-FREQUENCY AMPLIFICATION

Fig. 90. Aerial tuning inductance in this set comprises a No. 2½ Burndept concert coil with a ·0005 variable air condenser shunted across its leads. The tuned anode circuit includes a double-slider crystal set, with the crystal detector mounted on the end cheek of the slider coil. The telephone terminals are also mounted on the same cheek

Both inductances should be manipulated at the same time, and if the rough position of the aerial tuning inductance for broadcast wave-lengths is known, this setting will greatly help. A sensitive spot should first be found on the crystal, and when signals are coming in the detector may be adjusted for the most sensitive point.

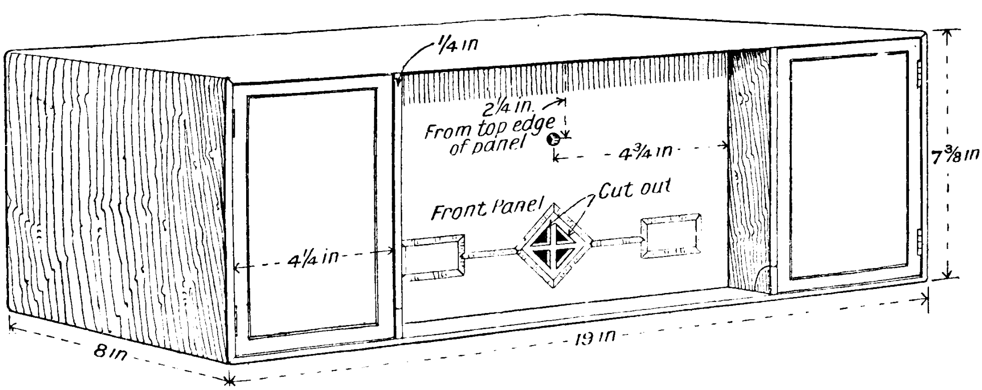
It may be necessary to add a ·0005 variable air condenser across the anode and high-tension positive terminals, in order to increase the wave-length of the tuned anode inductance. This is shown in Fig. 89, the remainder of the circuit being the same. Any form of variable inductance or capacity may be used to tune either circuit. This is illustrated in Fig. 90, where a Burndept No 2½ concert coil is used with a ·0005 variable condenser for tuning the aerial circuit, and the crystal set inductance consists of a double-slide tuning inductance.

Fig. 100, on the special colour plate facing page 616, with the aerial and earth connexions and telephones in position, as the set appears when in use. There is nothing elaborate about the circuit except, perhaps, the inductance, which is



THEORETICAL DIAGRAM OF SELF-CONTAINED SET

Fig. 91. Coupled by a transformer to the crystal detector circuit is a valve circuit, in which it will be noticed there is no filament resistance, and a switch breaks the filament battery circuit



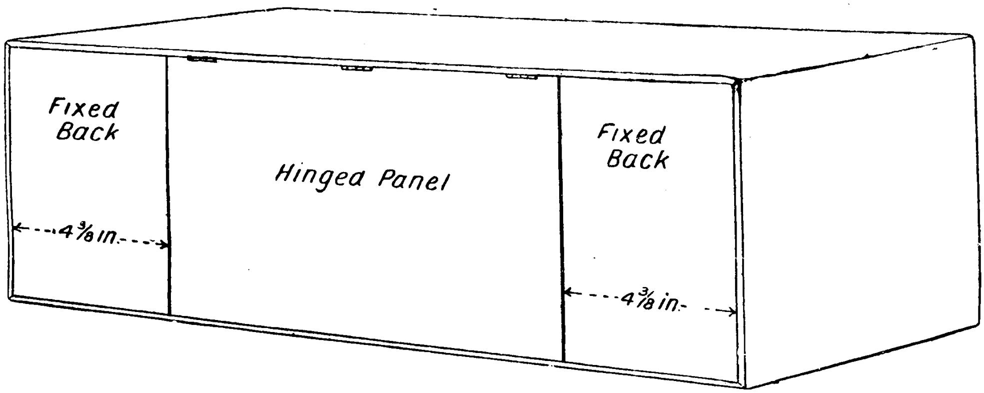
OUTSIDE DIMENSIONS OF SELF-CONTAINED CRYSTAL SET

Fig. 92. The over-all length of the cabinet is 19 in. In the centre portion the front is set back. This is not only for design, but to provide for the small cut-away portion seen at the inside corners of the cupboards. This set is illustrated on a special colour plate facing page 616

Self-contained Crystal Set. A special feature of this set is that the whole of the components are enclosed in one cabinet. This includes the crystal detector, inductance and controls, a compartment for the telephones, and a second compartment for the high- and low-tension batteries. A second notable feature of the set is the fact that only one control is provided, and this is simply for tuning to the local broadcasting station. The crystal is a particularly stable pattern, and, once adjusted, seldom requires further attention.

A switch is provided to break the filament battery circuit when the set is not in use. The general appearance is shown in on rather novel lines, comprising 12 turns of No. 24-gauge D.C.C. wire, one end of the wiring connected to the aerial and the other to the earth. A secondary winding of 80 turns of 24 gauge D.C.C. is taken around a cardboard tube former, and the two ends of these windings taken respectively to the crystal detector and one side of the primary winding of the transformer.

A variable air condenser is shunted across these leads, and is the means provided for tuning the set. The tuning is fairly sharp and good selectivity obtainable. The rest of the circuit is a simple, straightforward single stage of low-frequency amplification. The theoretical circuit diagram is given in Fig. 91.

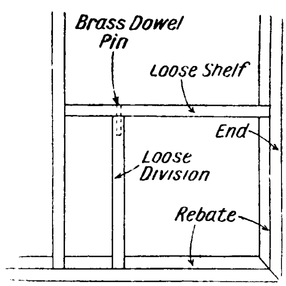


BACK OF THE CABINET FOR THE SELF-CONTAINED CRYSTAL SET

Fig. 93. Dimensions of the back of the cabinet are given here. It will be seen that the hinges for the back panel are at the top, while the backs of the cupboards are fixed

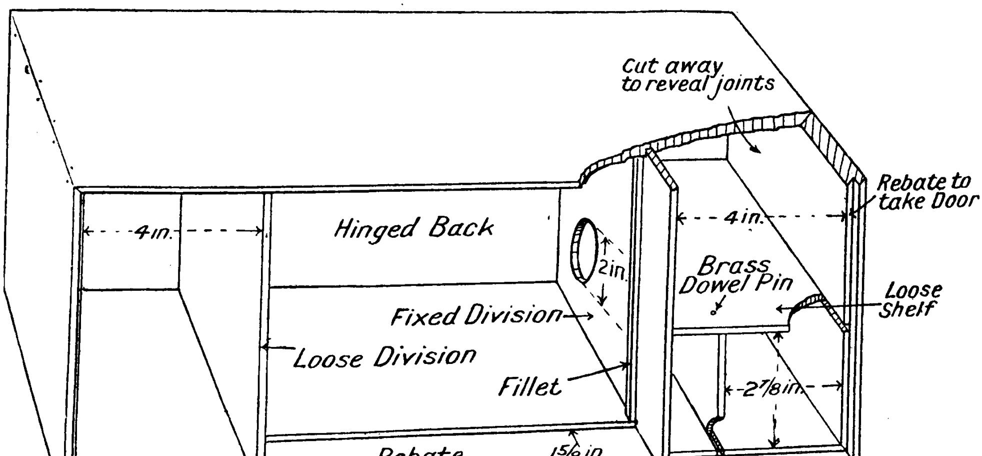
By far the greatest amount of work is presented by the construction of the cabinet, and to look well and be durable it is desirable to use good quality dry mahogany, or some other hardwood. The dimensions of the various parts are given in Fig. 92, illustrating the front of the cabinet; while Fig. 93 shows the arrangement of the back, the large centre panel being hinged.

The joints on the corners are made with a simple mitre, and all are rounded on the outside. The exterior of the case is prepared from ½ in. thick material. A broad rebate is worked in the centre portion, as shown in Fig. 95, and joins with two fillets fixed to the partitions. This forms a strong support for the front panel, which may be made from ⅜ in. mahogany pierced with four holes to act as peep-holes for inspection of the valve, and decorated with banding or paint work as desired.



SHELF AND PARTITION

Fig. 94. Brass dowel pins in the shelf fit into a groove in the partition beneath



INTERIOR DETAILS OF CABINET OF THE SELF-CONTAINED CRYSTAL SET

Fig. 95. Part of the top is shown removed, and the interior arrangement of the cabinet is seen from this diagram. The left-hand cupboard is for the headphones, and no shelves or divisions are necessary. In the right-hand cupboard will be seen a loose shelf which is fitted into slots, and the chamber beneath is divided by a partition to take switch leads and low-tension battery

The arrangement of the partitions, which are housed in grooves cut in the top and bottom of the cabinet, are clearly shown in Figs. 94 and 95, and are preferably prepared from ¼ in. mahogany, rounded on the front edges, and are arranged to slide in and out of the grooves.

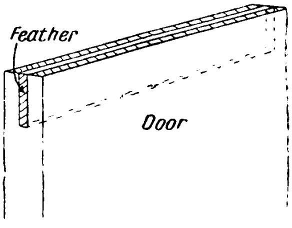
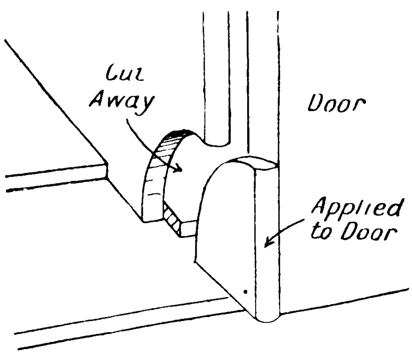


Fig. 96. Cut in the top and bottom of the doors is a groove to take a stiffening feather

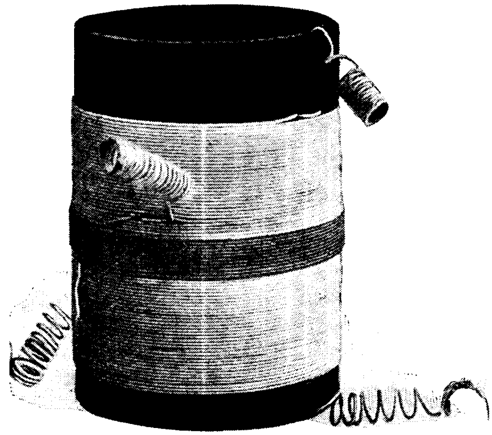


CORNER PIECES OF THE CABINET

Fig. 97. As a means of dispensing with a handle or knob for opening the cupboards the corners are cut away, with corresponding pieces fitting tightly on the door

The right-hand compartment contains a shelf and a second division for reception of the high- and low-tension batteries respectively. The partition which forms this compartment is pierced towards the back with a hole 2 in. in diameter, through which the valve is inserted when the set is finished. The two parts of the back, which are fixed, are rebated, glued and pinned in place. The hinged back simply fits into the rebate, and is hinged by small, brass hinges to the inner side of the top of the cabinet. These parts are shown partially assembled in Fig. 102, on the colour plate.

It is important to mark out accurately the positions of all these slots, and to cut them carefully, otherwise, the cabinet will probably be distorted or forced out of its shape. The two doors for the side compartments should be clammed with a feather on the top and bottom, as shown in the detail, Fig. 96, and hinged with small, brass hinges to the sides of the cabinet, as in Fig. 104. The lower corners of both partitions have to be cut away with



COILS OF SELF-CONTAINED CRYSTAL RECEIVER

Fig. 98. Superimposed on the secondary coil is the primary coil. The inductance is wound on a cardboard former. The primary coil is shown darker than the secondary

a fret saw, as in the detail, Fig. 97, the small post which goes down the partition being glued and pinned to the side of the door, and subsequently rounded off so that the finger-nail can be inserted to open the door. The small portion fixed to the left-hand door, which forms a compartment for the telephones, should be cut back so that the wires can emerge when the door is shut, as is shown in the first illustration.

The inductance, shown in Fig. 98, is wound on a cardboard former made from a piece of tube 3¼ in. in diameter and 4½ in. long. The secondary winding is wound on first, and then the primary winding wound on to the centre of it, and about 12 inches of wire left free at each end for connexions.

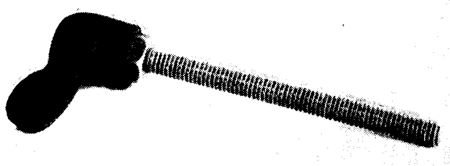
The next step is to prepare the left-hand partition by drilling holes near the top and bottom, and bushing them with ebonite cut from a piece of ebonite tube ⅜ in. in diameter, and which is sufficiently long to equal the thickness of the partition. This is shown in Fig. 105, on the colour plate. Two terminals and two ebonite washers have then to be fixed to these bushes by slipping one of the washers over the screwed shank of the terminal, passing it through the bush in the partition, and securing with the ebonite washer and a lock nut.

The inductance is mounted on this partition, as shown in Fig. 107, by means of two short ebonite supports, and the tube fixed to them by wood screws passed through from the underside of the cardboard tube, through the ebonite supports, and screwing into the ebonite partition. The variable air condenser should have a value of ·0005, and any standard apparatus can be used. It should, however, be mounted on a sub-base of ebonite, to which it should be fixed by three small screws, the heads of which should be countersunk beneath the surface of the ebonite sub-base. The latter is then secured to the back of the front panel with four brass wood screws, well countersunk below the surface of the ebonite.

To enable the spindle and the bush to clear, a ½ in. hole is drilled in the front panel, as shown in Fig. 104. The connexion to the moving plates is, in the case illustrated, effected by soldering a flexible wire to the end of the spindle and allowing it to protrude through a hole drilled in the spindle bearing. A length of about 15 in. should be allowed at this stage for subsequent connecting up, and Fig. 106 shows the appearance of the work at this stage.

As there are no other parts to be attached to the front panel, it may be screwed in its place with four wood screws passed through from the side partitions into the edge of the panel.

The valve is mounted on a flanged holder towards the end of the narrow division in the lower part of the right-hand compartment, and should be exactly central with the hole cut through the partition. Before the holder is screwed to this division, four connecting wires of No. 16 gauge tinned copper should be soldered to the four valve legs, and every trace of the soldering flux removed from the inside of the valve holder, which may then be screwed in its place with the anode terminals downwards, as indicated by the letter A in Fig. 109. To avoid surface losses, a disk of thin matt ebonite should be placed between the underside of the flange of the valve holder and the surface of the wood.



