G. W. PICKARD.

OSCILLATION DETECTOR AND RECTIFIER.

APPLICATION FILED SEPT. 3, 1907.

912,613. **Patented Feb. 16, 1909.**

Fig. 1.

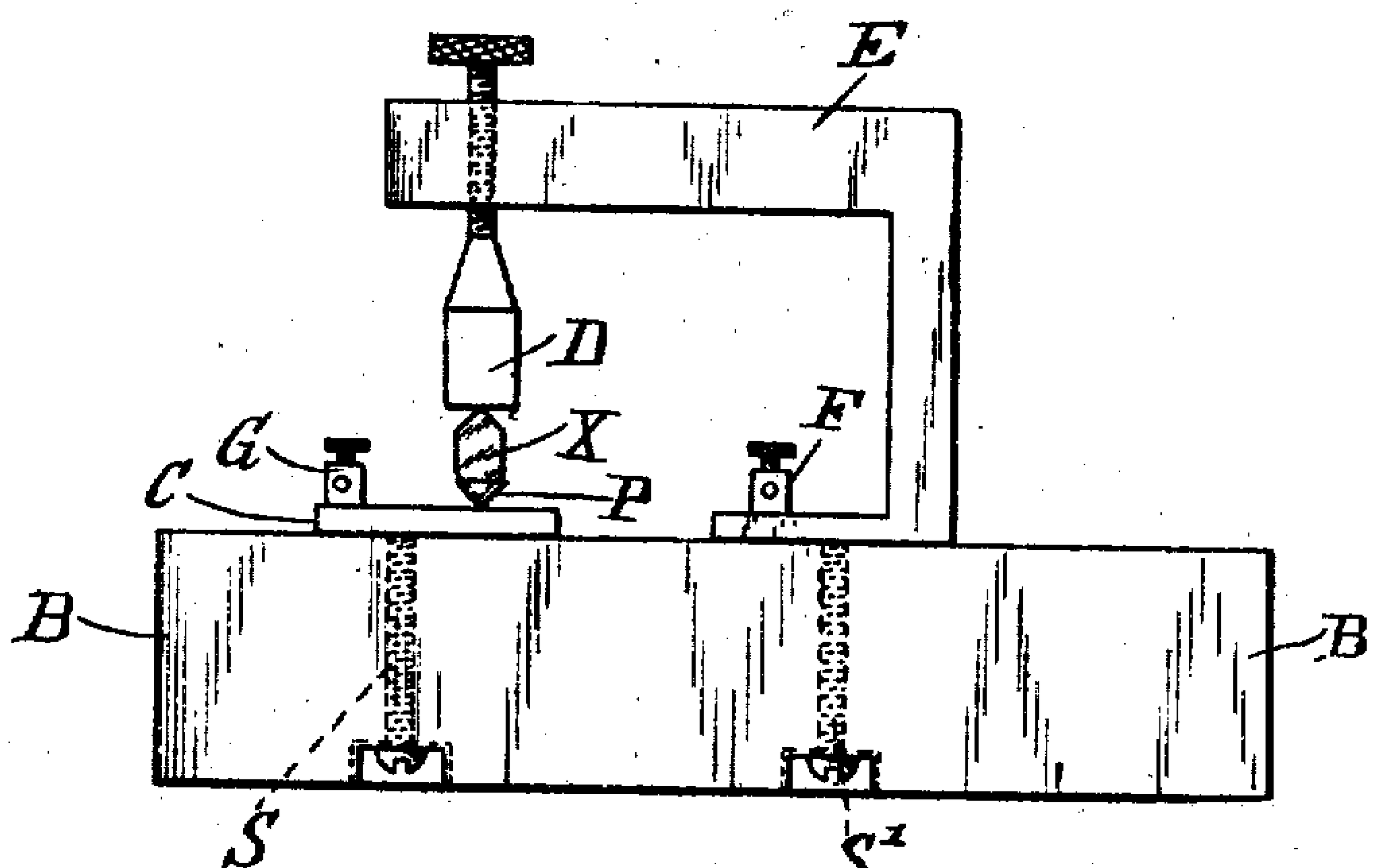


Fig. 5.

