THE "P.W." CRYSTAL Experimenter's Handbook

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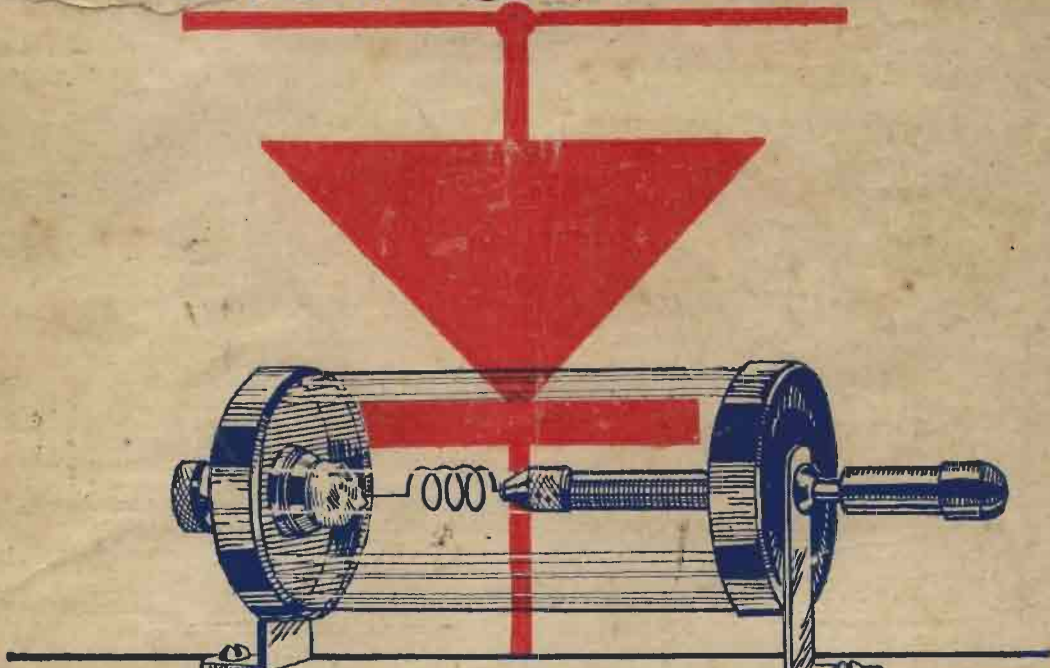

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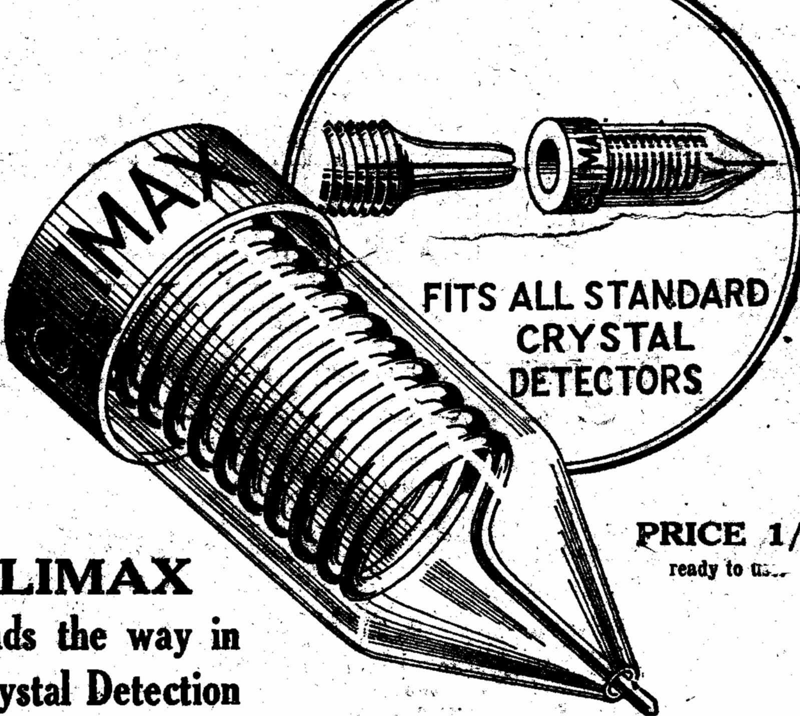

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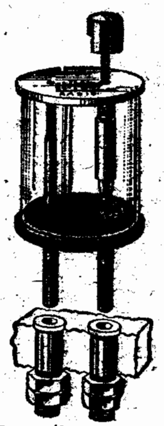

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THE "P.W."

CRYSTAL EXPERIMENTER'S HANDBOOK

INFORMATION YOU CANNOT DO WITHOUT

SPECIALLY WRITTEN FOR "POPULAR WIRELESS"

By

J. F. CORRIGAN, M.Sc., A.I.C.

(Staff Consultant to "Popular Wireless")

and

other "P.W." Contributors

THIS book, price 6d. (but presented free with every issue of POPULAR WIRELESS week ending October 3rd, 1925), contains a wealth of useful information for Crystal users. Written by a Master of Science and an acknowledged authority on crystals, readers will find that Mr. Corrigan and the other contributors to this volume have compiled a really up-to-date and invaluable book for those who own any type of Crystal Set.

CHAPTER I.
The Evolution of the Crystal.

If, by an effort of the imagination, the reader of this book can take his mind right back into the dim ages of the world, to an epoch of time long before the dawn of life on this planet, he will arrive at that period of the earth's history in which most of the modern radio-sensitive crystals and minerals were in the making.

The creation of the crystal took place when the earth was very young. Before the oceans came into being, when this globe on which we live was little more than a plastic mass of semi-molten material, when huge streams of sulphurous vapours and gases were belched forth from within the interior furnaces of the earth to pour over and to react upon the rocky lava on its surface, the greater number of the metallic ores and minerals which are now found in the earth's crust were made.

Early Investigations.

The crystal has a history which takes us back through countless ages almost to the beginning of the world. Man learnt to make good use of the many varieties of crystalline minerals which exist in the earth's surface at a very early stage of his mental development, but, curiously enough, it is only within the last hundred and fifty years or so that attempts to study the properties and characteristics of these numerous varieties of crystalline mineral products have been made in any really accurate and scientific manner.

That some species of minerals were capable of exhibiting mysterious and very peculiar electrical phenomena, however, has been known, more or less, for some considerable time. You may read, in many of the seemingly nonsensical and obscure writings of the alchemists, of minerals which have been known to shine in the dark, and to give out flashes of light when they were gently rubbed in contact with other substances. Probably the characteristic magnetic property of the *lodestone* in always pointing to the north when it is freely suspended was the first electro-magnetic characteristic of certain members of the mineral world which impressed itself on the mind of Man.

It is a far cry from the first investigation of the magnetic properties of the lodestone* down to the discovery of the rectifying power of certain other minerals, but, nevertheless, the history of mineral physics is a very fascinating one to trace out, showing as it does the fact that even the dead and inanimate objects of Nature are endowed with many remarkable properties which have for centuries remained entirely unsuspected.

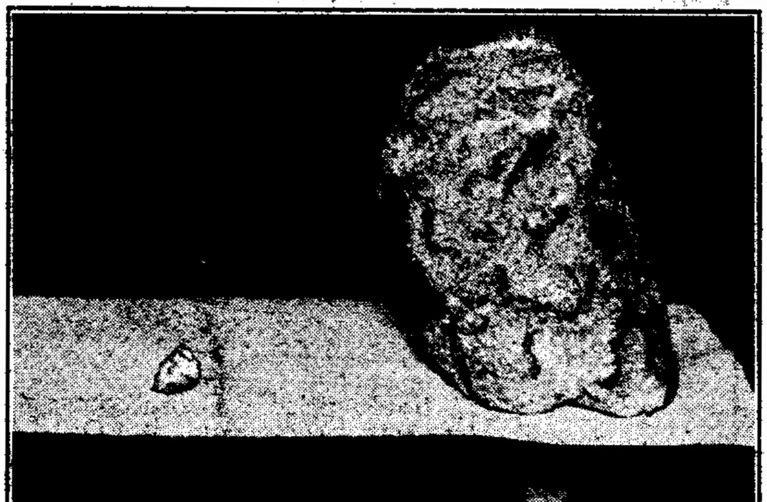
The Discoveries of Braun.

The first germ of the discovery of crystal rectification is to be seen in the now classical investigations of a certain Professor Ferdinand Braun, one of the pioneers in spark telegraphy, who, in the years 1873-4, experimented with many different kinds of contacts existing between oxid[illegible]metals and minerals. Braun made the discovery that, although these faulty contacts caused a very high impedance to the passage of an electric current, they had the remarkable property of allowing a greater amount of current to flow through them in one direction than in the other.

The discovery did not cause very much attention to be drawn to it at the time. It was duly published in the scientific journals of the period, a few other workers conducted experiments in the subject, and then all interest in the matter seems to have abated.

In fact, it was not until nearly ten years after the first experiments of Marconi that the crystal was applied for the purpose of rectifying wireless currents.

Carborundum was the first crystal to be used for this purpose, and, curiously enough, this material is not a natural product, but it is manufactured artificially. In 1906 General H. H. C. Dunwoody, of the United States' Signal Corps, patented the use of the now well-known carborundum detector for the purpose of receiving wireless telegraphy



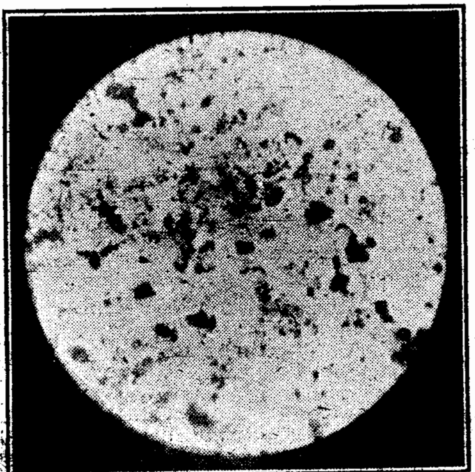
A small and large example of carborundum crystal.

**The attractive power of the lodestone (magnetic oxide of iron) is reputed to have been well known to the early Chinese. It was Dr. Gilbert, however, the renowned Physician-in-Waiting to Queen Elizabeth, who first thoroughly investigated the properties of this mineral at the end of the 16th century.*

transmissions. Dunwoody employed his detector with and without the aid of a local potential.

This was the beginning of the practical application of crystalline minerals to wireless reception. Soon after the first use was made of carborundum for this purpose other crystals began to be employed, and as interest in the subject grew, the number of crystals found to be possessed of rectifying properties in like manner increased.

In 1907 the now well-known "Perikon" detector first appeared. It is interesting to record the evolution of the term "Perikon." The word was first used by G. W. Pickard to apply to a rectifying contact, comprising a crystal of fused zinc oxide and a brass point (U.S.A. Patent, 886,154/07). Afterwards, Pickard applied the name to designate a contact between natural zincite and copper pyrites*. Pickard also investigated the rectifying properties of silicon contacts.



Minute pieces of lead sulphide showing their amorphous nature. Galena retains its crystalline structure even after powdering, as will be seen from the photograph below.

In England the quest for new rectifying combinations proceeded apace. Molybdenite, various pyrites, anatase, the rare mineral, hessite, tinstone, bornite, and a host of others, were examined and found to possess good rectifying properties when used in conjunction with suitable contacts. Among the names which may be mentioned in connection with these discoveries are those of Professor Pierce, Dr. Eccles, P. R. Coursey, and L. W. Austin. The radio experimenter who is specially interested in the details of crystal research will find all the data which he requires on this subject in the electrical and scientific journals of the period, say from 1906 to 1912.

Why Crystal Sets are Popular.

The introduction of the three-electrode valve, and the application of its highly valuable properties, however, almost completely caused a cessation of the interest which had until then been taken in the rectifying properties of the crystal; and, in fact, it was not until the advent of the broadcasting services in 1921 that popular interest in crystal rectification was again revived.

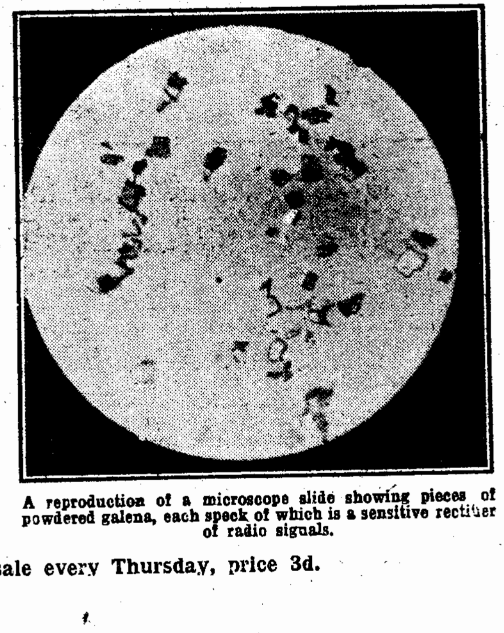
Now, after a period of some three years' use, the radio-sensitive crystal has been given what seems to be a permanent position in the science of amateur wireless reception, and, as I hope to show later on, the crystal is beginning to give evidence of further electrical properties which may have many valuable applications attached to them at some future time.

Why has the humble crystal attained such a large measure of popularity with at least seventy-five per cent of wireless enthusiasts at the present day? The reason is one which every radio experimenter knows. In the first place, a radio-sensitive crystal is not an expensive article like a valve is, nor does it require any expense of upkeep after it has been installed in the set. It gives pure reception, far better, in fact, than that which is obtained with most rectifying valves. It is convenient to use, and the circuits in which it is employed are of the very simplest type.

An Honoured Place.

Thus a crystal set appeals fundamentally to the man who is only interested in what he can get out of a broadcast concert, and who does not want to be bothered with acquiring the skill necessary for the effective operation of a valve set. Further than this, however, the radio crystal is of great interest to the experimenter who foresees the development of its effective scope, and who, as a consequence, endeavours to take his own share in the attainment of that end.

Of course, the crystal is not without its own inherent disadvantages. Its range is very severely limited, and at the present time there is no easy and straightforward way of appreciably extending its powers in this direction. Despite this fact, however, the crystal holds an honoured place among wireless receiving instruments for amateur use, and it will continue to occupy that position until some simpler and more efficient device is produced.



A reproduction of a microscope slide showing pieces of powdered galena, each speck of which is a sensitive rectifier of radio signals.

**U.S.A. Patent*, 912,726, 1907.

It is not within the scope of this little booklet to go with any detail into the many suggested reasons as to why certain crystals and minerals should rectify wireless high-frequency currents. However, most of the main theories which have from time to time been put forward to explain the crystal's action may be briefly gone over within the space at our disposal.

An Unsolved Problem.

The main characteristic of a rectifying mineral or crystal contact is its property of unilateral conductivity, a phenomenon, which, as every radio amateur knows, consists in the passing by the crystal contact of a current in one direction, but of the almost complete stoppage of it when it is made to flow in the opposite direction.

The great difficulty is, of course, to understand the reason why certain contacts of mineral and other materials should exhibit this property. Does the rectifying action take place entirely at the surface point of contact only, or does it take place in the interior of the crystal? Is it a phenomenon of heat effects at the point of contact, can it be explained on an electrolytic basis, or does it rest, after all, on some peculiar chemical or molecular structure of the crystal itself?