SIMPLIFIED BATTERY CONTROL

Fig. 99. No rheostat is used in the self-contained set, the filament being lighted by the simple switch seen in Fig. 111. Above is the switch arm

The low-tension switch is made by shaping a block of ebonite, as shown in Fig. 99. The lever handle should be about 1½ in. long, and is filed to shape from a block of ebonite ½ in. thick and ¾ in. wide. The base should be drilled and tapped to suit a short length of screwed brass rod, and the handle secured thereto by means of a lock nut, and subsequently pinned to the screwed rod by a $\frac{1}{16}$ in. diameter brass pin passed through the base of the lever.

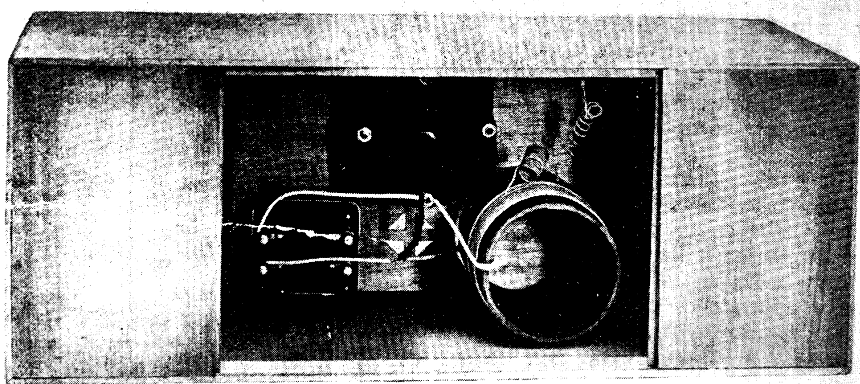
The switch is made up on an ebonite base 2¾ in. high and 1¾ in. wide, and comprises a short contact arm and two copper contact plates. The arm is attached to the outer end of the screwed rod by lock nuts and soldering. The rod itself turns in a small brass bush screwed to the inner face of the ebonite. Copper strips are used for making the contact plates, as shown in Fig. 111. The switch has then to be mounted just inside the right-hand partition, as shown in Fig. 103. A hole is drilled through the partition to register with the spindle hole on the switch, and the wood should be bushed with brass.

The exact length of the spindle can now be determined by passing it through the hole in the bushes until the base of the lever bears against the bush in the wood. The contact arm is then fixed in place, and any surplus cut off the end of the spindle. The lower part of the ebonite plate may have to be cut away slightly to correspond with the shape of the partition.

The next step is to procure a good quality low-frequency intervalve transformer, and to fix this to the bottom inside of the cabinet, opposite to the inductance, as shown in Fig. 108, by screwing it to the base by four round-headed wood screws.

The two ends of the inductance winding are now to be connected respectively to one of the primary windings of the transformer, and the other looped around one of the nuts on the post which holds the fixed plates, and thence to the opposite terminal on the primary side of the transformer. These joints may subsequently be made permanent by soldering if desired, but these wires are only temporarily fixed to the transformer at this stage.

The next step is to fix the flexible wire leading from the centre of the condenser to the wire which is taken direct from the inductance to the primary side of the



INTERIOR OF SELF-CONTAINED CRYSTAL RECEIVER

Fig. 113. Preliminary stages in the wiring of the self-contained set are fixing in position and attaching the wires of the inductance and condenser, and taking a temporary wire to the transformer prior to fixing the crystal detector. On the left, with two wires shown white, is the transformer, and the condenser is in the centre above the coils and transformer. Full details are illustrated on the colour plate facing page 616

transformer, and make a soldered connexion between them. This wire is the lowest visible in Fig. 108. The crystal detector is then mounted on the partition to the left of the transformer, and the wire removed from the other terminal of the transformer and connected to one side of the crystal detector. Another wire goes from the other side of the crystal detector to the other terminal on the primary side of the transformer. The primary windings of the inductance are taken through bushed holes in the partition, and thence to the aerial and earth terminals respectively. All the wires are best covered with systoflex.

The remainder of the wiring is completed by drilling three holes through the partition to the side of the large 2 in. diameter hole, and drawing the wires from the valve holder through these holes and connecting them as follows:—grid valve leg on valve holder to secondary on transformer, plate on valve holder to one telephone terminal. The latter is fixed to the partition forming the telephone compartment, by means of bushes, in the same manner as already described for the aerial terminal. The second telephone terminal is connected to the high-tension positive.

The other side of the secondary of the transformer is connected to one of the contacts on the switch, and a separate lead taken from it to the filament valve leg on the valve holder. The other filament valve leg is connected to the positive side of the low-tension battery. A short wire connects the negative high tension to the opposite low tension on the battery.

A second short wire connects the negative side of the low-tension battery to the contact arm of the switch. The high-tension battery is then placed in the upper compartment, as shown in Fig. 112, and connexions effected by wander plugs in the usual way. The low-tension battery is inserted in the lower compartment and connected up with flexible wire. The condenser knob and dial are now fixed to the projecting end of the spindle on the condenser, and may be of any desired pattern. That illustrated with an extension handle ensures fine tuning.

A valve of the D.E.R. type is inserted in the holder, and the telephones connected to their terminals by means of tags which should be clamped underneath the body of the terminals, thus leaving room for the addition of an extra pair of telephones at any later time. An interior view, with the valve in position and the whole apparatus complete, is shown in Fig. 110, which clearly illustrates the disposition of the whole of the parts.

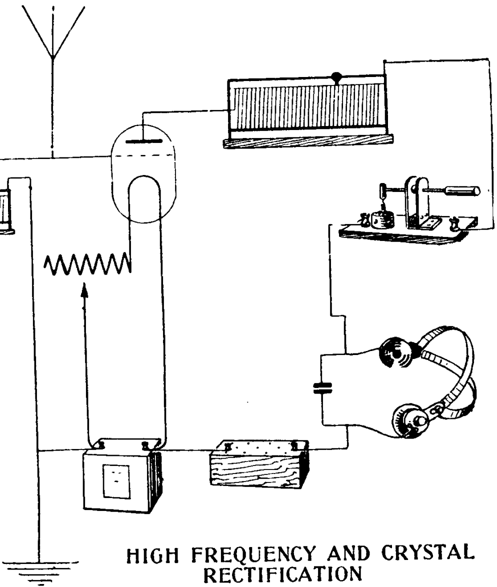
With this arrangement an ordinary 36-volt high-tension battery of the Ever-Ready type will supply ample current to the anode of the valve. The low-tension current should be supplied by an ordinary good quality dry battery with a nominal rating of 1·5 to 1·8 volts. This eliminates the need for filament resistance, and consequently simplifies the controls. If desired a Weconomy valve or other type of low voltage dull emitter valve can be used, preferably one particularly adapted for amplification purposes.

Fig. 101 shows a front view of the set with the telephones stored in their compartments and everything ready for reception. The cabinet may be finished with French polish, or a neat appearance obtained by dull polishing or waxing.—*E. W. Hobbs.*

Increasing Range of Crystal Set. The set shown in Fig. 114 will appeal to those who already have a crystal set and desire to increase the range and also the strength of received signals. High-frequency amplification is adopted in this set, the signals being amplified before they are passed on to the crystal set. Figs. 115 and 116 show how the crystal set may be used.

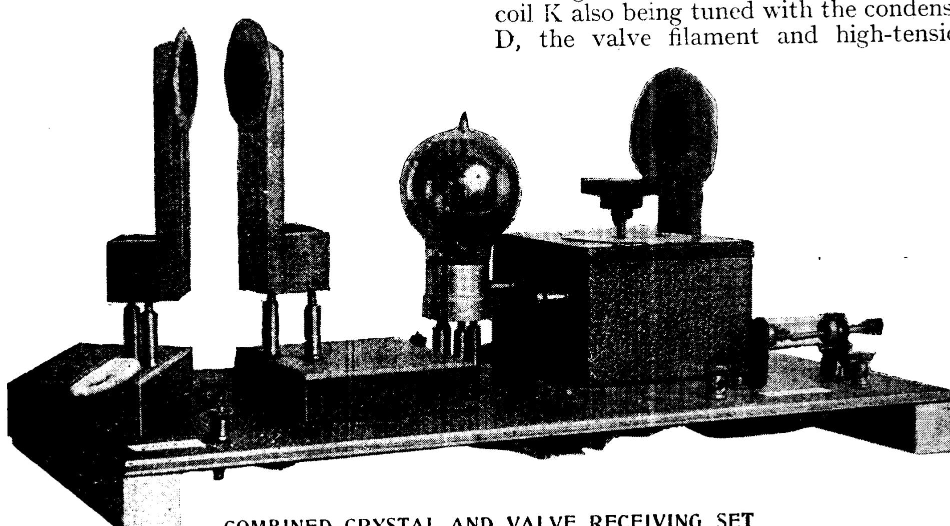
The circuit is shown in Fig. 117, A being the aerial, V the aerial tuning variometer, B the valve, C the crystal detector, D the anode tuning condenser, K the anode tuning coil, F the telephones, G the telephone condenser, H the high-tension battery, T the low-tension 4 or 6 volt accumulator for filament lighting, and FR the filament resistance.

It will be at once noticed that the portion shown in the dotted circle represents a crystal receiving set. The method of tuning is immaterial, except that if the coil only just covers the broadcast wave-length it will not be large enough to tune the anode circuit without the addition of a condenser or a loading coil. The variometer is tuned to the incoming wave-length, the signals passing from the aerial terminal to the grid of the valve, the anode tuning coil K also being tuned with the condenser D, the valve filament and high-tension



HIGH FREQUENCY AND CRYSTAL RECTIFICATION

Fig. 115. How a crystal set with high-frequency amplification is made up is here shown



COMBINED CRYSTAL AND VALVE RECEIVING SET

Fig. 114. This arrangement gives a means of increasing the receiving range of a crystal set and also increasing the strength of signals. On the right is the crystal set, including detector coil and telephone terminals. On the left are the coils, valve, and rheostat which have been added

battery being adjusted in order to obtain the loudest signals. There is thus obtained a considerable magnification of signals ordinarily obtained with a crystal receiver, and stations are heard which would be unheard upon a crystal set.

Referring to Fig. 114 of the complete set, it will be noticed that basket coils have been employed. Apart from the fact that they are quite inexpensive, they are easy to mount, can be adapted to many different uses, and lend themselves particularly to a clear explanation of this type of circuit.

The size of the panel is 14½ in. by 7 in., and is a piece of ¼ in. three-ply fitted with two end battens 1 in. by ¾ in., the board being well dried and coated with good shellac varnish. The holes for the terminals may be drilled and the terminals fitted, using thick shellac varnish round the holes and screwing home at the back.

The valve pins (or valve holder, if preferred) may be fitted about 2¼ in. from the upper edge of the board, and on the same central line. A hole may be drilled for the filament resistance spindle, the resistance being fitted in place immediately underneath. The basket coils are fitted to holders shown in Fig. 118, the upright wood being 4 in. high by 1 in. broad, with a small block of wood, 1 in. by ¾ in., fastened at the foot with glue and pins. Afterwards it should receive several coats of shellac varnish, this making a really substantial holder for the coils and avoiding all possibility of injury to the coil in plugging in.

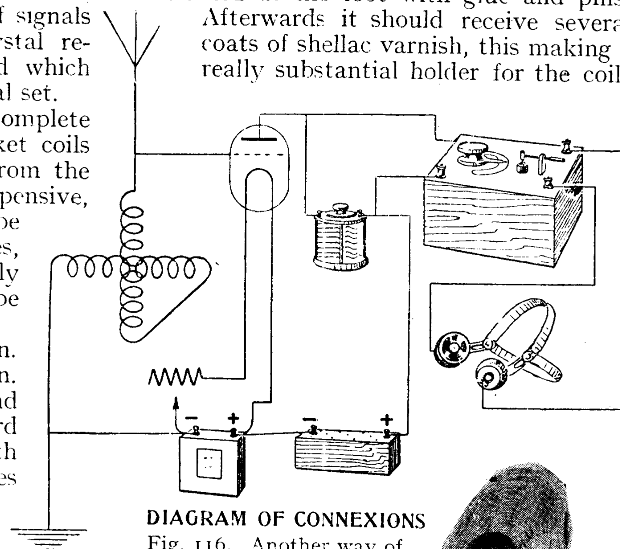


DIAGRAM OF CONNEXIONS

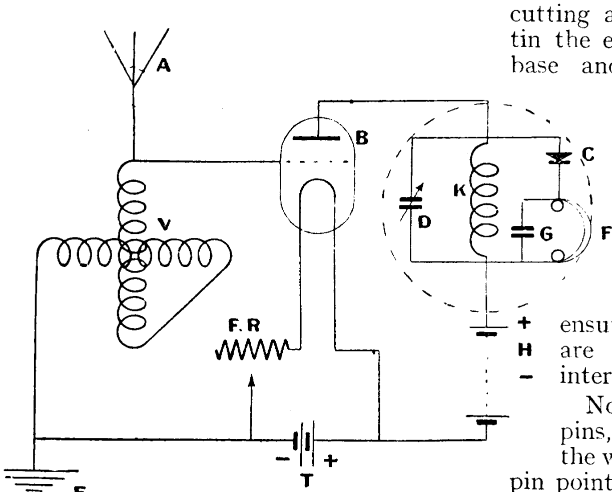
Fig. 116. Another way of adding high-frequency to a crystal is here shown. Fig. 114 gives an idea of the appearance of this set

Fig. 118. Basket coils are used as a variometer. Note wiring to the legs

Two valve pins are fitted diagonally in the base with a ¾ in. separation. This is best done by cutting a small piece of tin the exact size of the base and drilling two holes therein. This serves to mark off all positions, including the valve sockets which accommodate the coils upon the set, thus ensuring that all the pins and sockets are correctly spaced and the coils interchangeable in all positions.