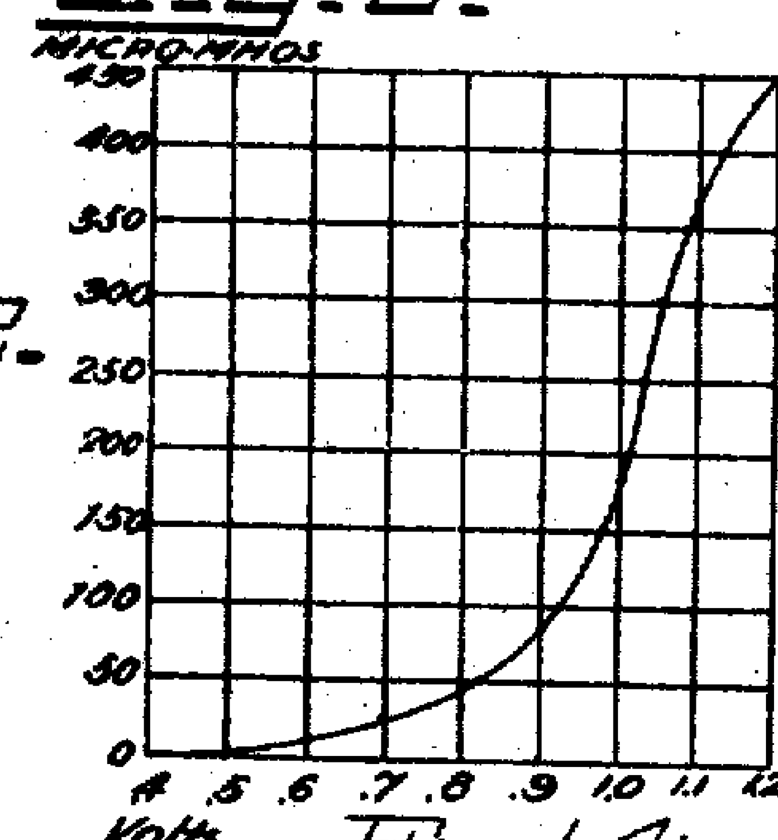


Fig. 2.

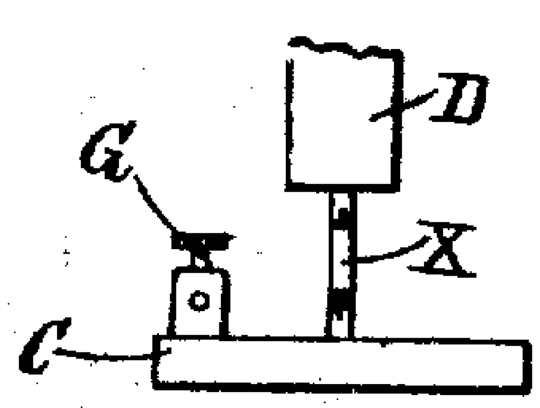


Fig. 3.