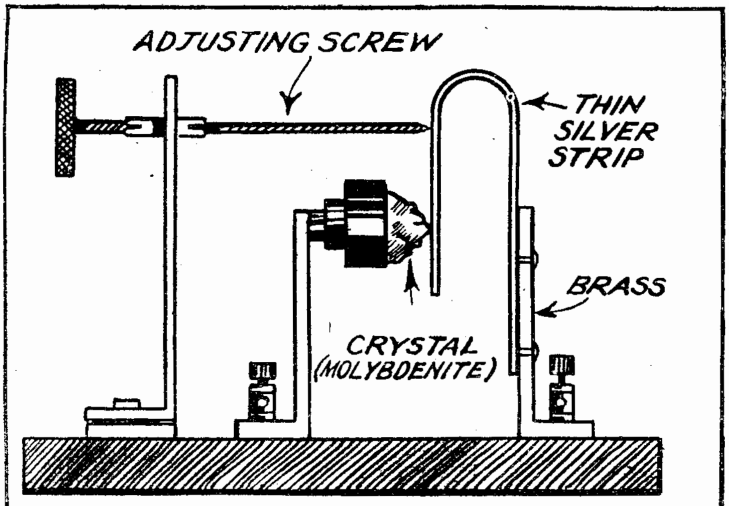


FIG. 1.

To be brief, these points have not been settled, and, despite many new suggestions, we seem as far off as ever from the completely satisfactory solution of the problem.

Theories of crystal rectification may roughly be divided into some four or five different categories. The first of these is concerned with the electrolytic theories which have been put forward to explain the crystal's action. Electrolytic theories of crystal rectification would explain the phenomenon, on the assumption that the presence of oxygen is necessary for the rectifying action. Adherents of these theories assume that a film of oxide (or sulphide) is always present at the point of contact, and that ionisation and polarisation of the oxide film produces the rectification by causing a sort of electro-motive force to be set up at the point of contact, this opposing the electron flow in one direction very greatly, whilst a comparatively free passage is made for the current flowing in the other direction.

Thermal theories to explain the effect of the crystal are usually based on the fact that local heating effects are set up when a current passes between a junction of two dissimilar metals. The heating effect between a crystal or mineral and its contact is, in general, supposed to alter the resistance to the current flowing in one direction more than it does to current flowing the opposite way.

Later Theories.

Further still, there are a number of theories extant which attempt to explain the problem by assuming that the area of contact and its state of imperfectness allows the passage of minute currents much more in one direction than it does in the other. These theories are perhaps the oldest of the lot, but they have very few good points to recommend them.

Most of the later theories of mineral rectification are of a physico-chemical or an atomic nature. It has been suggested, on the one hand, that if a perfectly pure mineral or crystal could be obtained (that is, one which does not contain the slightest trace of chemical impurity), it would probably be found to be a non-rectifier. We may call this the "chemical theory" of crystal rectification, for it is one which suggests that the rectifying action of the mineral is due to the upsetting of its regular pattern by the intrusion of small amounts of impurities, and of therefore setting up in the interior (or on the surface) of the crystal areas of varying resistance.

Finally, some crystal rectification theories explain the effect upon a physical basis only. We know infinitely more about crystal architecture at the present time than we did even ten years ago, and underlying all these modern theories is the idea that some peculiarity of the atomic pattern of the crystal is responsible, not only for the rectifying action of the crystal, but also for its function as a generator of oscillatory currents, and for other electrical properties which it exhibits.

Many Difficulties.

Those, in brief, are the themes upon which the theories of crystal rectification are based. Nearly every one of them has some good points to recommend it; on the other hand, they all have many difficulties which are not to be overcome in practice. It is obviously impossible to enter into a discussion of these theories in this book. They are all of a highly technical nature, and, as such, would not be of very great interest to the practical-minded radio amateur. Nevertheless, if any of my readers are specially interested in the subject, all the essential details and reasoning connected with these varying and opposing theories may be found in the journals of various scientific societies up to this date.

The Crystal's Discovered Prominence.

Thus the essential cause of the crystal's rectifying and oscillating action remains one of the many problems which science has not yet been able to solve. In fact, for many years the subject was regarded as being of little importance. The amateur wireless enthusiast, however, has placed the crystal upon a new basis. In view of his needs, the crystal has come into prominence again. The fascinating occupant of the detector cup is once again receiving some measure of the scientific attention which it deserves. The "mystery" of the crystal has not yet been solved, but, after all, the scientific study of the internal molecular architecture of crystals is one of the youngest of the sciences. It is barely ten years old. Who knows, therefore, what further capabilities the crystal will reveal after it has been studied for another ten years?

CHAPTER II.

The Crystal Classified.

When one comes to consider the question, there is really more difficulty in formulating a classification of radio-sensitive crystals than is usually supposed. For one thing, no scheme of crystal classification takes into account all the many varied properties which crystals exhibit; and, again, many of these schemes are highly technical in nature, and are not of very great assistance to the radio crystal enthusiast and experimenter in his endeavours to determine the nature of the crystal with which he is experimenting, and the degree of rectification which it may be expected to afford.

A Simple Scheme.

Mineralogists, and crystallographers generally, have a very elaborate and complicated scheme of crystal classification. These individuals do not classify a crystal according to its chemical composition, and so on, but they take one particular physical characteristic which all crystals exhibit, to wit, that of its angular form or shape, and they base their system of classification on that.

Of course, for most purposes this scheme of classification is found to be very desirable and efficient, but for wireless purposes it is of very little use indeed. To say that a crystal belongs to the cubical or the hexagonal class of crystals conveys little or no practical information to the wireless experimenter. Therefore, it is evident that before we can proceed very far with our study of radio rectifying crystals, we must have some simple and practicable scheme of our own, by means of which the properties and exact uses of a crystal for wireless purposes may be readily deduced.

Let us therefore consider a few simple schemes of classification in an endeavour to determine which of them is of the greatest use to the wireless experimenter in the sphere of crystal research.

In the first place, for general amateur purposes, crystals may very conveniently be divided up into two large categories—viz., "cat's-whisker" crystals and Perikon crystals. The former class includes, of course, all those crystals and mineral products such as galena and the multitudinous array of proprietary trade products which are derived from it, silicon, iron pyrites, and several others, which give their best results when employed with a single fine-wire metallic contact only.

On the other hand, in the category of Perikon crystals are included all those crystals and minerals which are most efficiently employed as rectifiers of high-frequency currents when they are used in combination with another crystal, which is generally of a different nature. Zincite, bornite, copper pyrites, tellurium, and graphite are perhaps the best-known examples of this type of mineral.

Not Universally Correct.

But still, however, this scheme of crystal classification cannot be said to be entirely satisfactory by any means, for, as every crystal experimenter knows, there are many crystals which can be used almost equally efficiently as single contact rectifiers, or as combination crystals. A galena crystal, although it is generally employed with an ordinary cat's-whisker contact, will make a very sensitive rectifying combination when it is used in conjunction with another galena crystal possessing a slightly different grain. Iron pyrites is a single contact crystal, but yet it will give excellent results when used with zincite, tellurium, and many other minerals.

Again, zincite can be used with an ordinary cat's-whisker, and this is especially true of the synthetic variety of this mineral. Copper pyrites can be similarly employed also.

Still further, there are some crystals, such as carborundum and molybdenite, which give their best results when they are used, not with an ordinary cat's-whisker contact, or in a Perikon type of detector, but when they are employed with a special type of contact, such as a flat piece of springy metal, which makes a very firm contact at many portions of their surface area.

Thus it will be evident that the cat's-whisker-Perikon classification of crystals, whilst it is a very convenient and practical scheme to use, is not a universally correct one.

Three Large Categories.

Besides the orthodox angular scheme for classifying crystals which is in use for most scientific purposes at the present day, there have been put forward from time to time various other methods of crystal classification. For instance, it has been suggested that all minerals might very well be tabulated and classified according to the degrees of hardness which they possess. Other crystal experimentors have measured the low-frequency resistances of varying kinds of crystals; they have investigated various thermal and electrical phenomena which are exhibited by many crystals and minerals, and they had endeavoured, as a consequence, to classify crystals in accordance with the results which have been obtained.

To cut matters short, however, the best scheme of crystal classification which may be formulated for the purposes of wireless experimenters is one which is based upon a consideration of the chemical nature of the crystal itself. There are many reasons for this. In the first place, the classification is more scientific than the ordinary cat's-whisker-Perikon sort of thing, and, again, it is definitely of value to the earnest crystal experimenter and research worker because it enables him to predict with a fair amount of accuracy the radio-sensitive properties which any particular crystal or mineral can reasonably be expected to possess—that is, of course, provided its chemical nature is known.

Further than this, if the chemical nature and composition of a mineral is definitely known, there is always a good chance of imitating the make-up of the crystal artificially in the laboratory, and of thus bringing into being a synthetic product, the rectifying powers of which will be greatly enhanced. The feat has already been performed with one or two varieties of minerals, as will subsequently be described in another chapter of this book.

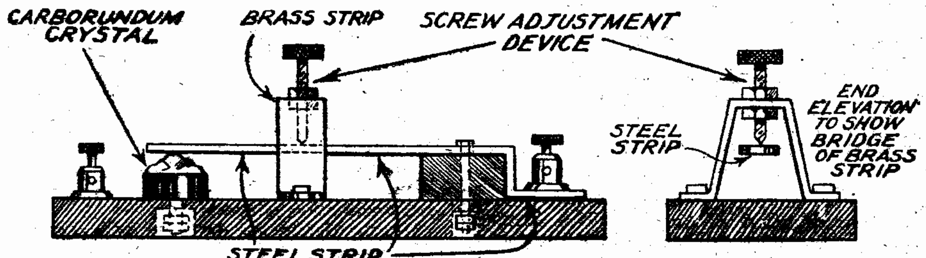


FIG. 2. DESIGN FOR A USEFUL CARBORUNDUM DETECTOR

If you take practically any efficient mineral rectifier of high-frequency currents and get to know its chemical composition, either by means of direct analysis, or by the much simpler method of looking up its chemical nature in a chemical dictionary, you will find that you will be able to include it in one of three large categories. In composition the crystal will be either a sulphide (or a similar compound) of some metal or mixtures of metals, or an oxide, or, on the other hand, perhaps it may be an elementary substance; that is to say, a substance such as graphite (carbon) or tellurium, which cannot be split up into any simpler material by the ordinary methods of chemical analysis.

A Classified List.

Almost every crystal or mineral, with perhaps one or two notable exceptions, such as carborundum, consists of either a sulphide or an oxide of a metal, or else it will be found to be an element only.

Going on these lines, therefore, let us now examine the radio properties of a number of well-known rectifying crystals and endeavour to find out how they may be the most efficiently used for the purpose of radio rectification. A list of crystalline and mineral products, arranged in alphabetical order, and classified according to their chemical nature, will be found at the end of this book. The experimenter will find this compilation of use to him should he be actively engaged in the process of testing out crystal combinations.

CHAPTER III.

Crystals Classified.

(Continued)

Galena.—Galena has the honour of being the most favoured of all rectifying crystals for general amateur use. It has well-defined rectifying properties, it affords reception of very great tonal purity, and it is fairly plentiful, and, in consequence, therefore, it is not very expensive. Perhaps the one factor which has so greatly influenced its popularity is the fact that it functions very well when used with a single cat's-whisker contact, and this, combined with the fact that the material does not readily lose its sensitive properties when treated with reasonable care, has encouraged crystal dealers and importers to attempt the manufacture of synthetic galenas, mineral products in which the necessary radio-sensitivity can be more readily standardised and kept constant from batch to batch of the material.

Galena is mined in various parts of the world. Most of the radio-sensitive material, however, comes from mines which are situated in various parts of Southern France, in the Andalusian regions of Spain, and in Mexico. In addition to this, it is also of interest to note that one or two English mines are now supplying radio-sensitive galena to the public.

Galena functions well as a rectifier when it is used with a moderately fine cat's-whisker contact. The metal out of which the contact is made is immaterial, so long as it does not become liable to corrode, or to become covered with a layer of oxide or tarnish, which, altering the nature of the rectifying contact, decreases the efficiency of the rectification. Gold, platinum, and non-corrodible metallic alloy cat's-whiskers work equally well with galena. A silver contact gives good results at first, but in city atmospheres it soon tarnishes, and decreases the strength of the reception.

For the utmost tonal purity with galena, use a crystal which possesses a fine-grained structure, especially if the mineral is employed in a valve or reflex set. If, however, the maximum signal strength is desired, it is generally better to go in for coarse-grained crystals, especially those with a metallic blue tinge about them. These give very great signal strength but the signals take upon themselves a peculiar tonal characteristic which, for want of a better term of expression, may be called a "roughness" of tone. When a very coarse-grained galena crystal is employed in a valve set, however, this tonal roughness may be very easily converted into an actual distortion of the signals by the amplifying valve. This is a point which some crystal-valve enthusiasts are apt to lose sight of when looking for the causes of distorted reception.

Probably the most sensitive galena contact is formed when a piece of graphite taken from a soft lead pencil is allowed to touch a coarse-grained galena crystal with the lightest possible pressure. This detector, however, is not convenient to work with. A galena-galena contact is also quite sensitive, but in this case the two galena crystals should not be selected from the same batch of crystals.

Zincite.—This is, *par excellence*, a combination crystal. Zincite and galena are undoubtedly the two crystals which are of the most use to wireless enthusiasts. Zincite may well be called a universal crystal. It can be used effectively with almost any crystal contact, and it works well with many ordinary single wire metallic contacts. In addition to this, zincite is beginning to find an entirely new use as an oscillating crystal.

Unfortunately, good zincite is scarce. The whole of the supply of radio-rectifying zincite comes from certain mines in New Jersey, U.S.A., and, therefore, the real material is able to command a good price. Real zincite should not have a very greatly streaked appearance. It should be vitreous in character—that is to say, it should have the appearance of dark ruby-coloured glass. Especially is this characteristic necessary when the material is to be used for oscillating purposes.

Zincite is really only an oxide of zinc which has been naturally coloured by the admixture of small traces of the metal manganese.

Synthetic Zincite.—On account of the scarcity of natural zincite, successful attempts have been made to produce an artificial variety of the mineral. Speaking generally, these products do all that the natural mineral does, except, perhaps, in the case of its oscillatory functions. Artificial zincite comes to the market in the form of hard yellow lumps of material, which are made by fusing ordinary zinc oxide ("zinc white") to a high temperature, and then allowing the mass to cool down slowly. Material such as this goes under the name of "Synthetic yellow oxide," "Gilvium," "Azinite," and so on.

Bornite and Copper Pyrites.—These minerals are, in chemical composition, sulphides of copper and iron. Bornite has a well-known characteristic iridescent appearance, and either crystal can be used as combination crystals in conjunction with zincite. Copper pyrites also works well with a tellurium contact.