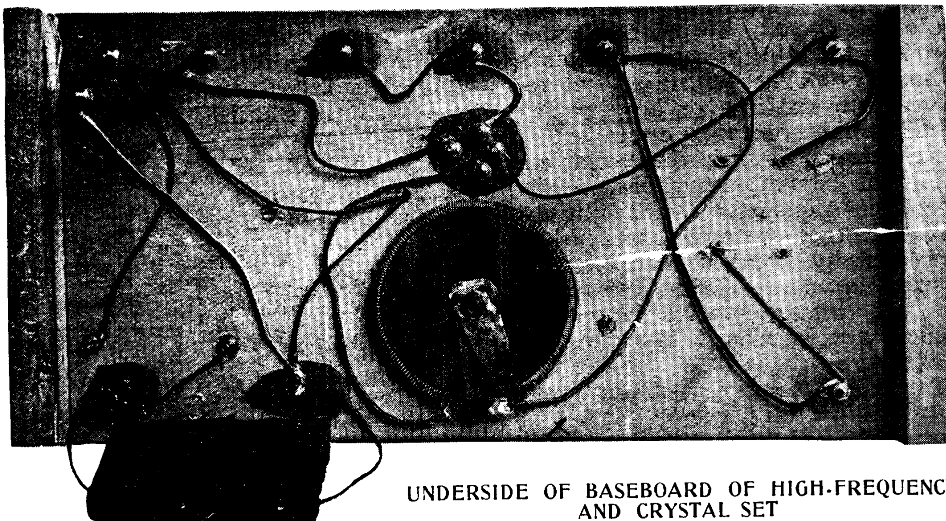
No nuts are required on the valve pins, as if a small hole is drilled in the wood and each thread of the valve pin pointed slightly with a file, the pins can be inserted after the manner of tapping a screw thread in metal, and they will hold firmly.

The leads of the basket coils are soldered to the valve pins, taking care that the



CIRCUIT OF HIGH-FREQUENCY SET

Fig. 117. Within the dotted circle is the original crystal circuit. The remaining part of this theoretical circuit diagram is the high-frequency amplifier



UNDERSIDE OF BASEBOARD OF HIGH-FREQUENCY AND CRYSTAL SET

Fig. 119. In order to raise the panel or baseboard, end-pieces are attached of sufficient depth to allow wiring terminals and rheostat to stand clear of the surface upon which the set stands. This photograph should be compared with that on page 618, Fig. 114

lead from the inside of the wire goes to the right-hand pin in each case, and that the coils are mounted the same way round. The basket coils themselves are held in position by a circle of shellacked cardboard with a central wood screw. The blocks on the baseboard may be 3½ in. by 1¾ in., and 1 in. thick, and should be recessed upon the lower side for flexible wire connexions to valve sockets. A wire from the aerial terminal goes to the nearest valve socket, and a wire from the second valve socket to the first socket on the second block, the latter being fastened rigidly to the base.

The first block is secured by one screw to the base, which acts as a centre upon which the block moves for tuning. The handle of an old toothbrush may be fastened in position to facilitate this. The valve sockets for the anode tuning coil may now be fitted at the top right-hand corner of the board, and the crystal detector near the telephone terminals.

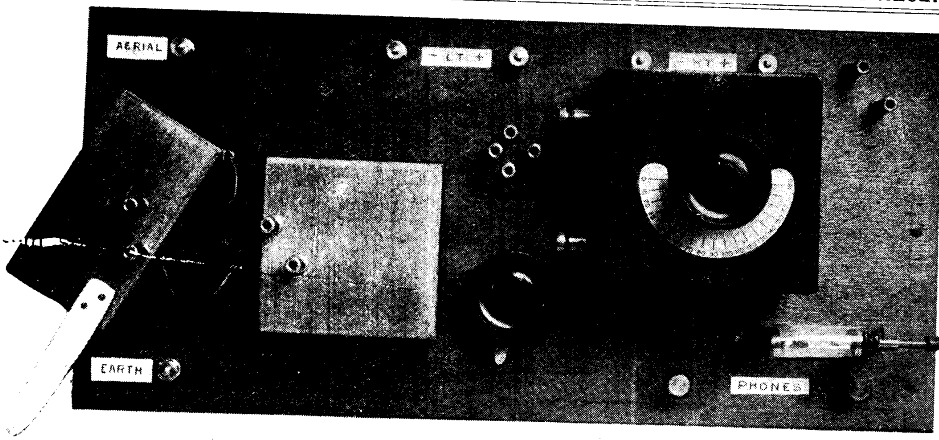
The variable condenser may be ·0002 capacity, and can be purchased cheaply in parts, assembled, and mounted in a neat box, as shown. The telephone condenser, in this case, is made from nine halves of ordinary clean quarter-plate old negative glasses, which will be 2⅛ in. by 3¼ in. Eight pieces of tinfoil, 1½ in. by 3½ in., are cut. A piece of glass is laid upon the table, and a piece of foil, with an equal margin on three sides, is shellacked to this. It is allowed to overlap at one end. Another sheet of glass, followed by tinfoil with overlap on the opposite end, and so on until completed, make the necessary part of the condenser.

The two sets of foil are clamped together at either end by a piece of thin brass or copper to which a lead of wire is soldered. If negative glasses are not available, paper, previously immersed in hot paraffin wax, may be substituted. The set may now be wired up from the diagram and photographs of under and top sides of the panel (Figs. 119 and 120).

The operation of the set for broadcast is quite simple. The two small coils of the set should be plugged in the variometer and No. 3 or 4 in the anode tuning plug. The crystal should be set with a buzzer in the ordinary way, and the filament and high-tension batteries connected. The variometer handle and the variable condenser may be moved until signals are heard. Fine tuning can then be done by careful adjustment of both. Alteration of amount of high-tension current and filament brilliancy may be tried for any further improvement.

Fig. 115 shows how the set may be used with two single-slide inductances, one of which should be larger than the other. Fig. 116 shows how the connexions should be made for a simple crystal set.

It should be noted that a single-slide coil will do as well as basket coils for



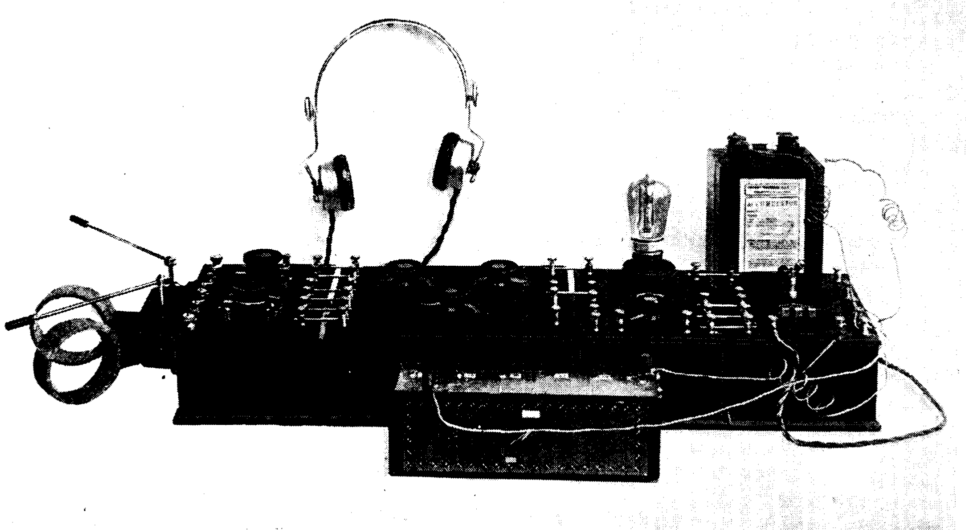
PLAN VIEW OF PANEL OF CRYSTAL SET WITH HIGH-FREQUENCY AMPLIFIER

Fig. 120. Arrangement of components is seen in this view of the top of the panel of the high-frequency crystal set. On the left are the two mounts for the variometer basket coils. A handle is attached to the movable base of the variometer. At the bottom right corner is the crystal detector

aerial tuning in the latter case, and that if the crystal receiver only just covers the broadcast wave-length a variable condenser will be required to tune what now becomes the anode or plate tuning coil. If the anode coil is sufficiently long and of reasonably small diameter, say 3 in., with a single slider or tappings and studs, the anode tuning condenser is unnecessary.

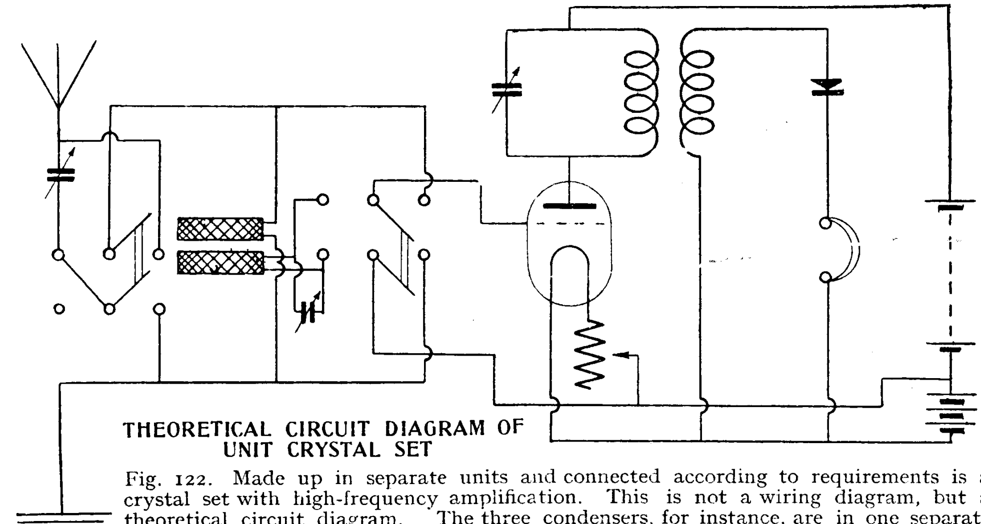
High-frequency Crystal Receiver. A convenient way of adding a high-frequency transformer-coupled amplifier to a crystal set is by means of a unit assembled from a set of parts supplied by Messrs. Peto-Scott, Ltd. The construction of the instrument is dealt with on page 89 under the heading Amplifiers. The high-frequency amplifier is added to the crystal unit, also part of the unit system.

Fig. 121 shows the self-contained high-frequency amplifier in the position it occupies between the condenser and the crystal detector units. The latter has a single pole change-over switch, enabling



COMMERCIALLY-MADE CRYSTAL SET WITH HIGH-FREQUENCY AMPLIFICATION

Fig. 121. Separate units are connected together in this set, made by Peto-Scott, Ltd. The high-frequency unit is between the crystal unit, on the right, and the condenser unit, with three tuning knobs mounted on its panel. This is part of the unit system described throughout this Encyclopedia



THEORETICAL CIRCUIT DIAGRAM OF UNIT CRYSTAL SET

Fig. 122. Made up in separate units and connected according to requirements is a crystal set with high-frequency amplification. This is not a wiring diagram, but a theoretical circuit diagram. The three condensers, for instance, are in one separate unit in the actual set, and their leads taken to the various parts of the apparatus where they are required. The valve unit is separate, and the inductance coils and switch are also a unit

either tuned anode or transformer-coupled method of amplification to be used. In the latter case the switch arm is engaged on the right side of the panel. A standard type of hard valve, such as the Marconi R valve, Cossor, or Mullard "Ora," will be found suitable. Regulation of current is provided by means of a filament resistance mounted to the front of the panel. The transformer may be of the plug-in variety in order to suit any wave-length it is desired to receive, as high-frequency transformers are periodic.

A small condenser of ·0002 mfd. capacity is shunted across the plate winding of the transformer to provide increased sharpness in tuning. A transformer, tapped on its plate windings, is now made giving a variety of wave-length ranges. These are usually made in two sizes, the smaller tuning from 200 to 1,000 metres and the larger from 1,000 to 1,800 metres.

If a tapped transformer of this type is used, care must first be taken to ascertain the connexions to the transformer holder are correct. The tapped winding of the transformer connects to anode and the high-tension positive and the secondary winding to grid, and low tension negative. In each case the connexions on the transformer holder are made directly opposite to each other, as anode to grid, and filament to filament.

In dealing with high-frequency currents, particular care should be taken in every detail to avoid losses. Best quality ebonite, well-matted on both sides, should be used. Terminals spaced well apart, and all connexions as short and straight as possible, materially help the efficiency of the unit. In addition, connecting wires should be well soldered to avoid possible losses through bad connexions.

Immediately preceding the high-frequency unit is the aerial circuit, consisting of the apparatus for tuning the incoming oscillations. These may take any convenient form, among the best known being a variometer, duo-lateral coils and tuning condenser, sliding contact on former-wound inductance, and inductance brought to contact studs with tuning condenser. In any form of tuning, the grid of the high-frequency valve is attached to the aerial terminal, and in most cases the low-tension negative is joined to the earth terminal.

Fig. 122 shows the wiring diagram for the set.

Increasing Range and Strength of Crystal Set. When suitable articles are available, or it is desired to build a complete receiving set, excellent results are possible by a combination of high and low frequency amplification with a crystal detector. Such an arrangement, by incorporating high-frequency amplification, gives a wide range receptive power, while the low-frequency amplification adds to the signal strength. This class of circuit should not be confused with those which are more properly called dual amplification circuits. In the latter case one or more valves are arranged to perform two or more purposes, whereas in the circuits dealt with here the valves are limited to specific duties.

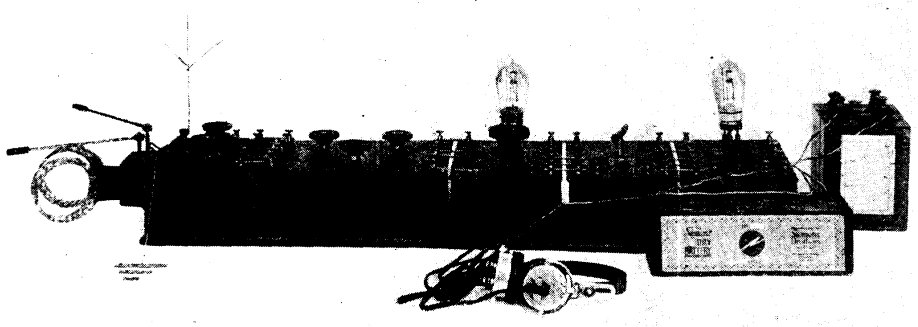
An example of the use of a standard unit, all of which are separately described under their respective headings in this Encyclopedia, is that given in Fig. 123. This represents a set comprising from left to right, tuner, condenser, high-frequency amplifier, crystal detector, and low-frequency amplifier units wired up with batteries and telephones. In this set, high-frequency amplification is effected by means of a transformer coupling and valve.

A plug-in transformer is used, across the primary of which is connected a small variable condenser of ·0003 mfd. capacity from the unit of condensers preceding it. The object of this condenser is to provide finer tuning in the anode circuit, resulting in better amplification and increased sharpness of tuning. The switch on the panel of the detector unit is thrown over to the left position, which, as explained in the article on crystal detector unit (*q.v.*), enables a low-frequency unit to follow it.