Iron Pyrites.—In its most usual forms, iron pyrites is a very common mineral, but radio-sensitive forms of the mineral are hard to find. If this were not the case, the mineral would prove to be a very formidable rival to the ever-popular galena, for a good radio-sensitive crystal of iron pyrites has an almost uniform sensitivity over the whole of its surface. It can withstand the effects of heat fairly well. It is not easily depreciated by handling, and it retains its sensitivity for a much longer period than galena. In addition to the above facts, iron pyrites gives reception of a tonal purity which cannot be surpassed by any other means.

Silicon.—Silicon was at one time a very much favoured crystal, but at the present day its popularity has almost entirely waned. It is a synthetic product consisting of the element *silicon*, which, as many readers will be, no doubt, aware, is one of the most abundant and widely distributed elements in the world. The best contact to employ with silicon is a fine wire made of brass or phosphor bronze. The best grades of silicon for wireless purposes are those which possess a light steel-grey colour. The sensitivity of silicon is almost entirely unaffected by heat.

Tellurium.—Tellurium is an element. In properties it is half-way between a metal and a non-metal, and on that account it is often referred to as being a "metalloid." It gives excellent results when used with zincite, and especially with artificial zincite. It may, however, be used almost equally as well in conjunction with other crystals, such as silicon, galena, iron pyrites, and copper pyrites. Tellurium melts at a temperature of 452 degrees centigrade, and therefore it should on no account be fixed to its cup by the use of ordinary solder. Fusible metal should always be used for the purpose of attaching this valuable and most useful crystal to its detector cup.

Molybdenite.—This is a natural sulphide of the metal molybdenum. It is not very greatly used now for crystal rectification, no doubt on account of the fact that its most effective employment for that purpose necessitates the use of a specially constructed detector. Nevertheless, good specimens of the mineral *will* function well with an ordinary cat's-whisker contact.

Molybdenite is very like galena in appearance, although it exhibits a flatter and more laminated surface, and sometimes it has a greenish hue. Most specimens of the mineral give their best results when they are used in a detector similar to the one shown in the diagram, Fig. 1 (page 6). The essential part of this detector is that it consists of a flat silver spring, which is made to press upon the crystal surface with a varying pressure which is adjusted by means of a screw.

Carborundum.—To carborundum belongs the honour of being the first crystal put to practical use in wireless reception. Carborundum consists of a compound of carbon and silicon (*silicon carbide*), and crystals of this material for wireless purposes should show a light steel-blue colour. Darker coloured varieties are almost useless.

Carborundum will very often work without any applied potential, but for the most effective reception it is necessary to employ a small local potential across the crystal of the order of some 1.3 to 1.8 volts.

The great point about the carborundum detector is, of course, its great stability. A carborundum crystal can be heated to redness without suffering any detrimental effects, so far as its sensitivity goes. It can also be handled in any way at all. And, as the steel contact with which it is employed must be applied with a very firm and decided pressure, the contact is not easily put out of adjustment. In fact, once properly adjusted, the contact will remain in good rectifying condition for many weeks, and in some cases months.

Every serious experimenter in the sphere of radio crystals should have in his possession a carborundum detector unit. It is very useful for employment in portable sets, and also as a standard against which many other crystal combinations may be tested. The contact possesses a fair average sensitivity to signals of medium strength.

A sketch of a typical carborundum detector and the details of a crystal receiving circuit employing such a detector are illustrated in the diagrams, Figs. 2 and 3 (pages 8 and 11).

CHAPTER IV.

Some Interesting Characteristics of Crystals.

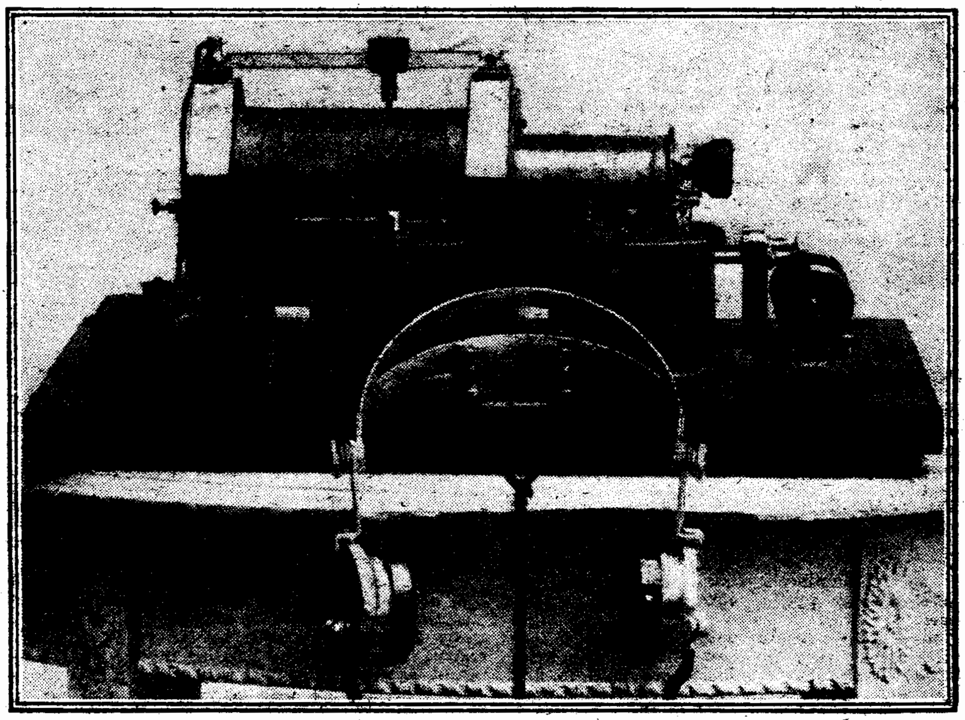
One of the many difficulties which beset the crystal enthusiast, especially if he be only a beginner in the subject, is the conception of what is known, and is so often referred to, as the "characteristic curve" of a crystal. However, the matter is not very difficult to understand when once the main fundamentals of the subject have been grasped.

Suppose you take a piece of metal, such as an ordinary bit of copper wire, and, after connecting it up in a suitable circuit, you pass varying potentials of current through it in alternate directions, noting with each varying potential the amount of actual current (in amperes) which is passed by the wire. It will be found that the greater the potential which is applied to the wire, the greater will be the current which will pass through it. Moreover, the current will pass through the wire equally as efficiently in one direction as it will in the other. The current passing through the length of wire, therefore, will depend upon the potential which is applied to it.

Properties of Carborundum.

Now, suppose, instead of the length of wire, you place in the circuit a crystal detector consisting of a carborundum crystal provided with an ordinary metallic contact. In this case, the crystal will offer a very great resistance to the passage of the current, and the latter will have to be measured in fractions of an ampere. However, if we apply known voltages across the crystal contact, and in varying directions (by means of one or two local cells and a potentiometer suitably connected), and measure the resulting current passing through the crystal contact, subsequently plotting the results on a graph or chart, we shall find that the current flows much more easily through the crystal contact in one direction than it does in the other. Thus the crystal is said to have a unilateral conductivity.

The graph obtained from such an experiment would be of the type illustrated at Fig 4 (page 14), and the curve obtained is said to be the characteristic curve of the crystal when that particular contact is employed with it.



An early but efficient type of crystal set employing a loose coupler and perikon detector.

When the voltage across the crystal contact is increased (in the direction in which the largest amount of current flows) the current flowing also increases, that is to say the conductivity increases with the applied potential. Now, in the case of an ordinary metallic conductor, such as the length of copper wire mentioned above, we could go on increasing the voltage, and the current flowing would show a constantly proportional increase, within wide limits.

Thus, the characteristic curve of the piece of copper wire would be a straight line, similar to the dotted line indicated in the diagram, Fig. 4.

The Critical Potential.

The crystal, however, produces a different effect. After a certain voltage has been applied across the contact, there is a sudden change in its behaviour. The current passed is no longer proportional to the voltage applied, and therefore a sharp bend is formed in the curve. This is the "critical" potential, and it is the potential which should be applied across a crystal contact if it is to give its best rectifying results. This point is brought out in the diagram, Fig. 4, in which it will be seen that, whilst the critical potential of a carborundum crystal is approximately 1·3 volts, the critical potential of an ordinary galena crystal is practically zero. Which means to say that, in order to afford its maximum degree of rectification, a carborundum crystal must have the necessary local potential of about 1·3 volts applied to it, whilst, on the other hand, galena is able to function quite well without any applied potential at all.

The reason for this may not be obvious at first, but after a little thought it will become quite plain. All radio rectifiers must, in order to act as detectors, either have a strongly marked unilateral conductivity, or else their conductivities should vary as different voltages are applied to them. In the case of a crystal which is used with a locally applied potential, the incoming currents flowing in the one direction cause a large increase of current at the critical potential. When no external currents are impressed upon the crystal, the current value drops to the normal, and, as this normal value is constant, no sound is produced in the phones.

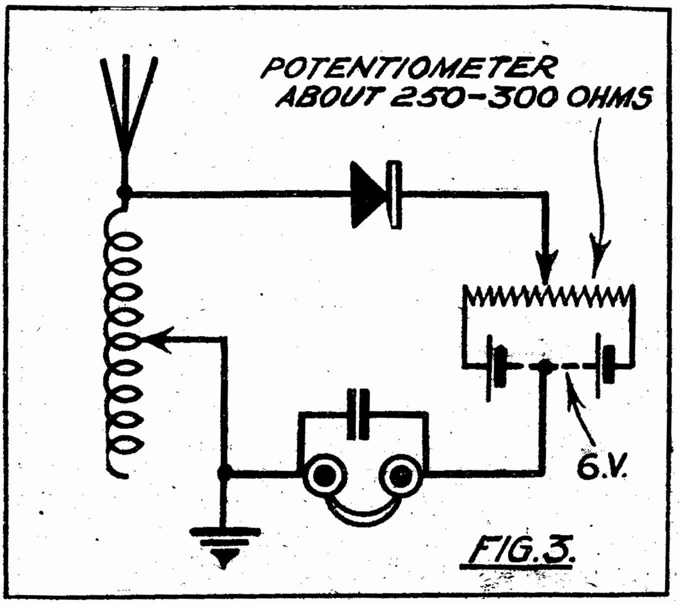


FIG. 3.

By inspecting the characteristic curve of a crystal, it is an easy matter to determine whether such a crystal can be employed without an applied potential or not. If the curve has a zero value to the left of the point of zero voltage, and if it rises immediately to the right of this point, the crystal can be used without an applied potential. If, on the other hand, the curve does not begin to rise immediately, or nearly so, at zero potential, some locally applied potential is necessary for it to afford its maximum rectification.

The question as to why the crystal should exhibit such peculiar properties is not known, and until it is the real nature of crystal rectification will remain a mystery. As I have previously pointed out, such rectifying action has been ascribed to purely local influences taking place at the point of contact only. Electrolytic and thermal explanations have been put forward to explain the cause of crystal rectification, but they are not wholly satisfactory.

"Crystal Cleavage."

Another interesting physical property of crystals is the various modes of cleavage which they show. This property of crystals is especially of interest to the crystal experimenter.

Suppose you take an ordinary piece of cubical galena, and bring into violent contact with the mineral the business end of a domestic coal-hammer. What happens? The galena is smashed into a thousand fragments. But, on the other hand, if you lay the blunt edge of a knife lightly on the surface of the crystal, parallel to its straightest edge, and then lightly tap the knife with a small hammer, the crystal will break into two smaller fragments, each of which will retain the same characteristic as the original crystal. This fracturing of the crystal is known as "crystal cleavage," and the type of cleavage which a crystal exhibits is one of the most characteristic physical properties of a mineral of crystalline substance.

Definite Atomic Structure.

Crystal cleavage may seem at first to be a very trivial matter to claim any attention from the scientist, but, as a matter of fact, it is a property of the crystal which has been very carefully studied. The reason why a crystal cleaves in such a characteristic manner is simply due to the fact that its atoms are not jumbled together any old how. They have an orderly arrangement, and the cleaving of the crystal represents merely the splitting up of the crystal along definite planes, planes which represent the weakest points in the crystal structure.

Galena, iron pyrites, molybdenite all possess what is known as a "regular cleavage." That is to say, when a large crystal of the mineral is carefully broken, each of the smaller crystals have roughly the shape of the original crystal.

The new surfaces of a cleaved crystal have usually a high sensitivity. Importers of crystals are well aware of this fact, and most of the natural crystal products which come to the market these days are pieces of mineral which, besides undergoing a preliminary cleaning operation, have been carefully cleaved, in order to intensify their sensitive properties.

Curved Surfaces.

Crystals such as zincite, cerussite, and so on, have what is known as a "conchoidal," or shell-like, cleavage. On splitting, these crystals break up into smaller crystals, possessing curved surfaces. Materials such as glass, cements, etc., which are amorphous or non-crystalline in character, do not possess any cleavage at all. On breaking, they merely split up into a large number of small fragments, no matter how carefully the breaking operation is carried out, and each of the broken fragments bears no relation whatever to the original substance. The reason for this is, of course, because the atoms in an amorphous substance have no regular arrangement. The atoms in a crystal may be very aptly compared to a parade of soldiers. They are well disciplined and arranged in orderly array, but the atoms in a non-crystalline material are like the individuals comprising an ordinary crowd. They have no regular arrangement whatever.

Thus the property of cleavage, which is possessed by all crystals to a greater or less degree, is an important one to consider when dealing with crystal rectification, for it is very probably upon this orderly arrangement of the individual atoms in a crystal that the rectifying action fundamentally depends.

Interesting Experiments Possible.

It has very recently been shown that some crystals are extraordinarily sensitive to the effects of light, and that, by some process as yet unknown, they are able to convert the ethereal vibrations which constitute light into electricity. Thus the crystal, besides acting as a rectifier of high-frequency currents and a generator of oscillations, is also able to effect the conversion of light waves into electrical energy. The conversion is a very mysterious one indeed, but it is, nevertheless, a phenomenon which must prove to be of intense interest to every crystal enthusiast, opening as it does a fresh path to further scientific research in the realm of crystals.

Very probably the triple functionings of the crystal—to wit, its rectifying action, its functionings as a generator of high-frequency oscillations, and its conversion of light into electrical energy—are all interconnected.

Galena is to some extent affected by light. The reception obtained by many grades of galena can be very appreciably strengthened if a strong beam of sunlight is focused upon the point of contact by means of a powerful lens. That is an experiment which is easily within the sphere of even the very beginner in crystal experimental work. If the light of an arc-lamp is substituted for the focused sunlight, there is no further effect. The influence of the intense light obtained from a mercury vapour lamp has not apparently been investigated, although sundry observations which have been made from time to time indicate that a pencil of X-rays playing upon the point of crystal contact can very greatly increase the reception. The influence of these factors upon the distance-sensitivity of the crystal has not yet been investigated, and therefore a fruitful field for research for the interested amateur is opened up here.

American workers, however, using silver sulphide crystals, instead of ordinary galena, have been successful in causing the crystals to produce a measurable quantity of current under the influence of intense light. That is to say, the crystal has been made to transform a portion of the light energy into electrical current, which is an extremely interesting discovery indeed, and one that opens up vast possibilities for the humble and very often despised crystal.

Crystals for Reflex Sets.

Another interesting point about crystalline galena is that when the material is fused up with the addition of definite amounts of pure silver sulphide, and then artificially recrystallised, the resulting product possesses a greater sensitivity than that of the original material. As the silver sulphide in the galena is increased, the sensitivity increases, until, with a galena crystal containing something like thirty or forty per cent. of silver sulphide the increased sensitivity reaches a maximum, and it begins to decrease if a greater amount of silver sulphide is added. Tin sulphide acts in a similar manner, but in this case the amount of the added material should not exceed five per cent. There is a very interesting sphere of action for crystal experimenters to discover the effects of other materials when added to galena, and also to other crystals.

For a reflex set, galena is undoubtedly the best crystal to employ. It combines the valuable properties of reasonable distance-sensitivity and good clear rectification. But not all galenas are suitable for valve work. The fine grain varieties of the mineral give the best results, and the ones which are the most free from distortion. A crystal of really good iron pyrites will often work wonders in curing a noisy valve-crystal set.

Perikon detectors are not so successful when employed in valve sets, the reason being that a Perikon combination of crystals usually requires strong signals in the first place in order to rectify clearly and well. Given strong, clear-cut signals in the first place, the Perikon detector has many advantages which are peculiarly its own, but on weak signals it does not do so well as a piece of sensitive galena.

Careful Adjustment Essential.

Now, a valve set, especially when it is employed for fairly long-distance work, deals with weak initial signals, and to deal with these effectively a galena crystal is needed. Fine-grain galena should be used, because it gives purity of tone, and the detector should preferably be a micro-adjustment

one, in order that the most sensitive degree of adjustment may be obtained and maintained.

For portable valve sets, a carborundum detector has many excellent points to recommend it, despite the fact that its use calls for additional apparatus in the way of potentiometer and batteries, and so, to some extent, complicates the working of the receiver.

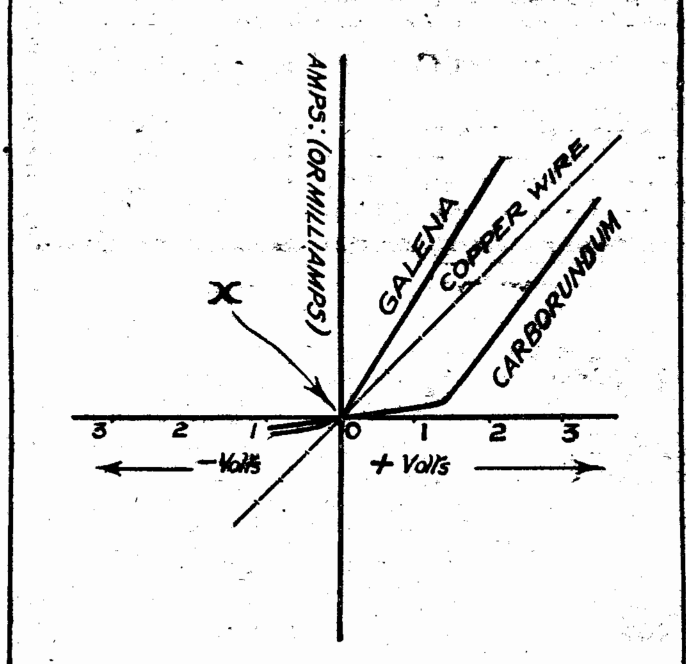
CHAPTER V.
How to Make and Test Crystals.

The home manufacture of various types of rectifying materials is an occupation not without a very considerable interest and practical use attached to it. Quite a number of naturally occuring minerals can be imitated in the home workshop, and, if the necessary processes are carefully carried out, the resulting products will be found to make very excellent rectifiers.

Perhaps the simplest artificial "crystal" to make is a substitute of bornite, or copper pyrites. In order to obtain such a crystal substitute, procure a quantity of ordinary common rock sulphur, and melt it up over a slow fire in an iron can. The sulphur should be heated until the liquid has attained a thin black appearance. Any fumes which may escape from the vessel will be drawn up the chimney of the fireplace, and thus will not escape into the room. Care, however, should be taken not to allow the molten sulphur to take fire.

Having obtained the sulphur at its necessary stage of liquefaction, a number of short, thick copper rods, which have previously been brightened up with emery-paper, are immersed half-way into the liquid sulphur, and held there for two or three minutes. Afterwards, they are withdrawn, and a lighted match is applied to their ends, in order to burn off the superfluous sulphur. The artificial copper pyrites will now be complete, and the sulphurised rods, if one may be allowed to use that term, will be found to give extremely good results when used in place of copper pyrites, or bornite, in a Perikon detector, in contact with zincite or one of its substitutes.

Similarly, an ordinary cat's-whisker, applied lightly to the treated surface of the copper rods, will be found to produce effective rectification. In fact, one experimenter I know has treated the whole of his brass crystal cup in this fashion, and now he nightly listens-in with a "crystal-less" crystal set!



ILLUSTRATING THE MEANING OF CHARACTERISTIC CURVES

FIG. 4.

Making Zincite.

Any amateur can make artificial zincite, provided he is able to obtain a suitable furnace, or high-temperature heating apparatus for that purpose. Synthetic zincite is made by heating ordinary zinc oxide (the "zinc white" of the paint shops), with or without the addition of very small traces of manganese dioxide, to a temperature of something like 1,200 degrees centigrade. Which means to say that in order to procure synthetic zincite, the crystal experimenter must have some means at his disposal for heating his materials to a cherry-red heat. At this temperature the zincite melts, and, if it is allowed to cool slowly, he will find a yellow-looking glassy mass is produced. And if this is carefully broken up and tested, a large portion of it will be noticed to be very sensitive to radio signals. The use of a small earthenware crucible and a hot blowpipe is about the best means of attaining the necessary temperature for the purpose, although, doubtless, by placing the crucible of zinc oxide, carefully luted over with clay, in a hot, "clean" fire, and by directing upon it a current of air, a suitable substitute for the blowpipe could be contrived.

Galena is another crystal which can be made artificially by the amateur, although in this case success is not so readily attained. The starting point of artificial galena is lead sulphide, obtained either by crushing up scrap pieces of galena crystal or by precipitating a strong solution of a lead salt (such as lead acetate or nitrate) with sulphuretted hydrogen or ammonium sulphide. The galena is finely powdered and placed in a small earthenware crucible. Over the surface of the galena in the crucible is placed a layer of litharge, in order to prevent the oxidation of the galena. The crucible is then covered with clay, placed in the middle of a very hot fire for four or five hours, and, if at all possible, an air blast should be directed upon the crucible.

After the elapse of this time, the fire is allowed to die out overnight, and in the morning the crucible is removed. It is then broken open, and, if the operation has been carried out successfully, the middle of the mass will be found to be composed of finely crystalline galena. If about 20 per cent of silver sulphide, together with 2 per cent of tin sulphide, are added to the galena before it is heated up, the resulting product will be found to be greatly increased in sensitivity. About 40 per cent of the fused mass will be sensitive.

Ordinary waste galena crystals may very often be converted into good sensitive material by mixing them with an equal weight of powdered *rock* sulphur, and by heating them in a luted crucible in an ordinary kitchen fire for half an hour or so. After this time, the clay should be removed from the top of the crucible, and the sulphur allowed to burn away before the mass of crystals is broken up and tested.

Artificial Iron Pyrites.

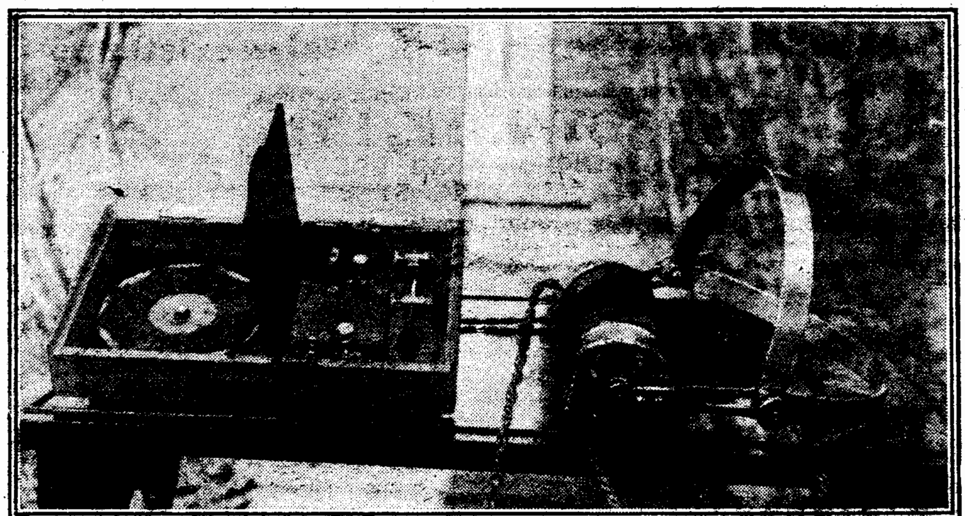
Sometimes a rectifying product can be successfully made by heating, in an iron can, a mixture of rather more than one part of powdered rock sulphur and one part of iron filings. Such a product is an artificial form of iron pyrites. However, this method must not be taken as being an invariably successful one. Nevertheless, I am giving it here, because it is a very simple operation to carry out, and there will be doubtless many amateurs who will be able to improve on the process.

Testing the Home-made Crystals.

The manufacture of crystals such as silicon and carborundum, both of which are essentially artificial products, is beyond the scope of the ordinary experimenter, for to obtain the degree of heat necessary for the fusion of the materials used, it is necessary to employ a high-temperature electric furnace.

Having obtained a crystal, the next thing to do is to test out its powers of rectification. The subject of crystal testing is an important one, not only to the commercial trader, but also to the crystal experimenter. The ordinary and well-known buzzer test for crystals is quite a good one for determining the relative sensitiveness of crystal products, and it has the advantage that it can be used anywhere and at any time. However, the buzzer test is not able to give the experimenter any idea of the tonal properties of the reception which the crystal gives.

Some experimenters endeavour to form an estimate of the crystal's rectifying properties by measuring its electrical resistance, and then by comparing the result so obtained with the average resistance exhibited by a number of standard crystals. However, this forms no real test of a crystal's capabilities; nor does an estimation of the amount of current in milliamperes which a mineral passes enable the experimenter to determine the tonal purity of reception which is obtained from any particular batch of crystals.



A neat crystal receiver of the portable type. Two basket coils are used for tuning on the variometer principle.

Where the experimenter is dealing with crystal testing in fairly small quantities only, he cannot do better than make use of some apparatus similar to the one shown in the diagram, Fig. 5 (page 18). Here the crystal is readily inserted between two metal jaws, and the necessary metal contact is brought into play upon the surface of the crystal by means of being suitably mounted on a wooden handle. Use may be made of a buzzer for testing the crystals, but generally it is better to carry out the test during the actual hours of broadcast transmission.

Before beginning the test it is best to detune the receiver, so that the signals with the standard detector (which should always be used for comparison) are only faintly audible. The variations in audibility of the reception which is obtained from the crystals under test will then be much more easily apparent.

An audibility meter connected across the 'phone terminals is also another practical and convenient method of testing out the performance of various crystals and crystal contacts.

The Best Detector.

The radio crystal experimenter is very often requested to recommend a good type of detector for everyday use. This is a question which is not so simple as it looks at first sight. The perfect detector, in the opinion of the writer, has not yet been invented, or, at any rate, put upon the market. Most commercial detectors have their own special advantages; they also have their faults.

But, for the average listener-in who is not very much concerned with the technicalities of wireless, I would recommend the use of either a good Perikon detector, fitted with some device for varying the pressure of the crystal contact, or else, if ordinary galena be employed in the set, a detector in which the cat's-whisker is held in a vertical position. The cat's-whisker should be a single one. It should have a spiral shape, and it should be composed of some non-corrodible alloy. There is no necessity to go to the expense of a gold or a platinum cat's-whisker for the best work. The main point is to have the cat's-whisker made out of some metal which does not readily oxidise, or even tarnish.

Perikon or Galena ?

The detector should, if possible, be glass enclosed, and it is now possible to secure enclosed detectors in which the cat's-whisker is held in a vertical position. For crystal-valve work, only the very best detector should be employed. One having a fine micro-adjustment is the best to use.

Finally, you cannot get the best work out of a Perikon detector unless there is some adjusting device present by which the pressure of the contact can be varied. This is a point which some manufacturers seem to forget. The adjustment of a Perikon detector is not so critical as that of the ordinary cat's-whisker type of instrument, but, still, there certainly exists a certain definite pressure of contact with each combination of crystals which will give rise to the best results in the 'phones.

Given a good Perikon detector, employing a combination of zincite, or one of its substitutes, and tellurium, and working with signals of moderately strong initial intensity, the results will be equally as satisfactory as those obtained by the use of an ordinary cat's-whisker crystal, and, what is more, the detector will hold its sensitive contact for much longer periods. It will not be half so liable to be affected by dust and other atmospheric impurities, and a good measure of the reliability of a carborundum detector will be obtained with it.

But, of course, if you are out for extreme range in crystal reception, a good synthetic or natural medium-coarse grain galena crystal, together with a micro-adjustment detector, are the things you require.

Cleaning Dirty Crystals.

Just one further word. If your crystal suddenly begins to give bad results, it is possible that its surface has become oxidised. Remove the crystal from its cup, and allow it to soak in a small bottle which is filled with a saturated solution of alum or hypo. After half an hour's time, put a quantity of very clean sand into the bottle, replace the cork, and shake well for five minutes or so. Finally, rinse the crystal well in clean water, and dry quickly. This treatment will give the crystal a new surface, and in very many cases the original sensitivity of the mineral will be entirely renewed.

CHAPTER VI.

The Oscillating Crystal.

The oscillating crystal itself is no new discovery, although most of the circuits in which it is employed represent new lines of experimental research. The credit for the discovery of the first oscillating crystal goes to Dr. W. H. Eccles, the well-known English scientist, who was one of the earliest investigators of the properties of radio-sensitive crystals.

In a paper read before the Physical Society of London, in 1910, Dr. Eccles showed that an ordinary galena crystal could be used as a generator of weak oscillations. Dr. G. W. Pickford, who is also very well known for his early crystal researches, conducted experiments on the oscillating crystal, as well.

Despite these facts, however, we must give the Russian experimenters their due, particularly M. Lossev, for it is through the labours of these research workers that a very great deal of renewed interest has been taken in this aspect of radio crystal research.

There is hardly enough space left in this book to enter into a full description of the precise mechanism of crystal oscillation, and, therefore, I propose to set forth some details regarding the practical side of oscillating crystal work, rather than go into the theoretical aspect of the subject.

A Crystal Transmitter.

The great interest which has been taken in the practical methods of causing the crystal to generate sustained oscillations is due to the fact that, owing to its power in this direction, a suitable oscillation-generating crystal contact can be employed as a transmitter of continuous waves, and these, of course, may be modulated in the usual manner. In fact, Lossev has employed an oscillating crystal as a transmitter for short distances of approximately a mile and a quarter.

Then, again, a crystal which is capable of generating sustained oscillations can be used as a high-frequency amplifier, and also as a low-frequency one, although in this latter instance there are many practical difficulties which have yet to be overcome before such a crystal can be worked successfully and reliably.

Let us, however, in the first place, deal with the practical methods by means of which a suitable crystal can be caused to set up oscillations. Suppose we rig up a simple circuit, such as the one which is depicted in the diagram, Fig. 6.