This unit follows standard practice in the wiring. In all units, except the tuner and condenser, battery terminals are carried right through from one side to the other, permitting the addition of any further units as they may be required. For the valves, any kind of hard receiving valve is suitable, either for high or low-frequency amplification. If it is desired to use a power valve in the low-frequency unit, separate high- and low-tension batteries may be used by removing the battery strips from between the high- and low-frequency units and the requisite voltages applied to each. Care must be taken to see that the low-frequency transformer is suitable to receive the extra voltage that a power valve requires.

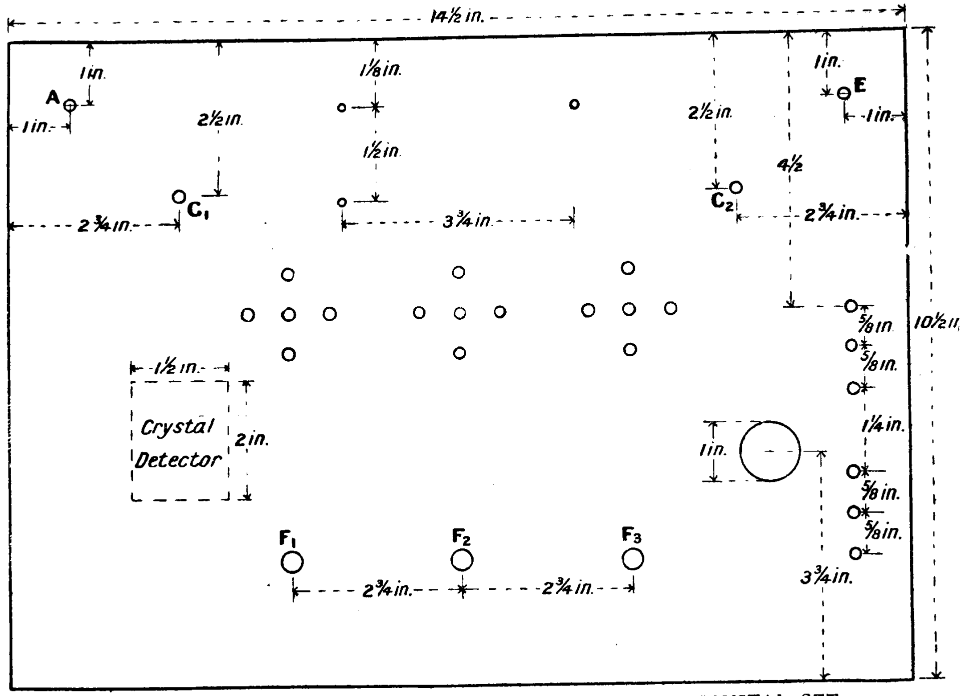
The unit system of set construction has much to recommend it. It may be changed about quickly in order to secure a different combination or arrangement of units, it may be added to as occasion demands, and owing to the comparatively large spacing between components, there is little fear of interaction.

Portable Set with High- and Low-Frequency Amplifiers. The set illustrated in Figs. 130 and 131 has been designed for extreme portability and rapidity of assembly for operating. These features are in no way detrimental to the efficiency of the set, which is of a high order. High-frequency, crystal detector, and the two low-frequency amplifiers comprise the set, which is housed in a travelling case, $15\frac{3}{4}$ in. by 12 in. by $7\frac{1}{2}$ in., as shown in Fig. 132. By careful arrangement of components interference is reduced to a minimum. The high-frequency amplification is obtained by tuned anode coupling, the tuning coil of which is inductively coupled to the aerial tuning coil, thus incorporating reaction. Rectification is performed by a Perikon (or zincite-bornite) combination. This gives the effect of another valve without its expense and upkeep, besides retaining the qualities of purity of speech and music. Two stages



COMBINED HIGH- AND LOW-FREQUENCY CRYSTAL SET

Fig. 123. Another stage is now added to the unit set shown in Fig. 121. On the right of the crystal unit will be seen another valve unit. This is a low-frequency valve. High-frequency amplification is effected by means of a transformer coupling and the valve in the middle unit. The plug-in transformer can be seen between the valve and the rheostat turning knob



PANEL DIMENSIONS FOR A PORTABLE AMPLIFIED CRYSTAL SET

Fig. 124. Three filament resistances are provided for in this scheme, and a space marked out for the crystal detector. Immediately facing the place where the three valves are mounted behind the panel three sets of four small holes are drilled for inspecting the filaments

of low-frequency amplification are used to secure volume of sound sufficient to operate a loud speaker within an approximate distance of 50 miles from the nearest broadcasting station. The set brings within range all the British stations, Paris and The Hague, from any part of the British Isles.

Special design of high- and low-tension connexions which plug into a valve holder on the panel enables all connexions to be made by the simple operation of inserting the plug. It is impossible to connect up wrongly to the detriment of the valves, as, owing to the off-set position of one of the valve holder legs, the plug can only be inserted one way. There is no necessity to alter the correct adjustment of filament resistances when they have been set for best effect, as removal of the plug automatically disconnects all battery current from the set. A list of components required for the construction of this set will be found on page 630.

A panel of best quality ¼ in. ebonite is cut and drilled to the sizes shown in Fig. 124, and matted on both sides. Although dimensioned sizes for all holes are given, and these will be found correct for the majority of components, it must be borne in mind that the mounting of components is not standardized, for which reason the experimenter is advised to procure or make component parts and drill the holes to suit particular requirements.

Three filament resistances are mounted on the panel as indicated by F_1, F_2, F_3 in Fig. 124. A number of small holes are arranged 3½ in. above each of these to allow of inspection of the valve filaments. The appearance of these holes will be improved by slightly countersinking them. They are countersunk considerably also on the rear of panel to allow of inspection from an angle. Two groups of three terminals on the right-hand side of the panel allow three pairs of telephones to be used in parallel. A little to the left of these terminals the battery sockets, a flanged-type valve holder, are mounted.

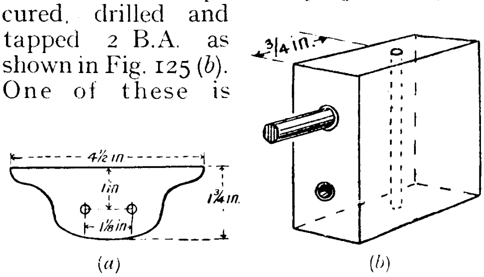
A 1 in. hole is drilled or cut, into which the valve holder will fit. Three blind holes are drilled and tapped 2 B.A. size in register with 2 B.A. clearance holes in the flange of the holder. The blind holes are now tapped 2 B.A., and a short length of about $1\frac{1}{4}$ in. of screwed rod screwed into each. A 2 B.A. lock nut is screwed on each rod, allowing the face of the valve holder to come flush with the panel. Another lock nut is screwed on to each rod on the outside of the valve holder flange, thus securing it tightly in position.

It is necessary to make a sound job of this, as it will be required to take all the strain of inserting the four-pin plug. If desired, an ordinary type valve holder as used to hold the valves, and seen in Fig. 131 of the back of the set, may be attached to the front of the panel. Although simplifying the work, this does not give such a finished appearance, however. In a corresponding position to this valve holder, on the left of the panel is mounted the Perikon detector. It is better to purchase this component and, removing it from its base, reassemble it on the panel.

C_1 and C_2 in Fig. 124 show the positions of the two condenser spindles, which are mounted to the panel in the most convenient way. C_1 is the aerial tuning condenser, of about ·0005 mfd. capacity. This may be purchased or built up from parts.

In the latter case thirteen fixed plates and twelve moving plates having $\frac{1}{8}$ in. spacing will be required. The other condenser, C_2, which tunes the anode circuit, may be of smaller capacity. A 0003 mfd. will be found sufficiently large. This should have nine or ten fixed plates, also of $\frac{1}{8}$ in. spacing.

Between these condensers is mounted a 2-coil holder. This may be purchased, if adaptable in design to the position it will occupy, or it may easily be made up in $\frac{1}{4}$ in. ebonite, as was used in the panel itself. Two identical cheeks cut to the size shown in Fig. 125 (*a*) will be required. Two standard Burndept coil plugs are procured, drilled and tapped 2 B.A. as shown in Fig. 125 (*b*). One of these is rigidly attached to the cheeks by two 2 B.A. by 1 in. cheese-headed screws. The remaining plug is filed or cut down slightly, enabling it to swing round when its central hole registers with the two holes in the cheeks. Care must be taken to secure perfect freedom of movement when this movable plug is assembled.



DETAILS OF COIL HOLDER

Fig. 125. (*a*) Between two pieces of ebonite this shape the coils are pivoted. (*b*) Dotted lines indicate the position of the pivot upon which the coil holder moves

The assembly is effected by screwing a 2 B.A. by 1 in. cheese-headed screw at the top side of the holder. At the power side a piece of 2 in. by $\frac{3}{8}$ in. brass rod is turned down and screwed 2 B.A. for 1 in. of its length. A hole drilled and tapped 2 B.A., in the thick part at an angle, provides a means of attaching an anti-capacity handle. This piece of brass is now screwed home, the hole drilled to receive the handle being kept in line with the plug itself. Two holes will be found at the back of the plug into which screws are inserted, locking the spindle and 2 B.A. screw solid to the plug.

Making and Fitting the Valve Shelf

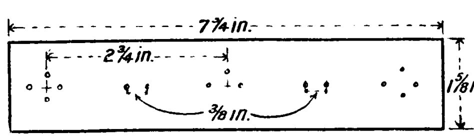
The anti-capacity handle is cut from a piece of $\frac{3}{8}$ in. ebonite 6 in. in length. A hole, tapped 2 B.A. about $\frac{1}{2}$ in. in depth, is made at one end, and a short length of 2 B.A. inserted and cut off with $\frac{1}{2}$ in. projecting. This in turn is screwed into the tapped hole in the coil plug spindle made to receive it. When the experimenter is satisfied with the movement of the movable plug, it may be mounted on the panel, as shown in Fig. 130, by drilling and tapping a 2 B.A. hole in each cheek lug and screwing to the panel from the back.

Two large terminals are screwed to the top left and right corners (see Fig. 124), which are respectively aerial and earth terminals. Suitably engraved dials with knobs are attached to the condenser spindles, completing the exterior of the set. It is not advisable to mount the crystals into their cups at the present stage, as they may receive some injury while the panel is being worked.

Fig 126 gives the dimensions of the valve shelf and positions of the three valve holders. Ebonite valve holders with screwed legs should be chosen, as the nuts on the legs can be used for securing them to the shelf. Between each valve holder two $\frac{1}{16}$ in. holes, $\frac{3}{8}$ in. apart, are drilled. Through each pair of holes a short length of brass or copper wire of about No. 16 gauge is threaded and bent over a single dry battery cell. Such a cell may be taken from a pocket-lamp battery, which consists of three of these cells wired in series.

A touch of solder on the wire secures the cells rigidly in position. The set may oscillate freely, and, to check this, grid-biasing batteries may be added as shown. The effect is to put a negative potential on the grid of the low-frequency amplifying valves, thus altering the position of their functioning on the characteristic curve of the valve. Owing to the position of the valve shelf, it is better to solder certain connexions first.

Solder the grid of the first low-frequency valve to the negative, or zinc, plate of the first grid cell, and the second grid in a similar way to the second grid cell. Wires about a foot in length are soldered to each anode valve stem and the grid of the high-frequency valve. The filament valve legs on the sides nearer the panel when the shelf is assembled are connected together and a short length of wire left over for attachment to the battery sockets. Insulated sleeving is used throughout in wiring up this set, and its use must be taken for granted when wiring up is mentioned. Tinned wire of about 22 gauge is used, and 2-mm. sleeving will be found suitable. Three short pieces of wire 6 in. in length are soldered to each of the three filament resistance coils.



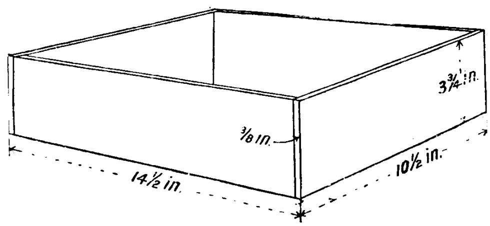
VALVE SHELF FOR PORTABLE SET

Fig. 126. Three valves are mounted on a raised ebonite platform or shelf, dimensions of which are given here

The moving arm connexions are all joined together, and taken to one of the valve stems of the battery socket. This valve stem would correspond to one of the filament valve stems if the valve holder were used for its legitimate purpose. The remaining filament stem will connect to the valve-holder filament stems later.

Before the valve shelf can be put into position a framework is made up, to which the panel is afterwards screwed. Dimensions of this framework are given in Fig. 127. It may be made up from $\frac{3}{8}$ in. wood; any convenient material available, such as planed-up deal, will suit. It can afterwards be stained as desired. The valve shelf stands on two blocks of wood $1\frac{5}{8}$ in. long, $\frac{1}{2}$ in. wide, and $\frac{7}{8}$ in. high, and secured to the shelf by two small countersunk brass screws at each end.

The position of the shelf is immediately behind the filament resistances, the outer edge of the shelf being $2\frac{3}{4}$ in. from the back of the panel. It is secured in this position by countersunk screws from the outside of



DIMENSIONS OF FRAMEWORK

Fig. 127. Framework of the portable crystal set with valve amplification is made according to the measurements in this diagram

the framework. Before screwing the panel to the framework, wires about 18 in. long are soldered to the aerial and earth terminals, which occupy positions in the top corners of the panel, as shown respectively at A and E in Fig. 124.

The three top telephone terminals are soldered together by a connecting wire, one end being left free. The other group of telephone terminals are similarly treated. The panel is now screwed to the framework, which should come flush with the panel on all sides. Two Cincinnati transformers are used with the low-frequency amplification. They are bolted to the base, one in each corner, by 4 B.A. by 1 in. countersunk screws and nuts, and are arranged with their terminals to the interior for ease of connexion.

An extra tap is made on the high-tension battery, allowing more high-tension voltage on the low-frequency amplifiers than on the high-frequency valve. In order to avoid confusion, it is as well to make the battery sockets of the valve holder. This is shown in Fig. 128. The filament legs of the valve holders that were previously wired together are jointed to low-tension negative battery socket stem, and the wire continued for connexion to the

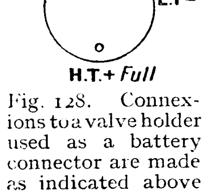


Fig. 128. Connexions to a valve holder used as a battery connector are made as indicated above

earth wire. The wiring diagram in Fig. 129 must be closely followed in completing the wiring.