Unusual Circuit Employed.

The crystal contact is indicated in the usual manner, whilst the local supply of energy for the oscillations is derived from an H.T. battery of between 15 and 25 volts E.M.F. In series with the battery is a fixed resistance of about 1,500 ohms, and the battery itself should be provided with a potentiometer, by means of which the amount of current supplied can be carefully controlled. In very simple circuits, however, the potentiometer can often be dispensed with, provided the H.T. battery is provided with a number of tappings.

The coil indicated in the diagram can be practically of any make or type. It should be capable of tuning up to at least 1,000 metres, and it should have the minimum amount of self-capacity. Generally it is better to make use of a series of plug-in coils for this purpose, so that the effects of different sized coils can be instantly determined. Cylindrical coils may also be employed, but care should be taken to avoid dead-end losses.

In series with the coil is placed a large-capacity fixed condenser (1 or 2 mfd.), and sometimes a small variable condenser, possessing a maximum capacity of ·0005 mfd., is placed in parallel with the crystal contact, in the manner indicated by the dotted lines in the diagram.

Good Crystals Necessary.

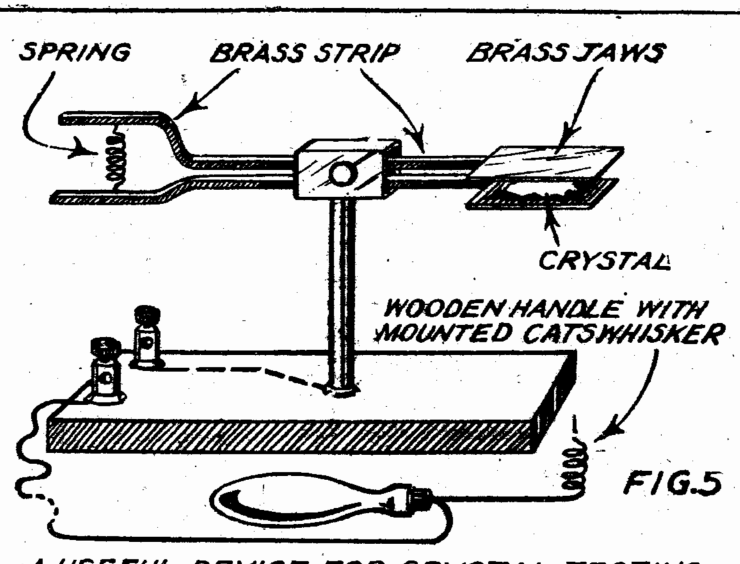
Such an arrangement of apparatus forms a very reliable crystal oscillatory device. The oscillator itself must consist of a steel-zincite contact, although, of course, other contacts may be experimented with after success has first been obtained with the steel-zincite contact. A suitable form of oscillator for this purpose is shown in the lower portion of the diagram.

The zincite employed must be the real material. Artificial brands of zincite, such as "synthetic yellow oxide," will not oscillate—at least, that has been my own personal experience, although, of course, I am open to correction on this statement. Zincite which is for the most part black in appearance, and which merely possesses a few reddish streaks over its surface, is also practically useless.

Straight Cat's-whisker Used.

In order to obtain any degree of success with the crystal oscillator, the zincite used must have a deep ruby-red glassy appearance. Very often, if the crystal is fractured, one of the broken surfaces will be found to give excellent results.

The contact should take the form of a straight piece of steel wire, or, at the most, the wire should only have one turn in it. The wire contact is best held in a vertical position, as shown in the diagram,



A USEFUL DEVICE FOR CRYSTAL TESTING.

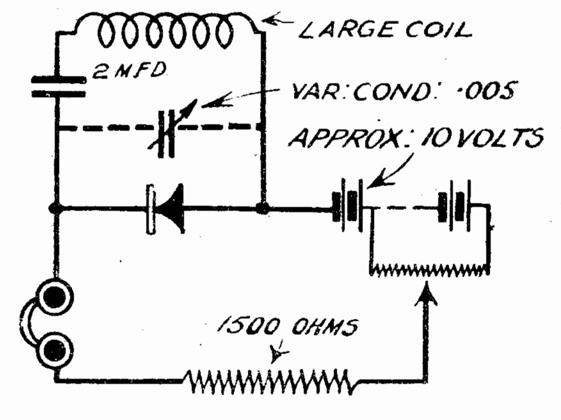
and arranged so that its contact pressure can be varied by a turn of the screw.

Starting the Oscillations.

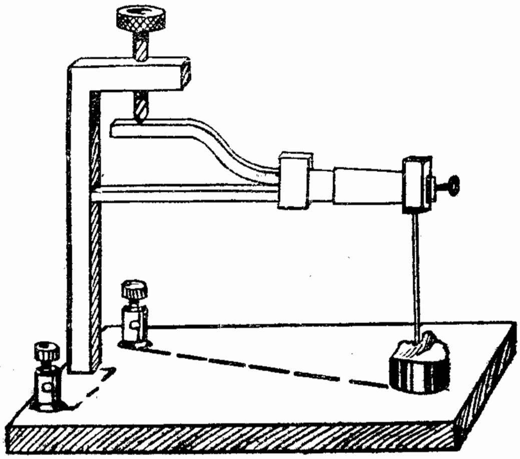
In order to obtain the required oscillations, the local H.T. should be first of all adjusted (by means of the potentiometer or tappings) until a current of about 15 volts is passed. It is a good plan to sharply tap the panel of the apparatus with the finger at this stage, and, if the necessary adjustments have been made correctly, the characteristic oscillatory hum will be heard very plainly in the 'phones.

If, however, no oscillations are apparent, and it is certain that the crystal in use is a good one, slightly increase, or decrease, the pressure of the contact, and at the same time vary the strength of the local current. Some crystals are inclined to be somewhat difficult to start the generation of oscillations with. It is often a good tip to give the crystal wire contact a slight touch with a match-stick after the final adjusrment has been made with it. Sometimes the switching on of the full strength of the local battery very suddenly, and then as suddenly decreasing it to the normal voltage found necessary, helps to induce a refractory crystal to commence the oscillations.

With a good crystal, the beginning of the oscillation business is not any more difficult than the act of starting a car or a motor-cycle on a cold morning. It is a matter of knack and the obtaining of the right adjustments more than anything else, a matter to which the time-honoured adage to the effect that "practice makes perfect" applies very closely.



CIRCUIT FOR GENERATING OSCILLATIONS



SUITABLE FORM OF CRYSTAL OSCILLATOR

FIG. 6.

Need for Research.

It must be pointed out, however, that because a zincite crystal will rectify well, it must not by any means be taken as a foregone conclusion that it will oscillate well. It is really impossible to tell at sight whether any given zincite crystal will or will not oscillate. The crucial test of the crystal's behaviour in the oscillator is entirely a practical one, and, therefore, if the amateur is only just beginning his experiments in this fascinating field of crystal research, he will be well advised to purchase a specially tested zincite crystal.

Several dealers, I notice, are now supplying these crystals, and for the beginner in this line of work the crystal will be found to be well worth the extra price asked for it, particularly as it can be kept as a standard for the purpose of comparing the behaviour of other crystals and crystal combinations.

The above are, of course, merely a few practical notes on the subject of getting the crystal to generate sustained oscillations in the first place. The utilisation of these oscillations is a matter which requires more complicated apparatus, and which at the present time cannot exactly be said to have been put on a simple, practical, and workable basis.

A crystal oscillator can be made to amplify at high-frequency or at low-frequency, but the best practical results are obtained when the oscillating crystal is caused to act as a high-frequency amplifier.

H.F. Amplification.

One of the simplest circuits for this purpose is shown in the diagram, Fig. 7. Here it will be seen that the crystal is placed in parallel with the aerial and earth, but, apart from this arrangement, the circuit is practically the same as that employed for the simple generation of oscillations only.

The variable condenser, which has a maximum capacity of ·0005 or ·001 mfd., may often be replaced by a fixed condenser of those approximate capacities.

It must be remembered, of course, that this circuit is purely an experimental one, and, as such, it will only be likely to prove of interest to the serious crystal experimenter. Nevertheless, it contains the fundamental germ of the idea of crystal high-frequency amplification, and, of course, it is capable of considerable modification and, incidentally, improvement. The main difficulty

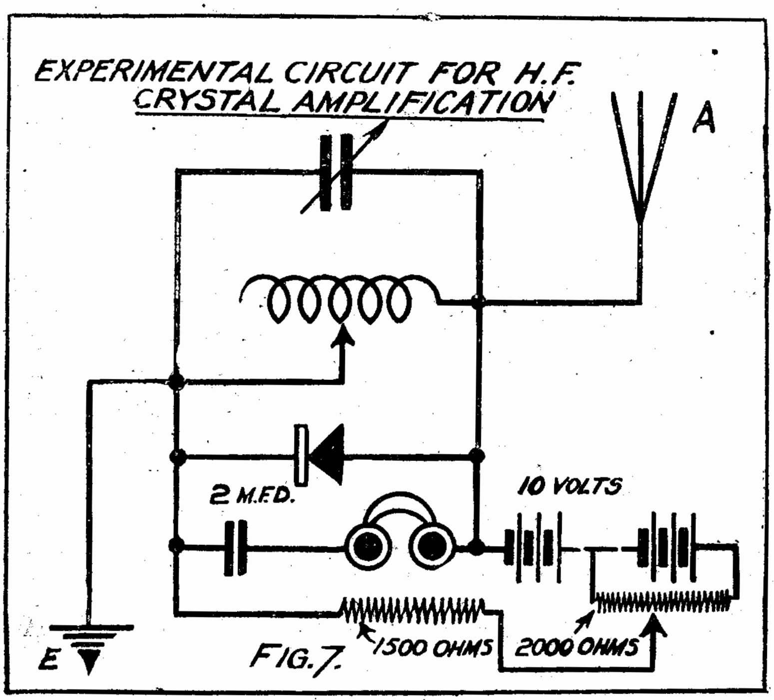
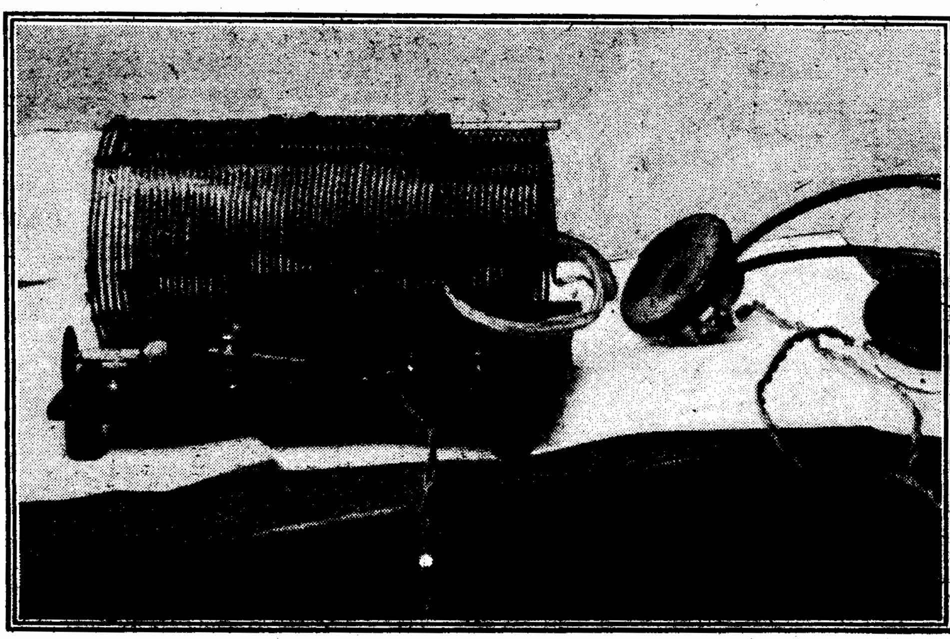


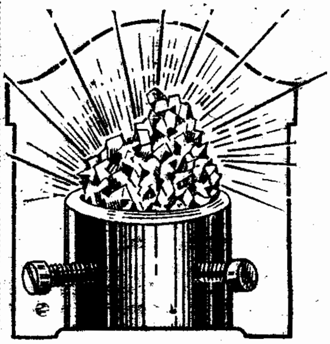
FIG. 7.

with the circuit would appear to be that of getting it to remain perfectly stable. The variable condenser, or the fixed condenser which may be substituted for it, acts to a very great extent as a stabiliser of the crystal, and, if any difficulty is obtained with the set, this portion of the apparatus should receive the first attention. Sometimes the smallest adjustment of this condenser will entirely cure the instability of the reception.

It is interesting to work with the receiver when it has been detuned very considerably. Here the signals are weakened, and small adjustments of the various portions of the circuit can be carried out,



A typical example of an amateur-constructed crystal receiver utilising a "low-loss" coil.



and their effects noticed instantly. Very interesting experiments can also be carried out with the set if an audiometer is placed across the 'phones.

Zincite-graphite contacts may also be experimented with, as also may tellurium-galena and zincite-silicon combinations.

A Difficult Problem.

The problem of crystal amplification at low-frequency is a more difficult one, and very little experimental work has been done on it—in England, at any rate. The most interesting circuit consists intrinsically of an ordinary crystal rectifying circuit, which is a transformer coupled to an oscillatory circuit. The oscillatory circuit is first of all carefully adjusted, and subsequently the crystal rectifier is brought into play.

However, even at its best, the circuit is not by any means a practical one. In the first place, the transformer has to be specially designed for the purpose. Then there is a tremendous amount of distortion set up, and, finally, the act of adjusting the crystal rectifier will very often completely upset the adjustment of the amplifier. These, in brief, are the difficulties which have yet to be overcome, and which are at the present time engaging the attentions of many a radio experimenter. That they will be completely solved in the course of time, and that the crystal amplifier will come into its own as a practical instrument, is not likely to be doubted.

Interesting Subject for Investigation.

And here this little book on the subject of crystals and their radio uses must be drawn to a conclusion. The crystal is indeed a wonderful example of Nature's architecture, and at the present day scientists are beginning to learn things about it which were never dreamt of in times gone by

It is now possible to look into the very heart of the crystal, and to see exactly how it is built up, how the atoms which compose it are arranged, and how they can be replaced, in progressive stages, by other atoms, without upsetting the crystal's structure.

The investigation of the crystal provides us with another path by which we may yet reach the solution of that ever-present riddle—the constitution of matter. Nevertheless, the interest of the purely practical radio experimenter will be more or less confined to the investigation of the crystal's uses in wireless reception and in allied topics.

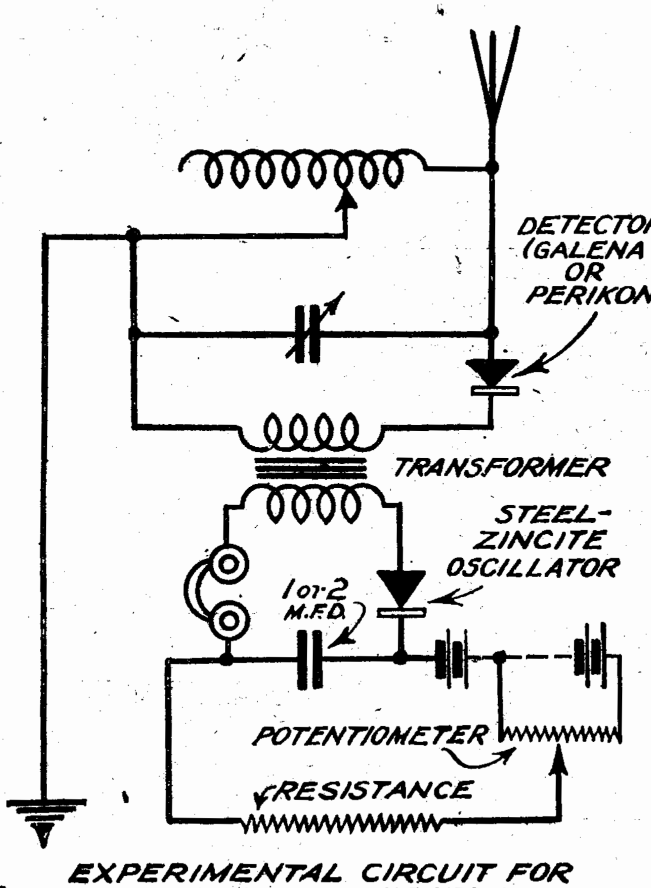


FIG 8. EXPERIMENTAL CIRCUIT FOR L.F. AMPLIFICATION.

The Future.

There is a great future in store for the crystal. Probably the triple functionings of radio-sensitive minerals may ultimately be found to be interconnected. Perhaps, on the other hand, they may not. The lines of research into the heart of the crystal are varied, but all are extremely interesting and well worth following. At any rate, the mystery of the crystal is being vigorously investigated in various parts of the world, and we may await further developments with interest, for it is the task of every scientist

"To search thro' all,
And reach the law within the law."

A LIST OF RADIO-SENSITIVE CRYSTALS, MINERALS, AND OTHER SUBSTANCES FOR GENERAL AND EXPERIMENTAL USE.

Mineral.	Chemical Composition.	Chemical Formula.	Crystal Category.	Suitable Contacts.
Anatase	Titanium oxide	$Ti\ O_2$	Oxide	Metals and zincite
Antimony	Element	Sb	Elementary	Zincite, silicon, etc.
Argentite (silver glance) ..	Silver sulphide	$Ag_2\ S$	Sulphide	Metals, graphite, tellurium.
Arsenic	Element	As	Elementary	Metals, zincite.
Bornite	Sulphide of copper and iron	$Cu_5\ Fe\ S_4$	Sulphide	Zincite, silicon.
Boron	Element	B	Elementary	Zincite, tellurium.
Bournonite	Sulphide of copper, antimony and lead	$3\ (Pb\ Cu_2)\ S\ Sb_2\ S_3$	Sulphide	Zincite, tellurium, antimony, bismuth.
Carborundum	Silicon carbide	Si C	—	Steel, zincite.
Chalcopyrite	See Copper pyrites.			
Cobaltite	Cobalt arsenic sulphide	Co As S	Sulphide	Zincite.
Cassiterite	Tin oxide	$Sn\ O_2$	Oxide	Metals.
Chalcocite (copper glance)	Copper sulphide	$Cu_2\ S$	Sulphide	Zincite, tellurium.
Copper pyrites	Sulphide of iron and copper	$Cu_2Fe_2S_4$	Sulphide	Zincite.
Corundum	Aluminium oxide	Al_2O_3	Oxide	Zincite, bornite.
Covellite	Copper sulphide	Cu S	Sulphide	Zincite, etc.
Cuprite	Copper oxide	$Cu_2\ O$	Oxide	Tellurium, antimony, etc
Erubescite	See Bornite.			
Frieslebenite	Sulphide of antimony, silver and lead	Composition varies	Sulphide	Zincite, silicon.
Galena .. .. (Natural or artificial)	Lead sulphide	Pb S	Sulphide	Metals, graphite, galena, silicon.
Graphite	Element (carbon)	C	Elementary	Zincite, galena, molybdenite, silicon.
Hæmatite	Iron oxide	$Fe_2\ O_3$	Oxide	Zincite, most sulphide minerals.
Illmenite	Oxide of iron and titanium	$Fe\ Ti\ O_3$	Oxide	Metals, silicon.
Iron pyrites	Iron sulphide	$Fe\ S_2$	Sulphide	Metals, silicon, zincite, tellurium.
Magnetite	Magnetic iron oxide	Fe_3O_4	Oxide	Silicon, etc.
Marcasite	Iron sulphide (containing arsenic)	$Fe\ S_2$	Sulphide	Similar to iron pyrites.
Mispickel	Sulphide of iron and arsenic	Fe As S	Sulphide	ditto.
Molybdenite	Molybdenum sulphide	$Mo\ S_2$	Sulphide	Silver, graphite.
Octahedrite	See Anatase.			
Psilomelane	Manganese oxide	$Mn_2O_3H_2O$	Oxide	Zincite, metals.
Pyrolusite	Manganese di-oxide	$Mn\ O_2$	Oxide	ditto.
Pyrrhotite	Form of iron pyrites.			
Silicon	Element	Si	Elementary	Metals, zincite, iron pyrites, etc.
Stannite	Mixture of iron, copper, and tin sulphides	Composition varies	Sulphide	Zincite, etc.
Stibnite	Antimony sulphide	Sb_2S_3	Sulphide	Zincite, etc.
Stromeyerite	Sulphide of copper and silver	$Cu_2Ag_2S_2$	Sulphide	Zincite and some metals.
Tellurium	Element	Te	Elementary	Zincite, etc.
Tin pyrites	See Stannite.			
Zincite .. .. (Natural and artificial)	Zinc oxide, containing manganese	Zn O	Oxide	Almost any contact
Zirconium	Element	Zr	Elementary	Can be used in place of tellurium or antimony.

Besides the contacts given in the last column, many other contacts of a varying nature may be employed. It should also be noted that several of the minerals in the above list are very rare, and are therefore extremely difficult to obtain in sensitive condition. They are given here, however, for the sake of interest and completeness.

HOW TO MAKE A VARIOMETER CRYSTAL SET.

By the "P.W." Technical Staff.

This receiver is easy to make and easy to operate. A glance at the photo and diagrams will show the reader that it is a neat and extremely compact set. Its efficiency we guarantee.

FOR ease of handling a variometer is probably the simplest available means of tuning, and one is used in the set about to be described. The stability of crystal setting available with the form of detector used, one of the new R.I. P.M. detectors, is another feature.

The variometer, as well as the detector, are mounted as plug-in units, a form of mounting favoured by many, as this enables the unit to be used in any set at will.

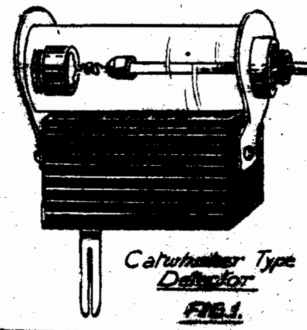


FIG. 1.

The detector is very simply mounted by screwing it down to an ordinary coil mount and connecting to the contact screws, either with wire or, as in this case, by pieces of brass or copper strip screwed down under the contacts.

An ordinary cat's-whisker detector can also easily be mounted on a plug in a similar manner as shown in Fig. 1, the plug-in type of mount enabling a quick comparison to be made of different types of detector.

Construction of Variometer.

The variometer is made up as follows: A piece of cardboard tube, 3 in. diameter, is cut to a length of 1½ in., and well shellacked and thoroughly baked. This forms the outer tube of the variometer. Another piece of tube, 2 in. in diameter and 1¼ in. long, forms the inner tube or rotor, and is similarly treated.

When thoroughly dry the smaller tube is fitted with pivot mounts made up from ⅛-in. brass rod, fitted with two nuts, and the end of each formed into a point which bears in holes in the terminals fitted to the outer tube in a manner to be described.

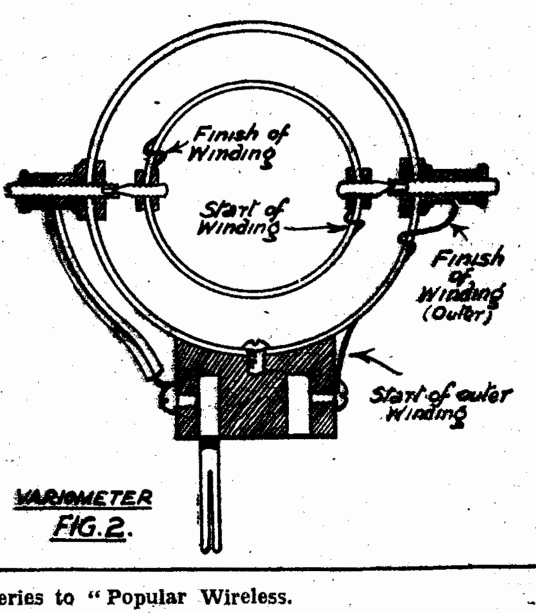
These two points are carefully fitted one on each side of the smaller tube by boring a small hole through the cardboard, exactly central both with the diameter and width of the tube, and secured with one of the nuts on both inside and outside of tube.

Winding the Stator and Rotor.

The larger tube has two holes made in a similar manner, in each of which are fitted small terminals, secured with a nut on the inside; a small hole is to be drilled up the shank of these terminals, and these when secured in position form the bearings of the inner tube, and into which the pointed ends of the pivots of rotor fit. The "spring" of the cardboard tube is sufficient to make good contact, enabling the rotor to be easily sprung into position and rotated. A little care is required in fitting these pivots and terminals, and it may be necessary to shorten the screwed ends of terminals to enable a good mounting to be made.

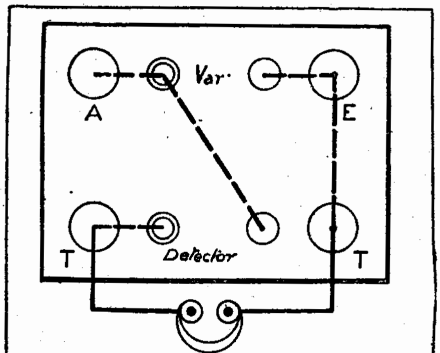
Fig. 2 clearly shows the method of construction.

The winding of both stator and rotor is done with No. 22 D.C.C. wire, 2 oz. of which should be ample.



VARIOMETER
FIG. 2.

The winding of the larger tube is started by making a small hole in the tube at the edge near the point where it is to be mounted on its plug, leaving a short length of wire for connection, and winding on 20 turns, 10 on each side of the centre; the finish of this winding is to be secured under one of the terminal nuts (the one on the same side as start of winding).



PRACTICAL WIRING DIAGRAM. FIG. 3.

The smaller tube is wound in a different manner, the starting end being soldered to one of the pivots and the finishing end to the other. Thirty-two turns are put on this tube, 16 on each side of the centre. These are wound on in two layers—i.e. 8 turns are laid on one side and then another layer of 8 turns wound on top of this, then, crossing over to the other side of centre, two layers of 8 turns are again wound on this side.

Completing the Set.

The inner tube can now be sprung into position in its mount by slightly squeezing the larger tube on the sides opposite to terminals, and when released will be found to nicely hold the rotor.

The whole unit is mounted on a coil plug by making a small hole through the tube and screwing it to the plug with a small brass screw. Finally, a piece of wire, which may be covered with systoflex, is secured under the terminal nut opposite to the starting point of outer winding, and taken down to the contact screw on the coil plug. This completes the variometer.

The base of the set is very simply made, and consists of a small piece of ¼-in. ebonite, which has been properly rubbed down where necessary, and in which are fitted four terminals, one each for aerial and earth, and two for 'phones, midway between each of which are fitted a plug socket to take the variometer and crystal detector. These are spaced $\frac{1}{16}$ in. apart, to fit the standard coil plug (see Fig. 3).

The wiring is very simple and is carried out in bare wire, which will be extremely short.

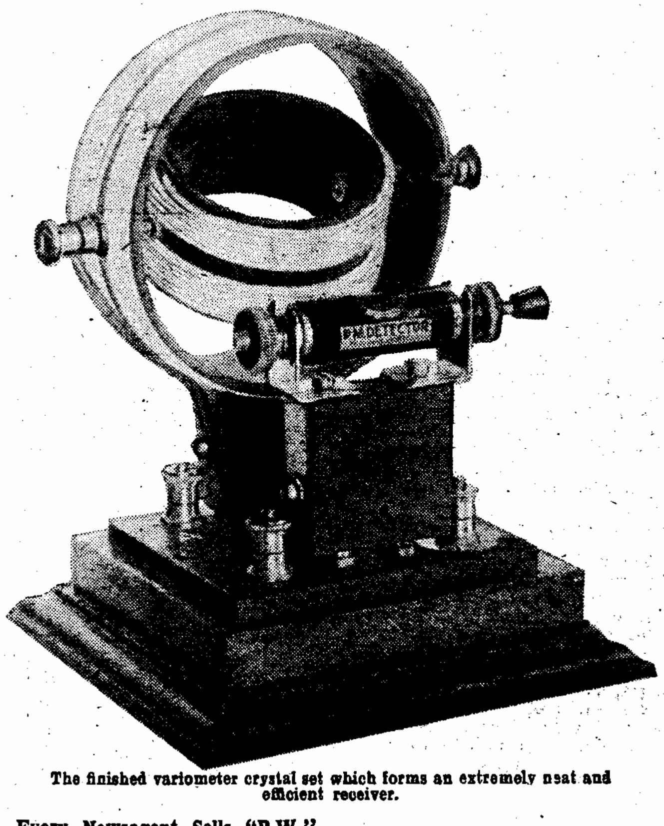
The ebonite "panel" is mounted on any suitable wood base, in such a manner that the wiring and terminals do not touch the wood mounting, and which suitably raises the set off the table.

Tuning is simply performed by rotating the rotor of variometer with the finger.

For the benefit of those to whom diagrams are not too clear, the details of the wiring are given in words in the point-to-point method familiar to readers of POPULAR WIRELESS.

Commencing at the aerial terminal, a short length of wire is taken to the variometer plug connection on the ebonite baseboard and thence, without breaking, to the socket side of the detector. Another wire is taken, retaining its continuity, from the socket of the variometer to the earth terminal and thence to one telephone terminal (the one on the earth side of the baseboard). The remaining telephone terminal is now connected by a third piece of wire to the plug connection of the detector, and this completes the wiring.

There is no need to solder the connections, though this makes for neatness and permanency if carried out properly, if the wires are tightly clamped to their terminals by nuts and washers, the wire being placed *underneath* the washers to obviate slipping.



The finished variometer crystal set which forms an extremely neat and efficient receiver.

DUO-RECEPTION CIRCUITS.

A NEW FIELD FOR CRYSTAL EXPERIMENTERS.

BY SEXTON O'CONNOR.

In a crystal set the strength of the received signals is mainly determined by the amount of energy that is absorbed by the aerial from the passing waves. If, therefore, every precaution has first been taken to prevent ordinary "resistance" and "leakage" losses in the aerial and detector circuits, no further increase in signal strength is possible unless some means can be found for increasing the aerial input.