The tuned anode coil of the two-coil holder is the fixed one, and the movable plug holds the aerial tuning coil. This arrangement brings them nearer their respective tuning condensers, as shortness and directness is an important factor towards the attainment of good results. Flexible stranded wire, such as lighting flex, is used for connecting the movable coil plug.

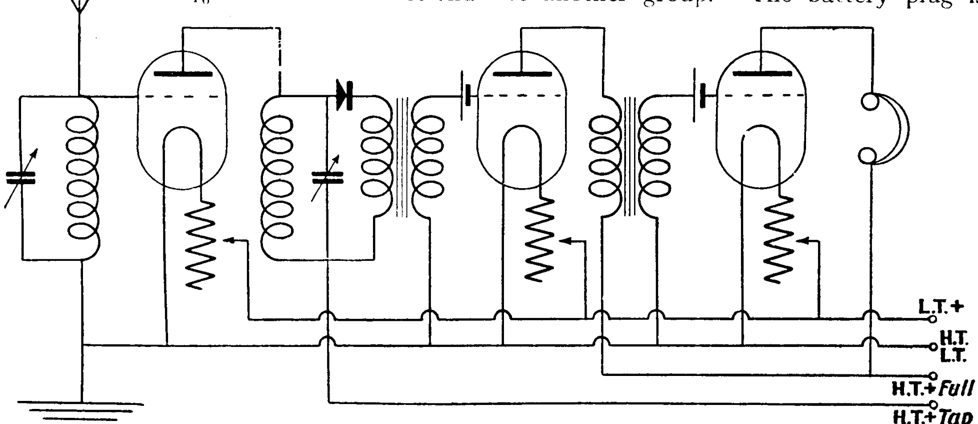
It is now necessary to construct the battery plug. A circular disk of ebonite, $1\frac{1}{8}$ in. in diameter, is cut from $\frac{5}{16}$ in. sheet, or sawn from $1\frac{1}{8}$ in. diameter rod. Four flanged split valve legs fitting the socket holes are procured and screwed on to the ebonite block, so that the four legs enter the sockets easily.. With a $\frac{1}{16}$ in. drill, four more holes are made, one adjoining each leg. A central hole is drilled and tapped 2 B.A. An ebonite knob such as is used on filament resistances is put into a lathe, and a recess $1\frac{1}{8}$ in. diameter and $\frac{3}{32}$ in. deep turned in it. In the centre of this knob a $\frac{3}{16}$ in. hole is drilled, and four holes of $\frac{1}{8}$ in. diameter are drilled to register with the four $\frac{1}{16}$ in. holes previously drilled in the disk.

Cut four 6 ft. lengths of lighting flex and, clearing the insulation from $\frac{1}{2}$ in. of each end, push the ends through the ebonite knob. The end of each bared wire is then well soldered to prevent a stray strand of wire causing a possible short circuit, and inserted through the $\frac{1}{16}$ in. hole. The free end of each wire is carefully wrapped around its respective leg, which is tightened up with pliers. In this way the ends are clamped under the bosses of the legs.

The ebonite knob is now screwed down with a 2 B.A. countersunk screw, a small loop of each wire being left in the recess. The object of this is to take the strain of a sudden pull from the ends of the wires, which would tend to pull them out of position. Four spade terminals are soldered to the free ends of the flex wires, and stamped according to the socket pin to which they are attached, as in Fig. 128. A neat effect is obtained by plaiting the battery leads together. Black and red twisted flex is obtainable, and obviates confusion in connecting up positive and negative terminals.

If a high-tension battery with plug sockets is to be used, the high-tension wires may have suitable plugs attached instead of spade terminals. In this case each positive plug should be marked whether " tap " or " full " voltage. It is usual to use red plugs for positive, and black or green for negative. As the negative is common to both high- and low-tension batteries, an extra wire for connexion to the accumulator may be made on the negative high-tension battery plug.

When the wiring has been very carefully checked with the diagram in Fig. 129, and all connexions tested, the valves may be put in. Aerial and earth terminals are connected up and two telephones inserted, one tag going to any terminal in one group and the other tag similarly connected to another group. The battery plug is



WIRING DIAGRAM OF PORTABLE AMPLIFIED CRYSTAL SET

Fig. 129. Low-tension and high-tension battery leads are taken to the right-hand bottom corner of this diagram. In Fig. 128 will be seen the method of attaching the four points to a valve holder for plug-in connexion

Care must be taken at this point to ensure the safety of the valves in the event of a wrong connexion. Turn out two of the valves and disconnect low-tension positive. Take the high-tension positive tap, and momentarily touch the lowest tap of the high-tension battery after the high-tension positive plug has been inserted.

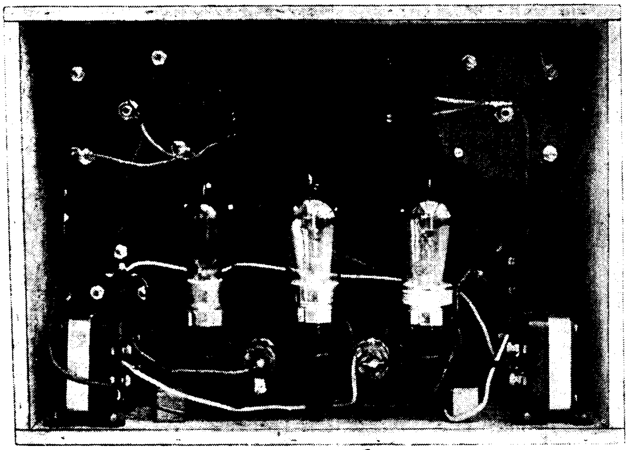
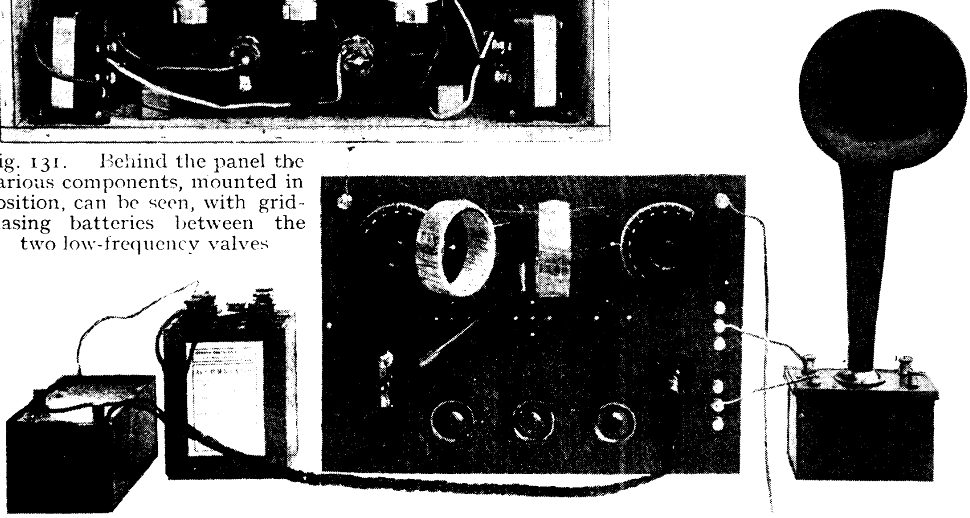


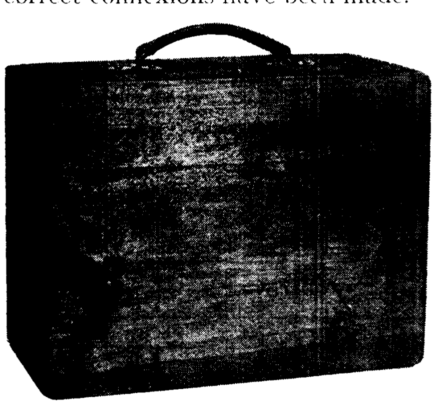
Fig. 131. Behind the panel the various components, mounted in position, can be seen, with grid-biasing batteries between the two low-frequency valves



BACK AND FRONT OF PANEL OF PORTABLE SET

Fig. 130. On the front of the panel is the four-pin plug-in socket connecting the batteries. A loud speaker is shown connected, and above the terminals to which it is wired will be seen the earth wire and terminal. The aerial connexion is at the left top corner

inserted into the valve-holder socket and the low-tension battery connexions made to the accumulator. The valves will now light if correct connexions have been made.



CASE FOR THE PORTABLE SET

Fig. 132. When the case of the complete portable crystal set is closed up its appearance resembles a portmanteau

If the valve remains out a stronger tapping may be tried. Do the same to the other high-tension positive plug, and if still correct, apply both plugs, finally reaching the correct position.

This position will depend on the type of valve used, which must be of the " hard " variety. The valve manufacturers usually state the voltage required for each type of valve on the box in which the valves are packed.

Pieces of bornite and zincite are now mounted into their respective cups and with a slight pressure their surfaces are brought into contact. This Perikon combination, as it is usually called, has practically no dead spots, and when a setting has been made, final adjustment should be left until a signal is heard.

For broadcast reception a No. 2½ Burndept concert coil or No. 50 Igranic coil is used in the aerial circuit, and a Burndept No. 4 concert coil or Igranic No. 75 coil in the tuned anode circuit. If the valves are oscillating this will be detected in a ringing, humming noise in the telephones when the panel is tapped. If this is not the case, the high-tension connexions should be followed around to ascertain that all are perfect. The removal of the high-tension plugs should be accompanied by a considerable click in the telephones. This will indicate that the high-tension circuit is in order.

On bringing the aerial coil nearer to the fixed coil, a loud rushing sound will be heard in the telephones, which, if the coupling is tightened still more, will give place to loud howlings. This must be immediately stopped, as it indicates the generation of oscillations liable to spoil the pleasure of listeners-in in the neighbourhood. Having found a coupling just before the rushing sound is manifested, the two condensers are manipulated until a station is picked up. The movement of the condensers should be very gradual, as owing to the selectivity of the set it is easily possible to pass a station over. The presence of a station is often notified by a faint howling entirely different from that occasioned by oscillations. When this occurs, it generally indicates the carrier wave of the transmitting station is being heterodyned, and true reception lies just beyond this point. Further movement of the condenser brings in the howling effect again, after which the tuning passes so much away from the station transmitting as to be entirely lost. If a station is brought in sufficiently loud to be uncomfortable in the telephones, a loud speaker may be attached in their place.

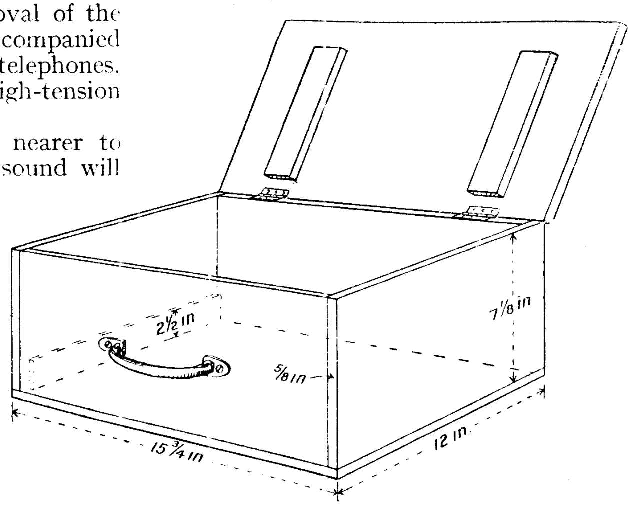
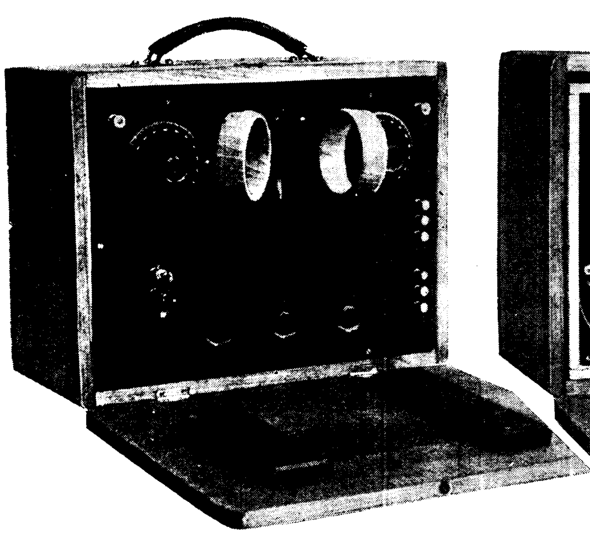
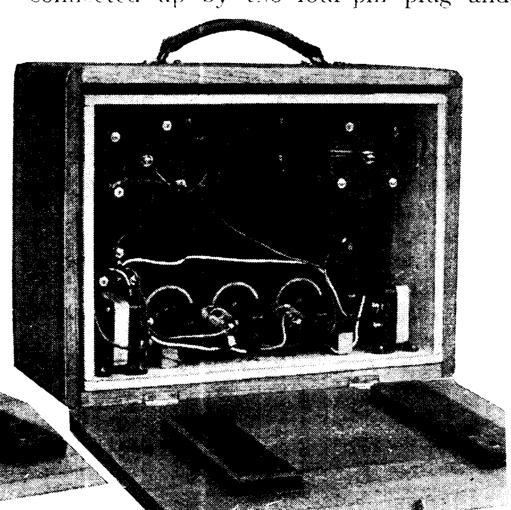


Fig. 133. Dimensions of the container of the portable set are here given

In Fig. 130 the front of the set is shown connected up by the four-pin plug and





INTERIOR VIEW OF AMPLIFIED PORTABLE CRYSTAL RECEIVER

Fig. 134 (left). With the case open and the panel slightly advanced, the appearance of the set is as here shown. The crystal detector is on the left and the socket holes for the battery plug on the right. Fig. 135 (right). In this view the panel is reversed and the interior arrangement is clearly apparent. Transformers are on either side of the valve shelf socket to the batteries, and a loud speaker attached. The general disposition of the interior is shown in Fig. 131. The grid-biasing cells are clearly seen between the valves and the transformers in each of the lower corners. The group of telephone terminals are seen connected together, and also the battery socket stems on the extreme left.