If two stations, say 2 L O and 5 X X, are simultaneously broadcasting the *same* programme on different wave-lengths, it is clear that a receiving aerial so arranged as to respond to both radiated waves simultaneously will be tapping two sources of power, instead of one, and in this way will absorb more energy than when tuned in to a single wave-length.

When, for example, simultaneous broadcasting is taking place from several stations, it is a well-known test of the selective powers of a multi-valve set to tune into each station separately, and receive the same programme on different wave-lengths. If each of these signals could be amalgamated into one common reception, it is obvious that the combined strength would be greater than that secured from any individual station.

Some Advantages.

Such a plan, however, has no particular utility in the case of valve reception, because a weak incoming signal can always be magnified up to practically any desired strength merely by adding one or more stages of amplification. With a crystal set, on the other hand, extra power applied to the aerial is practically the only effective means of increasing signal strength. For this reason, the various systems of duo-reception about to be described offer an extremely interesting field for experiment and research to the crystal enthusiast.

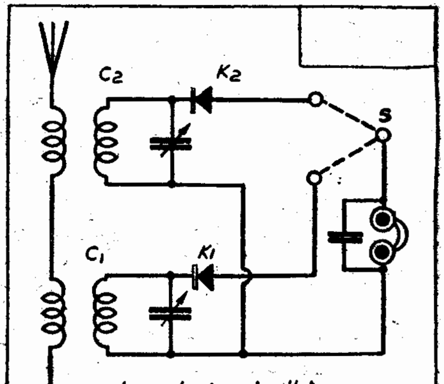
Before discussing the actual circuit arrangements, it may be of interest to consider whether the wireless wave from two different stations transmitting the same programme will be in phase as they arrive at a given receiving aerial, or whether there will be any appreciable lag or confusion between them.

Taking the specific case in which a programme originating in the London Studio is in one case radiated directly and in the other case is sent over fifty or more miles of land line, to Daventry, to be radiated (the receiving aerial being situated in a locality twenty-five or so distant from both London and Daventry, the London transmission reaches the listener at the speed of light—i.e., in about one ten-thousandth of a second. The Daventry transmission reaches the listener the same fraction of a second after it is transmitted from the Daventry aerial.

The difference, or lag, between the receipt of the two transmissions is therefore the actual time taken in the propagation of the telephone current along the land line from London to Daventry. This will be of the order of one ten-thousandth of a second, which is not sufficient to be detected by the ear. Therefore, any fears that the two receptions will not produce a summation effect in the receiving telephones may be disregarded.

In the circuit arrangement shown in Fig. 1 an untuned, or "aperiodic," aerial is used, and is coupled to two closed circuits C1, C2, which are tuned respectively to the two wave-lengths to be received. The couplings are kept as loose as possible, in order to avoid inter-action between the two closed circuits.

Crystal detectors K1 K2 are connected, as shown, to one terminal of each of the tuning condensers. The other terminals of the condensers are connected to each other and to one of the terminals



Aperiodic Aerial with two separately tuned detector circuits supplying same phones.
FIG. I.

of the telephones. The remaining telephone terminal is connected to a switch, S, indicated in dotted lines, which enables connection to be made to either crystal at will.

The switch is first connected to detector K1, and the circuit C1 is tuned to the shorter wave by listening in the 'phones. The circuit C2 is then tuned to the longer wave by moving the switch so as to connect in the detector K2 and disconnect K1. Finally, both detectors are connected to the 'phones, so that signals are received jointly on the two wave-lengths. Small adjustments of the tuning condensers should then be made until maximum signal strength is obtained.

In the arrangement of Fig. 1, the fact that there is no resonance in the aerial itself is a disadvantage so far as signal strength is concerned. The circuit shown in Fig. 2 has therefore been designed to render the aerial resonant at both the received wave-lengths.

For this purpose, the aerial is connected to earth through two parallel paths, each including an inductance and capacity in series. The coil L1 is of comparatively small size, and is tuned by a series condenser to the shorter wave-length. The other coil, L2, is larger, and is tuned by a series condenser to the longer wave. Both tunings are effected by listening in the 'phones when only one of the detectors, K1, K2, is in circuit.

The purpose of the two tune branches is to compel the oscillatory current at the shorter wave-length to flow from aerial to earth through the branch L1, and to exclude it from the branch L2. When the two wave-lengths differ widely (as in the case of Daventry and London) this object is substantially accomplished by the circuit shown, as the high inductance of the coil L2 will effectively choke the short-wave oscillations. The self-capacity of the coil L2 should be low, in order to ensure its efficiency as a short-wave choke. Similarly, the oscillatory current at the longer wave-length must be excluded from the branch L1, and, with this object, the setting of the series

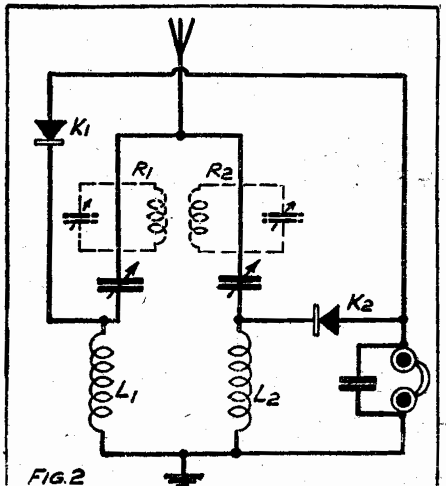


FIG. 2
DUO-RECEPTION WITH A DOUBLE-TUNED AERIAL.

condenser in that branch should be kept as small as possible.

A more complete separation of the two oscillatory currents may be effected by connecting rejector circuits R1, R2, in the positions shown in dotted lines, the circuit R1 being tuned to the longer wave and the circuit R2 to the shorter. The circuit R1 then offers very high impedance to the longer wave, and compels that wave to flow through the L2 branch, the shorter wave being similarly directed into the branch L1.

Fig. 3 shows a second form of branched aerial, in which there are three tuned circuits, L, L1, and L2, connected to a common branching point, X. The circuit L is tuned to one of the wave-lengths, preferably the shorter, by temporarily earthing the point X and connecting a crystal and 'phones across the whole or part of the coil L. The correct setting of the series condenser is thus discovered, and this setting is afterwards maintained. The direct earthing of the point X is now disconnected, and a second series condenser and coil L1 are inserted between the point X and earth. The correct setting of the series condenser for the same short-wave station as before is ascertained by listening for the loudest signals in the 'phones, which are now connected in series with the detector K1 across part of the coil L1. Finally, the loop branch circuit L2 is connected between the point X and earth, as shown, and tuned to the long-wave station.

To do this, the detector K1 is disconnected (i.e. the metal contact is lifted off the crystal) and the 'phones are placed in series with the second detector K2 across part of the coil L2. The series condenser is then adjusted until the longer wave signals are heard at maximum strength in the 'phones.

Receiving both Wave-lengths.

All these preliminary adjustments are best carried out when the short-wave and the long-wave stations are transmitting distinct programmes, in order that no confusion may arise as to which station is being received at any moment. The readings of the three series condensers should be carefully noted.

To receive both wave-lengths simultaneously the two detectors K, K2 are closed, the complete circuit then being as shown in Fig. 3.

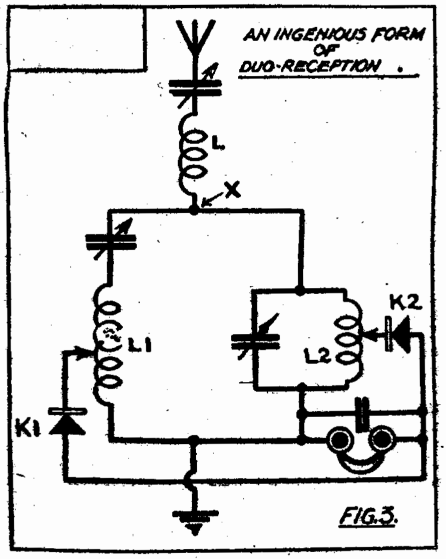
Although the circuit of Fig. 3 appears somewhat similar to that of Fig. 2, it is actually based on a different principle. On account of the identical tuning of the circuit L and L1, a node of potential is created at the point X. In other words, there is no potential difference between the point X and earth when the aerial is responding to the shorter wave. Consequently, any impedance such as the coil L2 and condenser C2 connected between these points, cannot divert any of the energy of the shorter wave from the desired path through the coil L1 to earth.

The whole system may be tuned to the longer wave by adjusting the series condenser in branch L2 without affecting the tuning already determined for the shorter wave. It is desirable to connect the crystal K1 (which necessarily introduces damping losses into the circuit) to a point on the coil L1 not too far removed from the earthed end of that coil. It is therefore advisable to provide several tappings on both the coils L1 and L2, and to try the effect of connecting the crystals K1, K2 to various points.

Conclusion.

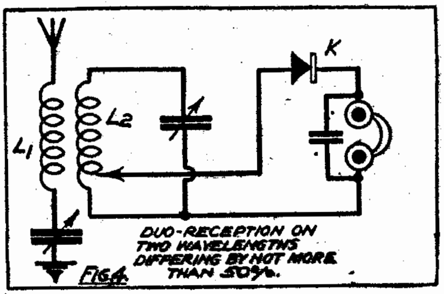
The circuits illustrated in Figs. 1, 2, and 3 will be found most effective when there is a considerable difference in wave-length between the two stations, as is the case with London and Daventry. The arrangement of Fig. 4, on the other hand, is intended rather for stations such as Liverpool and Manchester, where the wave-lengths are less than 50 per cent apart.

Here the aerial circuit is tuned by a series condenser, and the coil L1 is coupled fairly tightly to a closed secondary circuit, L2, the tuning of the two circuits being identical. It is well known that when two such circuits are coupled the combined circuit responds to two wave-lengths, which are respectively $\sqrt{1+K}$ and $\sqrt{1-K}$ times the



wave-length of the tuned circuits, K being the coefficient of coupling between the circuits.

The Liverpool and Manchester wave-lengths are respectively 315 and 378 metres, and a simple calculation shows that for these stations the coefficient of coupling should be ·18, and that each circuit should be tuned to a wave-length of 340 metres. The combined circuit will then respond to



both waves simultaneously. By connecting a crystal K and telephone to either circuit, for instance, as shown, the joint effect of both signal waves is heard in the 'phones.

HOW TO MAKE A PLUG-IN CRYSTAL SET.

An Efficient Set for a Few Shillings.

DESIGNED AND BUILT BY THE "P.W." TECHNICAL STAFF.

There are very few components required for the set described in the following article, and the receiver is extremely simple to build. The circuit is a straightforward one and is ideal for household use.

THERE are very few components necessary for this set, and the cost of the different parts, as detailed below, are given against each item.

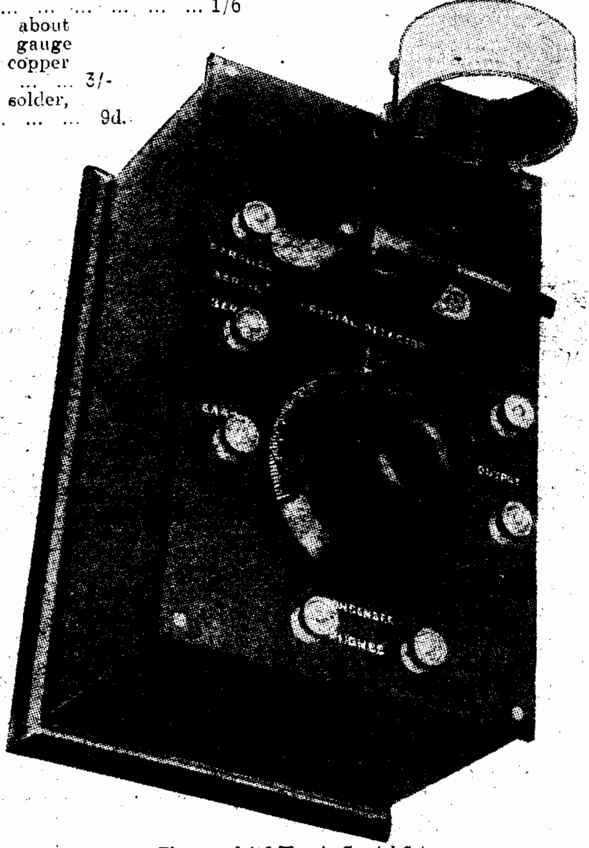
PARTS REQUIRED.

	Price.
1 Wooden cabinet, 5 in. x 8 in. x $3\frac{1}{2}$ in. deep (outside dimensions)	4/-
1 Ebonite panel, $8\frac{1}{4}$ in. x $5\frac{1}{4}$ in. x 3/16 in.	1/6
1 Coil plug for panel mounting	1/3
1 Variable condenser, .0005	6/-
1 Crystal detector of the enclosed glass type	1/6
7 W O terminals, about 8 ft. of 18 gauge square tinned copper wire	3/-
Set of transfers, solder, etc.	9d.

The constructor is advised to buy the cabinet, as it is an extremely tricky job to make one at all well, and this item will only cost a few shillings. The cabinet, of course, will be chosen so that the panel has an overlap of about $\frac{1}{8}$ in. all the way round. The cabinet walls should not, however, be more than $\frac{3}{8}$ in. thick.

The first step in construction is to file up the edges of the panel in order to make it fit properly in place. When the rough saw cuts have been smoothed off in this way, i.e. by the file, the edges are sandpapered down, the components are laid out upon the panel, and it is marked for drilling. (See Fig. 3.) This is not at all a difficult operation, as only about ten holes are necessary; an ordinary carpenter's brace can be employed, or one of those small hand-drills obtainable at most wireless dealers.

The only thing that is likely to prove at all troublesome is the mounting of the variable condenser, which, as will be seen from the list of components and the photographs, is of the single hole mounting type, and which will in all probability require a hole of about $\frac{1}{2}$ in. diameter. It may be that no drill of this size is available, and in this case a hole of about $\frac{1}{4}$ in., or larger if possible, should be drilled, and enlarged by using a reamer, a tool which should be in every constructor's tool-box, and which only costs about 1/-.

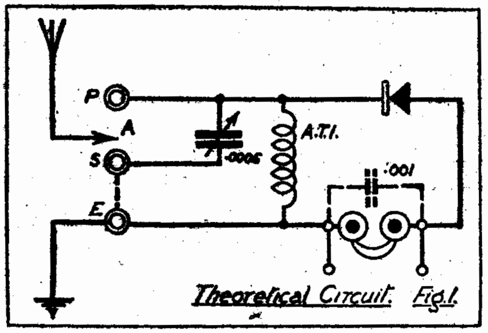


The completed Plug-in Crystal Set.

If the ebonite is of the highly polished variety, but not guaranteed with regard to efficiency, it is advisable to remove the polished surface, as this may contain traces of tinfoil and other impurities liable to cause leakage. After the drilling has been done the surface of the panel should be rubbed carefully with fine sandpaper or emery cloth until a matt surface is obtained. Finish off with emery cloth (00 size), and finally rub over with a little machine oil and a clean cloth. The result will be a neat matt coating, which will have really efficient insulating properties.

The three terminal method of obtaining a series or parallel variable condenser has been adopted, the aerial being connected to either the top or centre terminal, according as parallel or series tuning is required. In the former case the series terminal has to be shorted to earth, and the reason for this will be made quite clear from Figs. 1 and 2, which give the theoretical and pictorial diagrams of the circuit.