Dimensions of a carrying box illustrated in Fig. 132 are given in Fig. 133. This is made up from ½ in. finished deal or other wood, and glued and screwed. A fine appearance is given if covered with a Rexine cloth, or the box may be stained as desired. Two ledges of wood are nailed to the inside, measuring 11 in. by 2½ in. by ½ in. thick. They support the set, which is placed in the travelling box panel first. A hinged lid, when closed, holds the set tightly in position. A carrying handle and fasteners complete the case. Fig. 134 shows the method of carrying the set in the case. The high-tension battery may also be carried in the case, by fitting it to the inside of the lid to clear condensers and valve shelf. The valves are not carried in position, but returned to their boxes for transport purposes.

List of Materials Required for the Portable Set.

Ebonite panel, 14½ in. by 10½ in. by ¼ in.
Ebonite shelf.
3 unflanged ebonite valve holders with screwed legs.
1 flanged valve holder.
1 rod ⅜ in. ebonite, 6 in. long.
1 ebonite 2-coil holder.
1 ebonite knob.
1 ebonite disk, 1½ in. diam., $\frac{5}{16}$ in. thick.
3 ebonite former filament resistances complete.
8 terminals.
2 Cincinnati low-frequency transformers.
1 Perikon detector.
1 variable air condenser, 0003 mfd. capacity.
1 variable air condenser, 0005 mfd. capacity
2 Burndept coils, Nos 2½ and 4.
3 hard valves.
High-tension battery
Low-tension battery.
Telephones and/or loud speaker.
2 grid cells
Quantity of ⅜ in. and ½ in. planed timber for travelling case and panel box.
Quantity of screws, wire, and 2 mm. insulating sleeving.

CURRENT. An electric current is produced in a conductor either by applying an electro-motive force at every point of that conductor, or by maintaining a difference of potential between two points. The first can be exemplified by a metallic ring or closed coil through which the pole of a magnet is being pushed, or in the core of which the magnet is being excited, or, more generally, by any completed conducting circuit through which the number of magnetic lines of force are being varied. The second case is exemplified by connecting a voltaic battery to the two ends of a metal wire. It also applies to any part of the external circuit of a dynamo inside which a current is being generated by the first method.

An electric current is not visible, and for its existence to be known, therefore, it is necessary to depend upon certain effects which are associated with a flow of current. Some of these effects are as follows.

How Currents May be Detected

When an electric current is flowing in a wire, and the latter is brought near to a compass needle so that the axis about which the needle turns is parallel to the axis of the wire, the needle is deflected. The deflection is constant as long as the current is constant in strength and direction. A reversal of the current deflects the needle in an opposite direction.

The passing of an electric current through a wire raises the temperature of the wire, and if the current is great enough the wire may become incandescent. Such an effect is seen when a current is passed through a valve filament.

If the wire through which a current is flowing is cut and the separated ends attached to two metal plates immersed in a solution, say, of copper sulphate, there is a chemical change in the solution, and copper is deposited upon one of the metal plates—the one towards which the current is flowing. This gives a means of finding the direction of a current.

There are many more effects of an electric current, but these three are among the more important, and various instruments are based upon them for measuring the current.

It is clear from the first effect that the direction of a current passing along a wire, as well as its strength, may be measured by the deflection of a magnetic needle. The propelling force is measured in volts and the strength of the current in amperes, and the instruments by which these quantities are measured are known as voltmeters and ammeters, or ampere meters, respectively. In both a pointer is mounted and free to move over a dial which, when calibrated, enables the amount of current passing, or its strength, to be measured. The heating effect of an electric current is taken advantage of in hot-wire instruments for measuring purposes, the increase in the length of a wire when it is heated being utilized to permit movement of a pointer over a dial.

Not all electric currents are the same, and there are various ways of classifying them. Different names, too, are given to the same current used in different ways. First of all, electric currents may be divided into two broad divisions—direct currents and alternating currents.

Direct currents are those currents which are constant in direction—that is to say, they deflect a compass needle always in the same direction. Such currents are not necessarily constant, but may be intermittent or pulsating. When a direct current continues to flow uninterruptedly, it is known as a continuous current. Most direct currents in practical use are not continuous currents, though those due to primary and secondary cells are so. But the current supplied by a dynamo is discontinuous, though direct.

A diagrammatic representation of the direct current generated by a dynamo would show the current in a series of tops of ripples or half-waves, plotted along a time base. As the number of commutator segments and armature poles increased, so would the number of ripples per second increase, and the times between successive pulsations of current decrease. In actual practice such direct current is hardly distinguishable from continuous current.

High-Tension and Low-Tension Currents

In wireless, the two most commonly used expressions in connexion with direct currents are high-tension current and low-tension current. Neither of these terms admit of a strict definition, for what may be called a high-tension current in one circuit is a low-tension current in another.

The low-tension current is usually taken to mean a low-voltage current—such a current as is supplied for filament lighting of thermionic valves. The low-tension current for this purpose may be supplied from dry cells or a storage battery, at voltages from 1·4 to 6 volts.

In wireless, high-tension current is loosely used for any current over 6 volts pressure. A battery of up to 200 volts may be used for the anode or plate of a thermionic valve for receiving purposes, and the current is said, then, to be high-tension current, and the battery a high-tension battery.

Alternating currents are more important in wireless than direct currents, in a sense. All the so-called radio-frequency currents, audio-frequency currents, oscillating currents, etc., are nothing more than alternating currents.

An alternating current is one in which the electric current flows round a circuit first in one direction and then in the opposite direction, the maximum value of the current in one direction being equal to the maximum value in the other. The reversal of the current occurs at regular time intervals. The nature of an alternating current may perhaps be best understood by considering what takes place as though it took place slowly.

Cycles in Alternating Currents

If the alternations took place so slowly that we could watch the slow movement of an ammeter needle, the latter would be seen to swing slowly over to some maximum value, say 15 amperes. It would then slowly begin to swing back through the zero reading and over to the other side of the dial until it registered 15 amperes in the opposite direction. The cycle of changes would take place at equal intervals of time in accordance with the regular alternations of current. It will be found that the value of the current as read on the dial of the ammeter will be the same at certain definite equal intervals of time, say every twenty seconds. This time interval is called the period of the alternating current.

Actually the cycle of change in most practical alternating currents takes place very much more rapidly than the period suggested. In the ordinary alternating current lighting circuits, for example, the current may pass through sixty complete cycles per second, and is said to have a frequency of 60 cycles per second. In wireless, radio-frequency currents have frequencies of 40,000 to 3,000,000 or more per second, and audio-frequency currents frequencies to about 30,000 per second.

Machines for the production of alternating currents are known as alternators, alternating current generators, or simply generators. The action of the machines depends upon the fact that the motion of a conductor across a magnetic field causes an electromotive force in the conductor, or vice versa. The way this fact is made use of is described in this Encyclopedia under the heading Generator

But in the production of alternating currents of the high frequencies used in wireless transmission there are certain practical difficulties which have only been overcome by the design of special forms of generators. These may be realized from the following facts. To produce a frequency of 60 cycles per second by the use of a single magnet with two poles requires a speed of rotation of 60 revolutions per second. To get 500 cycles would require 30,000 revolutions per minute. These speeds are not practicable, and they are reduced by using a number of magnets. A machine using one magnet is said to be bipolar, and two or more magnets multipolar.

Radio-Frequency Currents

But for the high frequencies used in wireless increasing the number of poles indefinitely does not solve the practical difficulty of the high speeds which are still necessary and the difficulties of construction. Suppose, for example, the diameter of the rotor be two feet and a speed of 2,500 revolutions per minute be allowed. Then to produce a current of 100,000 cycles there would be 4,800 poles necessary, and the pole pitch would be only ·016 of an inch, making it impossible to wind the machine properly. Even with a speed of 20,000 revolutions per minute some 600 poles would be required, and the width of the winding would then only be ·12 of an inch.

A special type of alternator known as the inductor alternator has been devised to overcome these practical difficulties. The field magnets and armature are both stationary. A considerable gap separates the armature core from the faces of the field poles, and in this gap are masses of iron, called inductors, which are free to revolve. The passing of each mass of iron causes a complete cycle of electromotive force, whereas with ordinary alternators it requires the passage of two poles to cause such a cycle.

Frequently there occur in wireless definitely named currents, as anode current, grid current, and so on. These currents differ in no way from those described, and are the currents which go to the anode or plate of a valve, to the grid, and so on, just as the high-tension current, which is delivered by a high-tension battery.

How Eddy Currents Waste Energy

Among other currents not mentioned, however, are eddy currents. In many types of dynamos the armature has an iron core. Electro-motive forces are generated in the iron core, and of course the iron body of the armature, by their revolution, and currents are caused to circulate continually in the metal. These currents are known as eddy currents. They represent so much waste energy, and. to retard them from flowing armature cores are often built up of a large number of thin plates of iron separated from one another by very thin paper or varnish, or some other insulator.

The terms conduction current, displacement current and convection current are sometimes met with. By a conduction current is meant an electric current which will flow in a conductor which forms a closed circuit if some source of electromotive force is inserted in that circuit. A displacement current is a current that flows momentarily in a dielectric or insulating material, or when an electro-motive force impressed on that material is changed in intensity. Convection currents are those currents which are due to the movement of electricity, electrons or positive or negative ions, through the acid of a cell, across a spark gap or a Poulsen arc, between the anode and filament of a transmitting valve, and so on.—*J. L. Pritchard, F.R.Ae.S.*

CURRENT DENSITY. The current density in a conductor is the number of amperes which are passing through the conductor per square inch of its area.

With direct current this is perfectly straightforward, as the current can be considered as uniformly distributed over the whole area of the conductor.

In order to state the density of the current in a conductor it is therefore only necessary to know the area of the conductor and the current which it is carrying to state what the density is. For instance, if a conductor has an area of 1 sq. in. and a direct current of 1,000 amperes is passing through it, the density is 1,000

In the case of alternating currents the distribution in the conductor is not uniform, for the current is more dense near the surface of the conductor.

This packing up of the current near the surface of the conductor is a function of the frequency of the alternations, the permeability, and conductivity of the conductor; it is called "skin effect," and whilst of small importance at commercial frequencies, it becomes very marked when considering large conductors at wireless frequencies. In fact the current then becomes so concentrated on the surface, and near to the surface of the wire, that the central part of the wire may be neglected as far as current carrying is concerned. The solid wire may be replaced by a tube of the same external diameter without increasing its effective high-frequency resistance.

L. W. Austin states that for copper wires up to ·33 mm. diameter the high-frequency resistance is less than 1 per cent greater for wave-lengths from 100 to 3,000 metres.

The high-frequency resistance of a round straight wire may be calculated from a formula by Lord Rayleigh:

$$R_1 = R\left(1 + \frac{h^2}{48} - \frac{h^4}{2880} + \frac{h^6}{58647} \cdot \cdot\right)$$

where R_1 = the high-frequency resistance,
R = the direct current resistance,
and

$$h = \frac{n}{\rho}c^2$$

where n = the frequency,
ρ = volume resistivity,
c = πd or the circumference of the wire.

When h becomes greater than 5 the formula given by Dr. A. Russell should be used. This is

$$R_1 = R\left(\frac{\sqrt{h}}{2} + \frac{1}{4} + \frac{3}{32\sqrt{h}} - \frac{1}{16h\sqrt{h}}\right)$$

which Dr. J. A. Fleming shows may be generally abbreviated to

$$R_1 = R\left(\tfrac{1}{2}\sqrt{h} + \tfrac{1}{4}\right)$$

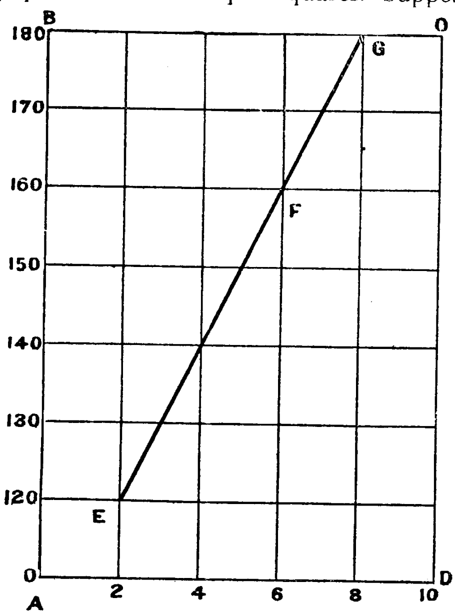
CURVE. Any line whose course can be defined by an equation or general statement applicable to each and every point upon it. A straight line is only a particular case of a curve.

Thus, if a point in a plane moves so that it is always at a fixed or constant distance from another point in the plane, it describes the curve known as the circle. If a point moves so that its distance from a fixed line remains constant, it describes a straight line parallel to the fixed line. The curve described by a point under given conditions is often known as the locus of that point. Thus, the locus of a point in a plane which is always equidistant from a fixed line in that plane and a fixed point is a parabola.

The knowledge of the meaning of curves and the way to plot them is important in science, engineering, and mathematics, and often a curve enables one to visualize what is happening far more easily than a long series of tabulated figures. The curve, too, enables one often to predict what will happen if certain conditions are fulfilled.

Thus, suppose it is known that for a certain conductor when 2 amperes of current are passing the temperature is 120° F., that for 6 amperes the temperature becomes 160° F., and for 8 amperes the temperature has risen to 180° F. The question might be asked how much current must pass to raise the temperature of the conductor to 140° F.

Fig. 1 shows the way in which the problem may be solved. ABCD represents a sheet of squared paper—that is, paper divided into equal squares. Suppose



EXAMPLE OF CURVE

Fig. 1. Represented in this example is a graded rise of amperage and temperature in a conductor passing current. The fact that the curve appears as a straight line is immaterial

along the side AD there is marked off equal increments of amperage. For convenience one might increase the amperage by 2 amperes at a time, and such points can very conveniently come at the bottom of each vertical line. It might equally have been decided to increase in steps of 1 ampere or 3 or any other, so long as the steps were equal for simplicity of marking off the positions along the line AD. Or unequal steps might be chosen, in which case proportionate unequal lengths would have been measured along AD

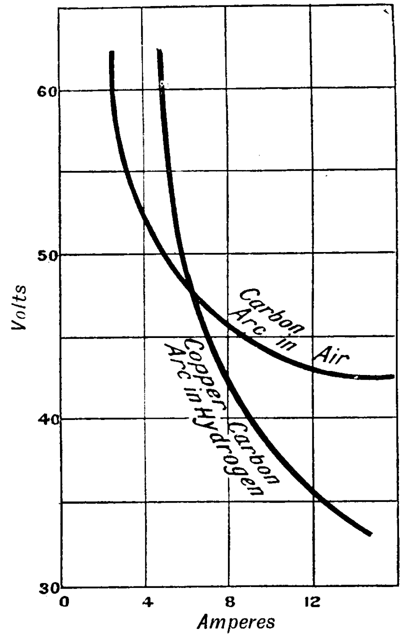
In a similar way equal increments of rise in temperature are marked off along the line AB. In this case the equal increments have been made of 10° F

Now, it is known that at a temperature of 120° the current passing is 2 amperes. Run a pencil along the horizontal line marked 120, and one along the line marked 2. These lines meet at E. Similarly for 160° and 6 amperes, meeting at F, and 180° and 8 amperes, meeting at G There are now three points known on the curve which express the relationship between the increase of temperature in the conductor with the increase of amperage. If these three points are joined they will be found to be in a straight line, the simplest of curves. In other words, the increase of temperature with increase of amperage in this particular conductor is said to follow a straight line law. The question is asked what current must pass to raise the temperature to 140° for this particular conductor ?