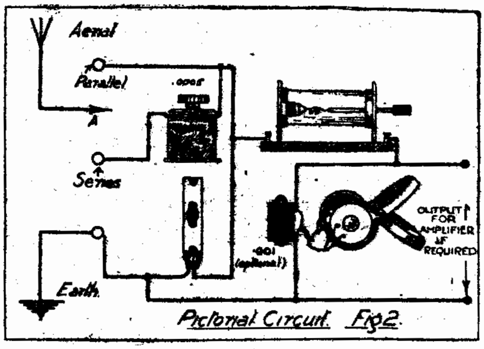
In connecting up the components 18 gauge square wire should be used, and all the joints must be carefully soldered to ensure perfect connections. A full wiring diagram is given in Fig 4, but, as an additional check, the "point-to-point" connections are provided below:



Theoretical Circuit. Fig. 1.

Parallel aerial terminal (right-hand side looking down on underside of panel with aerial coil plug away from you) to crystal side of crystal detector, to plug side of aerial coil holder, and to the fixed vanes of the variable condenser.

Cat's-whisker side of crystal detector to bottom "Output" terminal and to left-hand 'phone terminal. Series aerial terminal to moving vanes of variable condenser.

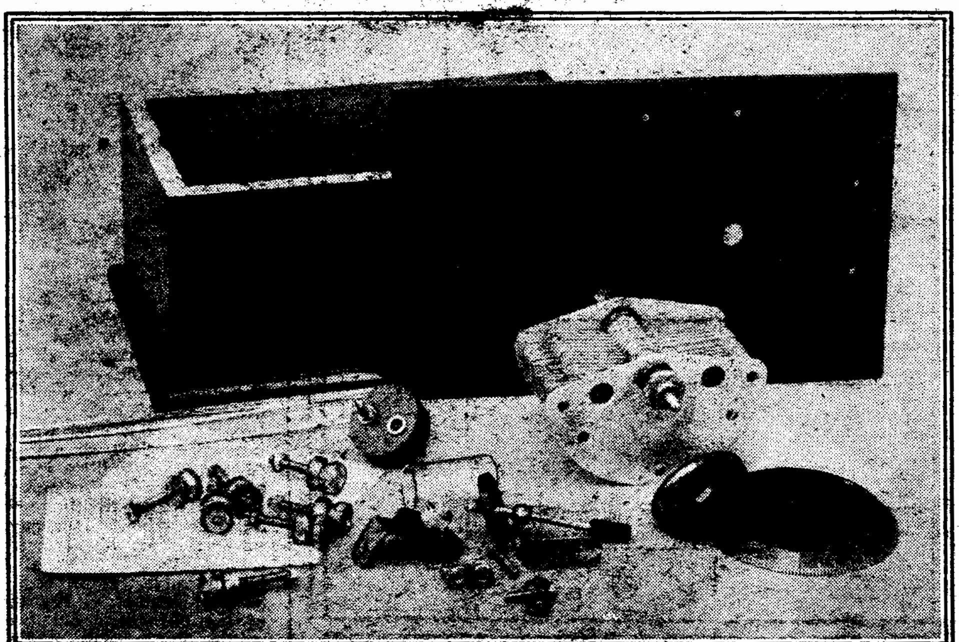


Pictorial Circuit. Fig. 2.

Socket side of aerial coil to top "Output" terminal, to right-hand terminal, and to earth terminal.

The Coils Necessary.

This completes all the wiring up, and when this has been checked from the diagrams, and it has been seen that all the joints are firmly made, the set is ready for testing. Though the home-made basket coils or other plug-in types can be used, the original set photographed here employed bought coils, such as Lissen, Igranic, or Burndept. It is advisable for the constructor to get either a No. 50 or a No. 75 and a 150-turn coil, so as to cover both his local broadcasting stations and the new high-power station at Daventry. In all cases



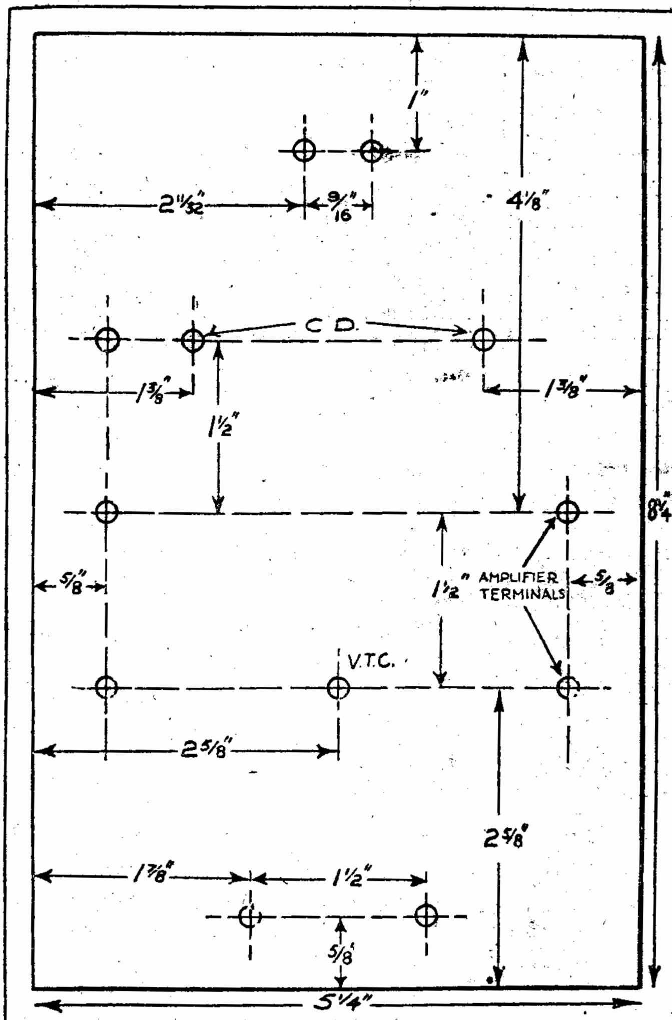
The cabinet and all the components required to build the Plug-in Crystal Set.

of wireless reception, the exact wave-length range covered by a set depends partly upon the aerial used, so that if a long aerial is employed, or one which has a high capacity, the listener will find that he cannot get down so far with a certain coil as perhaps his neighbour who is using a smaller aerial and employing similar apparatus. For instance, in the case under consideration, for the reception of stations below 350 metres it is advisable to use a 50-turn coil, employing the condenser in its series position. For stations over 400 metres, no matter what size the aerial is, a 75-turn coil should be most suitable. It is usually best to use series tuning for ordinary broadcast wave-lengths, as this enables the listener to take advantage of as large a coil as possible in the aerial circuit, this making for increased signal strength. For 5XX parallel tuning must be employed and the 150-turn coil used.

Range of Reception Available.

With regard to the range of reception, it is difficult to lay down any hard and fast rules, but the set herein described should be able to give really good 'phone signals up to a distance of seven miles or so from a relay station or fifteen miles from a main broadcasting station, while approximately a 100-mile range should be obtainable from 5 X X. These figures, of course, will vary according to local and atmospheric conditions, and they can only be taken as a rough indication of what the receiver will do.

Tuning in is accomplished as usual, of course, by merely varying the condenser readings and the setting of the crystal detector until loudest signals are obtained. Any well-known make of crystal should be suitable, and the operation of the set in the hands of the most inexperienced listener should not present any difficulties.



Panel Layout of the Plug-in Crystal Set. Fig 3.

The receiver described above is adaptable to any wave-length, so that if, after a few weeks' experience of broadcast reception, the listener desires to search round a little for ship and other spark stations —a fascinating pastime to all who know the Morse code—all he has to do is to use his 75-turn coil with the condenser in a *parallel* position; or, if he wants the Paris time signals from the Eiffel Tower, a 250-turn coil and parallel condenser will bring them in in most places in Great Britain.

Apart from the actual construction of the set, the problem which causes the most perplexity to the newcomer who is taking up wireless for the first time is the question: "What crystal shall I use?"

As all crystals fulfil the same function—i.e. turning the high-frequency voltages developed across the aerial coil into currents at low-frequency, which can operate the telephones—it would at first appear that the particular type of crystal used was not important. But, as a matter of fact, a very little increase of strength will often make all the difference to the enjoyment derivable from a crystal set, and it is just this little increase that the use of the best possible crystal ensures. But, unfortunately, the truth of the old adage about one man's meat and another's poison, applies very closely to the choice of a crystal, for whilst a certain specimen will

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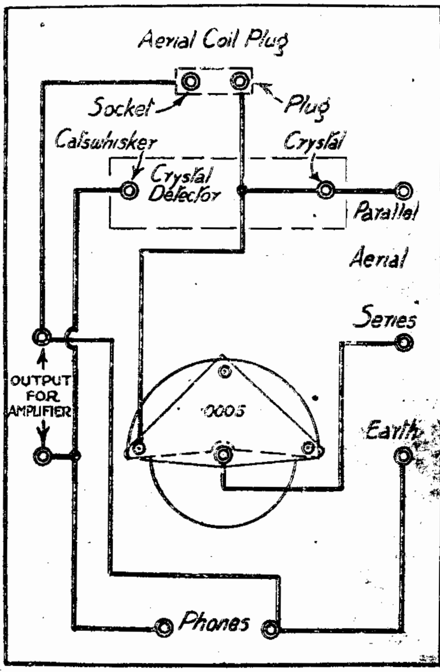


Fig. 4. *Wiring Diagram of the Plug-in Crystal Set.*

give excellent results in one pair of hands, or under one set of circumstances, the same piece will prove somewhat disappointing under other conditions.

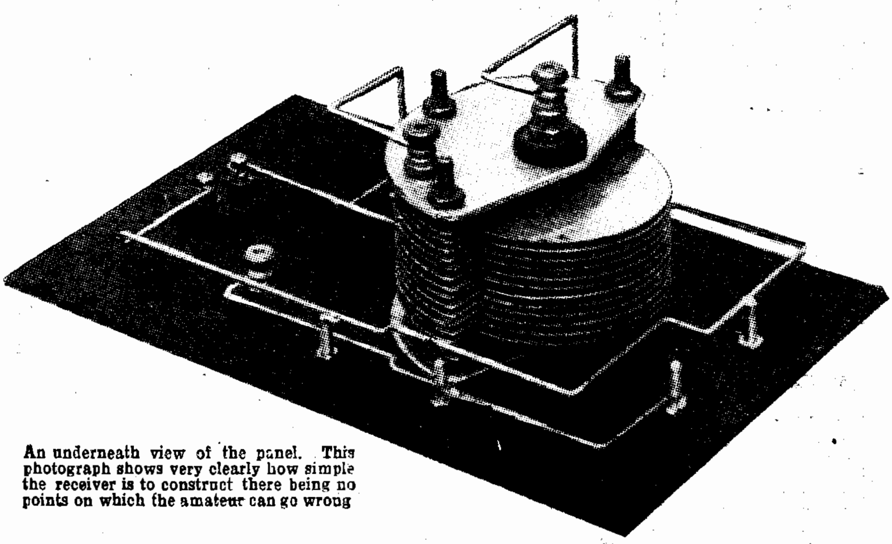
Choice of Crystals.

This is partly due to certain electrical or wireless conditions—such as the strength of current to be handled by the crystal, resistance of the 'phones used, etc.—and partly due to the personal equation. Some crystals require "coaxing" a little, and gentle handling, to get the last ounce from them, whilst others are almost equally sensitive all over. In different hands these would naturally give different degrees of success. Where adjustment and re-adjustment of the crystal contact is regarded as a nuisance, a good plan is to use a "fixed" or permanent detector, in which a sensitive point has been found and sealed. Such a component is generally quite satisfactory, but for those who prefer a little tinkering in order to get maximum results, the ordinary galena crystal—which embraces most of the "-ite" family—cannot be beaten at ranges of over two miles from a broadcasting station.

Perikon Best for Strong Signals.

If, however, the listener happens to live quite near to the broadcasting station, and his signals are already very loud in consequence, certain of the "perikon" type of detectors will be found to handle the loud signals and strong detector-currents better than the highly sensitive galena type.

The perikon detectors consist of two crystals in contact—instead of one crystal and a cat's-whisker—and such combinations as Zincite-Bornite, or Zincite-Tellurium, can handle strong signals more effectively than the average ultra-sensitive galena crystal. But the latter scores in most cases, for at a distance of three or four miles from the broadcasting station the signals are not too strong for it to rectify effectively, and its distance-getting ability makes it a better proposition than the two-crystal or perikon combination.



An underneath view of the panel. This photograph shows very clearly how simple the receiver is to construct there being no points on which the amateur can go wrong

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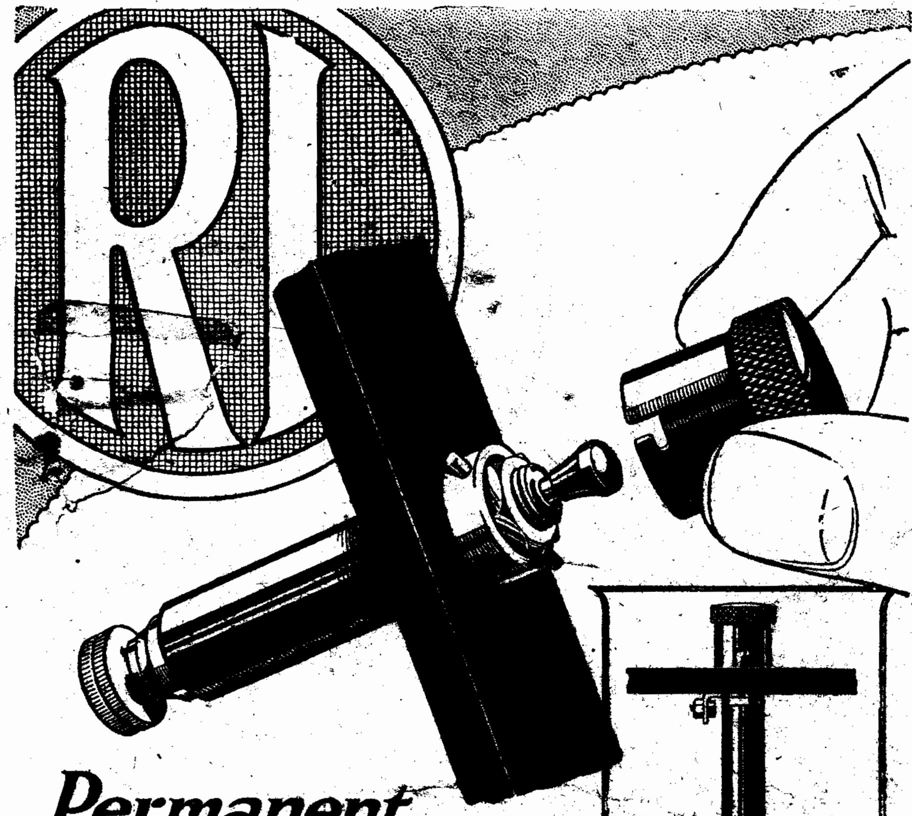

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