Run the pencil along the line marked 140 until it reaches the line EFG. From the point where it meets this line run the pencil down vertically, and it is at once seen that the required amperage is 4.

Unfortunately, most relationships between two quantities in engineering do not follow simple straight-line laws, and can often only be expressed by more or less complicated curves. Fig. 2 shows a graphical representation of the relationship between volts and amperes for carbon arcs burnt in air, and for copper-carbon arcs burnt in an atmosphere of hydrogen.

It will be seen from the two curves that the voltage increases in both cases as the amperage decreases The curves tell more than that however They show that the voltage in the case of the copper-carbon arc increases more rapidly as the amperage decreases than is the case with the carbon arcs burnt in air The curve in the first case

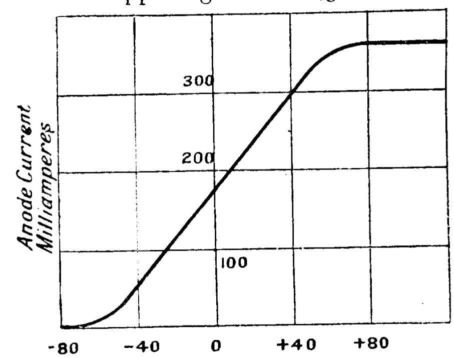


VOLTAGE-AMPERAGE CURVE

Fig. 2. Graphical representation is here made of the relationship between volts and amperes for carbon arcs

is steeper, and from a knowledge of the physics of the problem it follows that the carbon-copper arc in hydrogen is more suitable for generating powerful high-frequency oscillations than the carbon arc in air.

Figures 3 and 4 show two characteristic curves of thermionic valves. The curves illustrate two anode-current grid-voltage curves for the same valve with different anode voltages applied. Figure 3 shows what is happening when 2,500 volts is

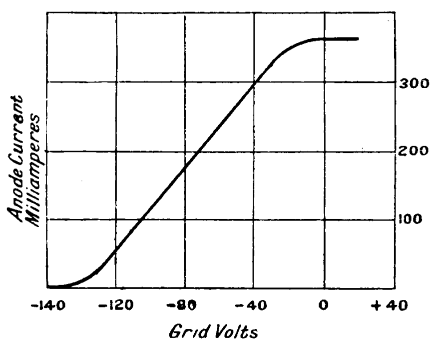


CURVE OF THERMIONIC VALVE

Fig. 3. This curve is plotted to show what happens when a voltage of 2,500 is applied to the anode of a thermionic valve

applied to the anode. It will be seen that the anode current when the grid and filament are at the same potential is about 170 milliamperes. When the grid voltage is varied by plus or minus 50 volts, the anode current is varied between 320 and 20 milliamperes.

In Fig. 4 the anode voltage has been increased to 4,000. The curve expressing the relationship between the grid volts and the anode current remains the same in form, but has moved bodily to the left of the zero lines. In other words, for any particular grid potential the anode current has increased by increasing the anode voltage. When the grid and the filament are at the same potential, for example, the anode current has increased from 170 milliamperes to about 350—that is, it has more than doubled, though the anode voltage has not doubled. The curves express quickly, in fact, the effect of increasing the anode voltage on the anode current. The same result might have been obtained by



HIGH-VOLTAGE ANODE CURVE

Fig. 4. Anode voltage is in this case 4,000, and the curve shows grid potential and anode current increases as compared with the example in Fig. 3

tabulating laboriously the increase of anode current with anode voltage from actual tests carried out with ammeters and voltmeters. But it would have not been so easy to visualize the result immediately.

With the aid of this kind of graphical representation of results it is only necessary to calculate or measure a few points on the curve and then draw a fair curve between them. Care must be taken to plot an extra number of points where it is suspected the curve bends sharply, as, for example, in Fig. 3, at the top and bottom of the curves. Such points may often be detected when plotting the points through which the curve passes by finding some point or points apparently failing to come on the fair curve drawn through the other points. This means the curve may be beginning to bend sharply.

Throughout this Encyclopedia many examples of curves useful to the wireless experimenter are given, and they enable him to get a clearer understanding of what is happening. Knowing a number of points on the curve enables him, too, to find out other points in between—that is to say, to interpolate results.

In Fig. 1, for example, the amperage when the temperature was 140 degrees was interpolated from the known temperatures for 2, 6, and 8 amperes. And so the temperatures might have been interpolated an amperage of say $7\frac{1}{2}$.

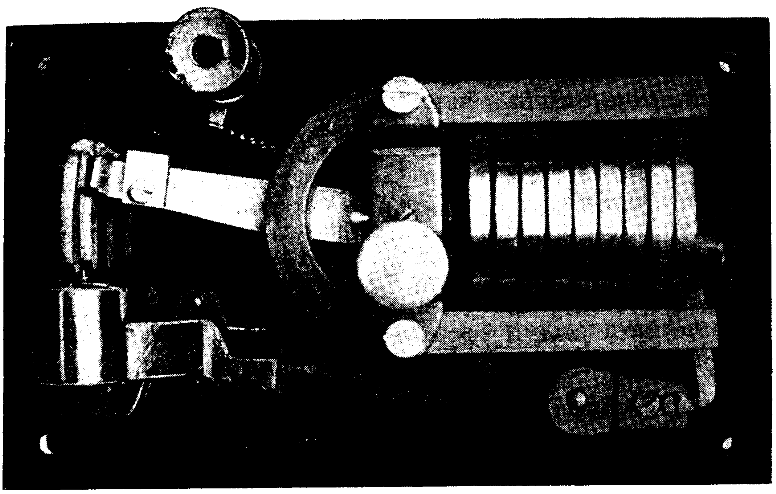
Among the types of curves which are useful to the wireless amateur are those showing the rise and fall of voltage in alternating currents at definite time intervals, the characteristic curves of crystals, of thermionic valves, of arcs, etc. *See* Abscissa; Alinement Chart; Characteristic Curve; Ordinate.

CUT-OUT. An automatic cut-in and cut-out is an instrument used to break or complete a circuit automatically according to some predetermined electrical circumstance. In a well-known example it is used in conjunction with engine dynamo battery charging sets to protect the battery from discharging through the dynamo should the engine fail. It also automatically closes the dynamo-accumulator circuit as soon as the dynamo has gained sufficient speed to generate a voltage above that of the battery.

The instrument shown in Fig. 1 is a standard type. Contact is made and broken by dippers, which are arranged to move in and out of mercury cups. The dippers are attached to a pivoted arm, to which is fixed a moving coil. This coil is arranged to work in the field of a large stationary coil, through which the whole battery-charging current passes. A horseshoe type of permanent magnet surrounds both coils. The whole instrument is mounted upon a slate base.

The method of operation is as follows. It will be seen from the wiring diagrams, Figs. 2 and 3, that the moving coil, which is of high resistance, is connected across the mercury cups, and it is therefore energized in proportion to the difference of potential between that of the dynamo and battery.

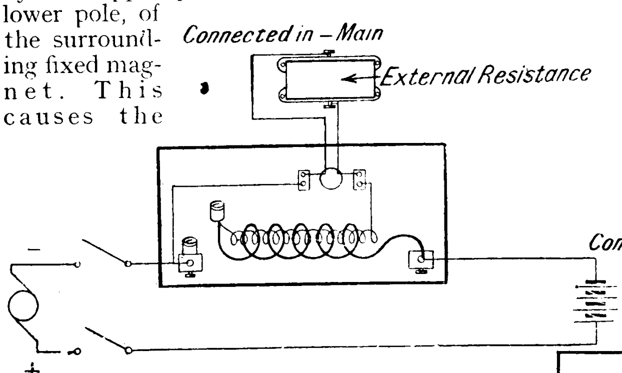
When the dynamo voltage exceeds that of the battery the direction of flow in the coil is such that a soft iron armature, energized by the fine wire coil, is attracted by the upper pole, and repelled by the lower pole, of the surrounding fixed magnet. This causes the dipper arm to make contact with the mercury and complete the main circuit. Immediately the dippers enter the mercury, however, the fine coil is short-circuited, but the armature is still held in position by reason of the attraction of the series coil, or heavy external coil, which is now energized by the main current.



CUT-OUT INSTRUMENT FOR BATTERY CHARGING

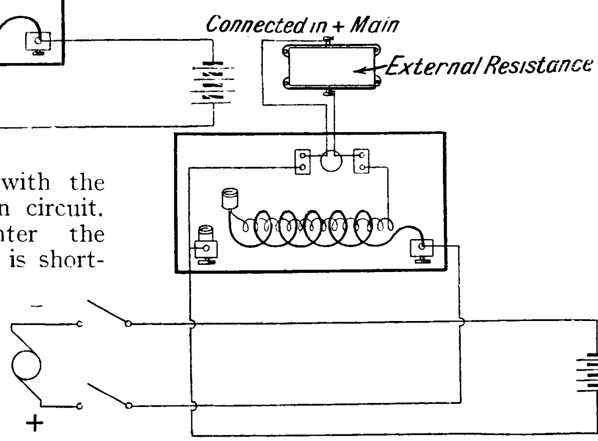
Fig. 1. Dippers in mercury cups complete or break a circuit working automatically—as, for example, while charging a battery by means of a dynamo

Courtesy General Electric Co.



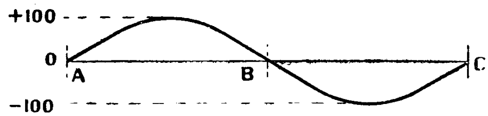
If for any reason the dynamo should fail, the dippers immediately spring out of the cups, for the current in the series winding reverses. The high-resistance coil comes once more into play, but this time firmly holds the dippers out until the dynamo voltage again rises above that of the battery. The external resistance shown in the diagram is placed in series with the high-resistance moving coil only when the instrument is designed to work on voltages above eight. An advantage with this type of instrument is that no sparking occurs at the mercury break when the circuit is actually being completed or broken, for the arrangement is such that the make or break occurs at zero difference of potential between the dynamo and battery. *See* Automatic Cut-out.

CYCLE. Series of events which occur in the same regular order. In wireless, the term is usually used in connexion with alternating currents, and a cycle is one complete set of positive and negative values of an alternating current. Thus, in the figure, if



THEORY OF CUT-OUT INSTRUMENT

Fig. 2 (top). Method of operation of a cut-out. High-resistance moving coil is connected across the mercury cups. Here connexion is made to positive main. Fig 3 (below). Negative main connected



CURVE ILLUSTRATING A CYCLE

Cycle is the term used in wireless to indicate a series of values such as that represented in this diagram, which shows a set of positive and negative values of an alternating current

the curve A B C shows the curve of potential for such a current, the flow from A to B—*i.e.* from zero potential to 100 volts and back to zero potential—is called an alternation. Two alternations—*i.e.* from A to C—form a cycle. *See* Frequency ; Wave.

CYMOMETER. The name cymometer is applied to the particular form of wave-meter invented by Dr. J. A. Fleming.

The instrument shown in Fig. 1, and diagrammatically in Fig. 2, is mounted on a long polished wood base, and consists of a long condenser and inductance, both of small diameter relative to their length, and arranged parallel to one another on ebonite end-pieces.

The condenser is of tubular form, consisting of two concentric brass tubes, with an ebonite tube separating them.

Immediately behind the condenser is the inductance, which is formed from a spiral of heavy-gauge bare copper wire, mounted on ebonite.

Arranged parallel to the inductance is a flat board on which are mounted scales for reading wave-lengths directly in metres, wave-length in feet, number of oscillations per one-millionth of a second, and the oscillation constant $= \sqrt{LC}$

An insulating handle is attached to the outer tube and also to a sliding contact. This handle has an extension which forms a pointer running over the surface of the scales.

In order to indicate when the instrument is in tune with the oscillating circuit whose wave-length it is desired to measure, a neon vacuum tube, Fig. 2, is connected across the terminals of the condenser, the glow in this tube being used to indicate the tuning point.

Provision is also made for inserting a thermo-electric ammeter in series with the condenser, this enabling more accurate readings to be obtained.

In using the cymometer, or any other form of wave-meter, it is important to work with the coupling between the instrument and the oscillating circuit as loose as

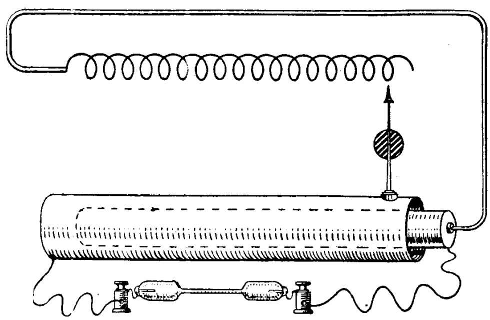


DIAGRAM OF A FLEMING CYMOMETER

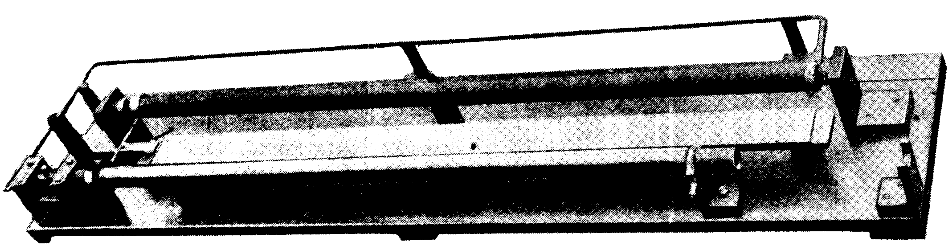
Fig. 2. Diagrammatic representation of the connexions of a cymometer for measuring wave-lengths. A neon tube is inserted to ascertain the tuning point

possible, for when the circuits are tightly coupled two tuning points will be detected, one of which will be greater and one less than the natural wave-length which it is desired to measure.

Dr. Fleming gives the following instructions for the use of his cymometer in "The Wireless Telegraphist's Pocket Book":—

1. To measure the frequency of the oscillations in any circuit within the range of the instrument.

Place the cymometer so that its copper bar is near to and parallel with the circuit



CYMOMETER OR FLEMING WAVE-METER

Fig. 1. An instrument as shown in this photograph, and known as a cymometer, is used for measuring wave-lengths either in metres or feet. A long tubular condenser and a long spiral inductance are the principal features of the instrument

or wire in which exist the oscillations of which we desire to know the frequency. Join in the neon tube to the holder connected to the terminals of the condenser. Slide the condenser tube along until the neon tube glows most brightly. Then move the cymometer bar away from the circuit under test until it is found that the neon tube only just glows when the cymometer condenser is adjusted to one particular position. Then read off on the scale the corresponding oscillation constant $O = \sqrt{CL}$ and the corresponding frequency

$$n = \frac{5 \times 10^6}{CL} = \frac{5 \times 10^6}{O}.$$

If there are oscillations of two frequencies present in the circuit, then the neon tube will glow brightly when the cymometer condenser is set to two positions, the oscillation constants of which correspond to these frequencies.

2. To measure the wave-length of the electric waves sent out from any radiator or aerial wire.

Place the cymometer with its bar parallel and near to part of the radiating circuit or aerial wire and move along the condenser until the neon tube glows most brightly, using the same precautions as in the former test. Then observe the oscillation constant for that setting.

Relationship of Wave-Length

In the case of all wave motions the wave velocity, W, is connected with the wave-length λ and the wave frequency n as follows:

$$W = n\lambda \qquad (A)$$

In the case of electric waves in space, the wave velocity is 3×10^{10} centimetres per second, or 300,000 kilometres per second or nearly 1,000 million feet per second.

Hence we obtain the wave-length in metres by dividing 3×10^8 by the wave or oscillation frequency n. Now the oscillation frequency n is connected with the oscillation constant $O = \sqrt{CL}$ by the relation,

$$n = \frac{5 \times 10^6}{O} \qquad (B)$$

Hence from (A) and (B)

$$\lambda = \frac{3 \times 10^8}{5 \times 10^6} O$$

or

$$\lambda = \text{(wave-length in metres)} = 60O \qquad (C)$$

where O is the cymometer oscillation constant when tuned with the circuit tested.

If we work in feet, then

$$\lambda = \text{(wave-length in feet)} = 200O \qquad (D)$$

These formulae are only approximate; when great exactness is required, we must put for (C) and (D) the expressions

$$\left.\begin{aligned} \lambda \text{ (metres)} &= 59{\cdot}60 \\ \lambda \text{ (feet)} &= 195{\cdot}56O \end{aligned}\right\} \qquad (E)$$

If there are waves of two wave-lengths, λ_1 and λ_2, emitted from a tuned coupled transmitter, and if λ is the natural wave-length of the antenna, then we have

$$2\lambda = \lambda_1 + \lambda_2$$

3. To employ the cymometer to measure an inductance or a capacity.

We can employ a wave-meter or cymometer which has been carefully standardized as a means of measuring a capacity or an inductance for high frequency as follows.

Measuring Capacity and Inductance by the Cymometer

An oscillatory is set up which consists of a condenser comprising one or more Leyden jars. These are connected in series with a rectangular circuit formed by laying insulated copper wire, say of No. 14 S.W.G. size, round the edge of a rectangular board This wire should be interrupted in two places; in one a spark gap should be inserted, and in the other gap the condenser should be inserted, so that condenser spark gap and rectangular circuit are in series with one another. It is convenient, also, to have another gap in the rectangular wire which can be bridged over or in which can be inserted any loop of wire of which the inductance is required. The spark gap in the above circuit is connected to an induction coil so as to set up damped oscillations in the rectangular circuit.

The cymometer is placed near to this rectangular circuit with its copper bar parallel to one long side of the rectangle and adjusted to loose coupling. It will then be found that on taking a cymometer reading, oscillations of one single frequency exist in the rectangle, and these have a frequency n, and the circuit has an oscillation constant $O = \sqrt{CL}$ of a certain numerical value as read on the scale of the cymometer when the latter is adjusted so that the neon tube glows most brightly.

This means that the product of the inductance L of the rectangular circuit reckoned in centimetres, and the capacity reckoned in microfarads, has a certain numerical value equal to O^2. Now suppose the capacity in the rectangular circuit is increased by the addition of another small unknown capacity C_1, which is joined in parallel with the Leyden jars of capacity C, then if we take another reading of the cymometer we observe a fresh oscillation constant O_1. Hence we have

$$O^2 = CL$$
$$O_1^2 = (C + L_1)L,$$
$$= O^2 + C_1L,$$
$$C_1 = \frac{O_1^2 - O^2}{L} \qquad (F)$$

Now the inductance L of the rectangular circuit can be calculated from the dimensions of the rectangle and the thickness of the wire, hence when we know the value of this inductance L we can calculate by (F) the value of C_1.

In the Fleming cymometer the lid of the box which contains it has a rectangular wire circuit with two gaps in it extended into short connecting wires attached to it. The calculated value in centimetres of this rectangular inductance is given with the instrument. Suppose it to be 6,000 cm., and let the two readings O and O_1 be respectively 3 and 5, then we should have

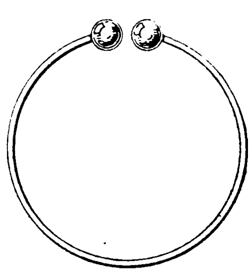
$$C_1 = \frac{25 - 9}{6{,}000} = 0{\cdot}002{,}666 \text{ mfd.}$$

or 2,666 micro-microfarads. *See* Wavemeter.

CYMOSCOPE. Any instrument which enables us to see or detect the presence of electrical or other waves may rightly be called a cymoscope.

The name has now taken on a particular significance, and is generally applied to those forms of apparatus which enable us to detect wave-lengths of the order which are used for wireless telegraphy and telephony. These may, at present, be said to fall between waves one metre in length and those of several thousand metres.

One of the earliest forms of cymoscope to be used was the Hertz tuned loop (Fig. 1), such a loop consisting of a ring of brass tube or wire, cut at a point, and having brass balls mounted on its two ends. It is not only a cymoscope, but a cymometer or wave-meter, for, due to its self-capacity and inductance, it will respond to a definite wave-length.

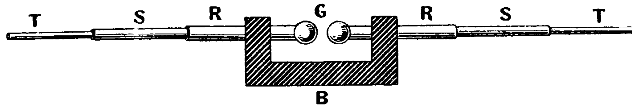


EARLY FORM OF CYMOSCOPE

Fig. 1. One of the earliest cymoscopes was a Hertz tuned loop, as here illustrated

If it is brought near to a wireless transmitter which is sending out waves of a short wave-length, and if the transmitter is capable of adjustment so that the wave-length of the wave sent out may be adjusted, it will be found that when one particular wave is sent out a small spark will pass between the balls of the cymoscope.

Such an instrument may be useful as a standard of wave-length, but is not adjustable.



ADJUSTABLE CYMOSCOPE

Fig. 2. Held by an ebonite holder are two brass tubes with balls forming a spark gap. The distance across the gap is variable. See text for letter references

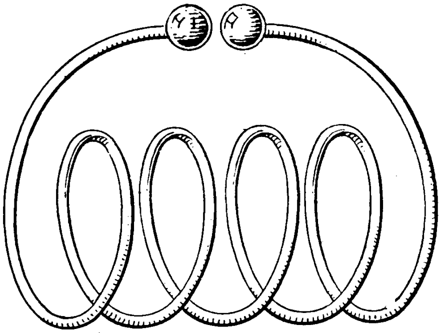
In a variation due to Blondlot the wire was made rectangular in outline and a condenser inserted in it. The balls were made adjustable by screws to vary the gap between them.

A form of double tube with a spark gap in the middle has therefore been used (Fig. 2). This consists of an ebonite holder, B, having the brass tubes, R, which are terminated in balls, mounted in it; sliding tightly in the tubes R are others, S, and within these again are others, T.

The wave-length to which such a cymoscope will respond is adjustable, for by extending the tubes the natural wave-length of the instrument is increased. These simple instruments are only suitable for use with short wave-lengths of the order of a metre or so, for when the wave-length becomes longer the instrument becomes too big for convenient handling.

The spark gap is an insensitive apparatus to use, and may well be replaced by one of the very small electric lamps which are used for electric torches or hand lamps; or, better still, by a low reading, hot wire milliammeter.

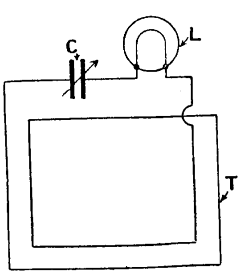
From the single loop it is an easy step to the multiple loop, Fig. 3, which will respond to longer waves; and again replacing the gap by a lamp, we have a more sensitive instrument. Now the wave-length of such an instrument depends on its inductance and its capacity. Any increase in either will increase its natural wave-length. Replacing the small balls by others of larger capacity will put the wave-length up; but instead of having a selection of various-sized balls it is far



MULTI-LOOP CYMOSCOPE

Fig. 3. Longer wave-lengths respond to this type of cymoscope than to that in Fig. 1, but the arrangement is not variable

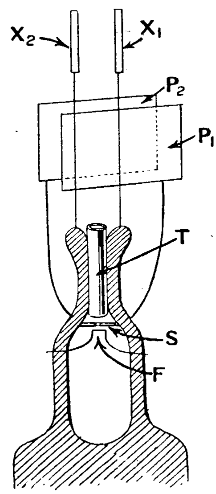
more convenient to replace the balls by an adjustable condenser. Then, still retaining the lamp as an indicator, we come to a modern form of wave-meter (Fig. 4), in which T is the turns of wire wound on a former, C is the adjustable condenser, L is the lamp which indicates, by the brilliancy of its filament, when the wave-meter is in tune with the transmitted wave.



MODERN CYMOSCOPE

Fig. 4. Modern form of cymoscope, including the turns of wire T, a variable condenser, and lamp indicator

Cathode Ray Oscillograph. This type of cymoscope, which is really an oscillograph, owes its origin to Braun. It was not, however, made in simple form until November and December, 1922, and January, 1923. A. Dufour described in "L'Onde Electrique" a form of cathode ray oscillograph. This was still a complicated piece of apparatus, but at the same time in England, *i.e.* November, 1922, at the Institute of Electrical Engineers, R. Webb showed the commercial cathode ray oscillograph, which is now manufactured by the Western Electric Company. This instrument consists (Fig. 8) of a glass bulb of rather curious construction. It is like an inverted glass funnel, but has a slightly convex top to it. In the neck of the funnel is mounted a small electric filament, F (Fig. 5), above this is a screen, S, above this again is mounted a tube, T, then above that again are two square plates, P_1, P_2, whilst lastly there are other similar plates, X_1, X_2, but mounted in the tube at right angles to the plates P_1, P_2.



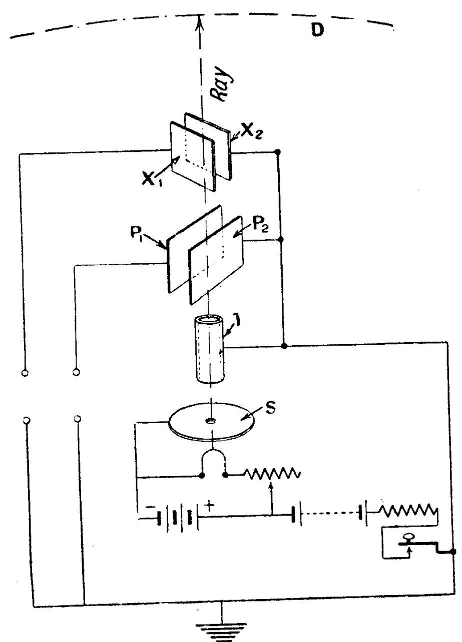
OSCILLOGRAPH

Fig. 5. Details of the cathode ray oscillograph

The curved top of the bulb is coated on the underside with a fluorescent screen, D (Fig. 6), which becomes luminous when subjected to bombardment by electrons.

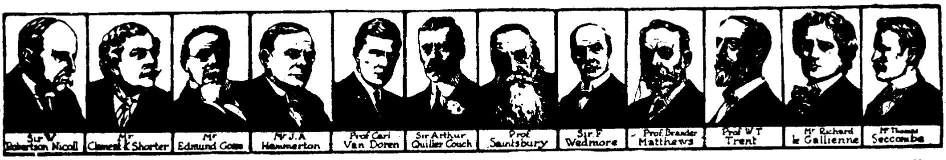
The principle of the action (see Fig. 6) is as follows:

The coated filament F is heated by a local battery. This



CATHODE RAY OSCILLOGRAPH PRINCIPLE

Fig. 6. From this diagram the principles on which the cathode ray oscillograph works will be seen. The curved top of the bulb is coated with a fluorescent screen



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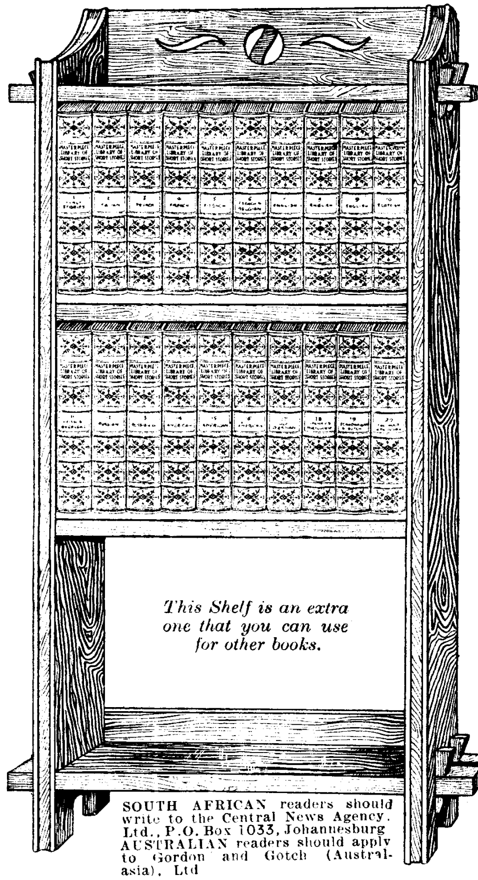

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