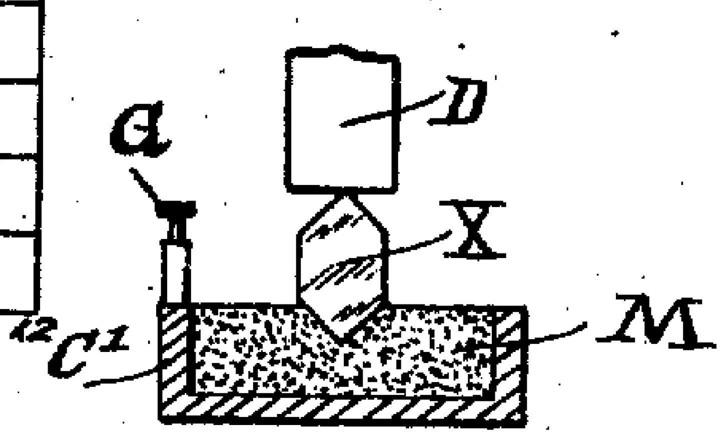
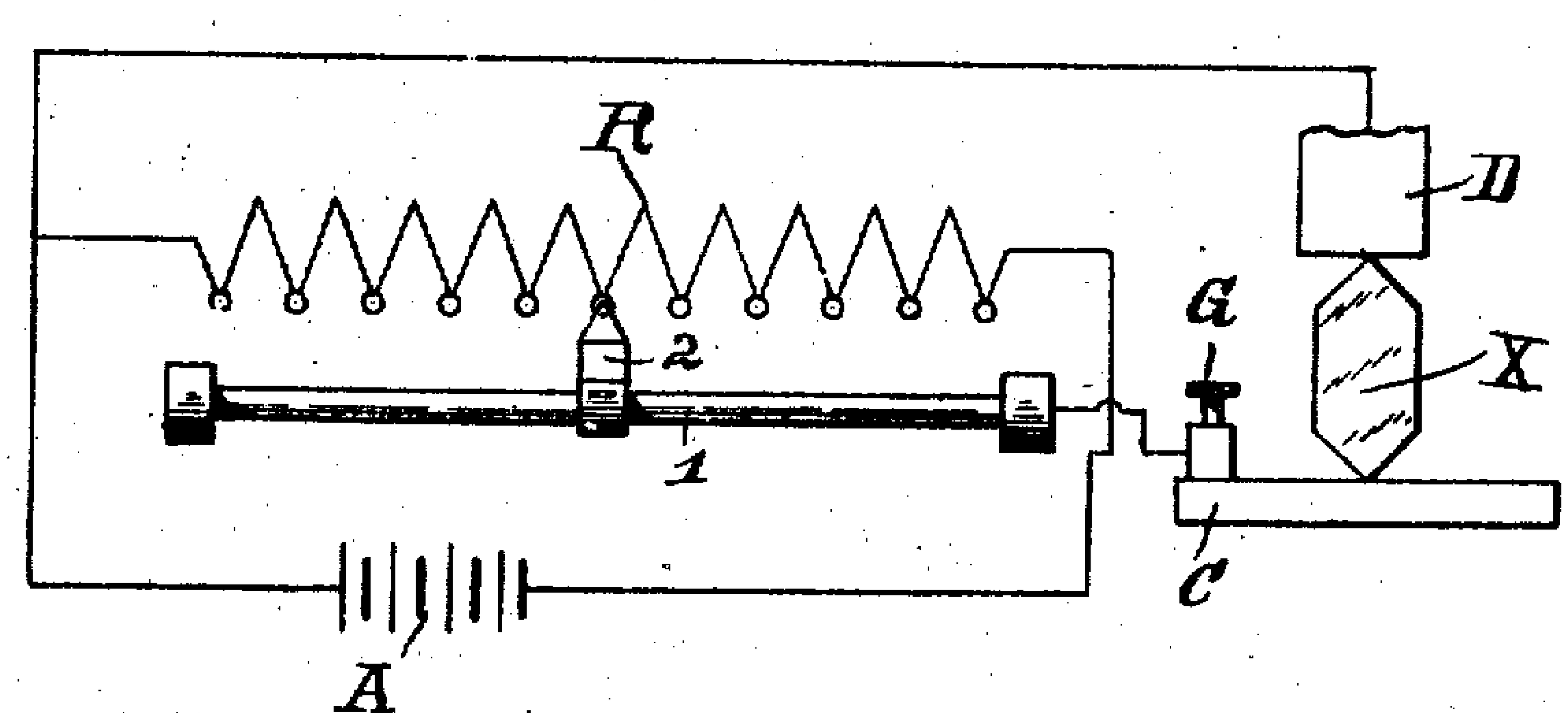


Fig. 4.



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OSCILLATION DETECTOR AND RECTIFIER.

No. 912,613. Specification of Letters Patent. Patented Feb. 16, 1909.

Application filed September 3, 1907. Serial No. 391,082.

To all whom it may concern:

Be it known that I, GREENLEAF WHITTIER PICKARD, a citizen of the United States of America, and a resident of the town of Amesbury, State of Massachusetts, have invented certain new and useful Improvements in Oscillation Detectors and Rectifiers, the principles of which are set forth in the following specification and accompanying drawing.

This invention relates to improvements in rectifiers of alternating or oscillating electromotive forces useful for various purposes in the arts, such as the reception of intelligence communicated by electro-magnetic waves and other similar purposes such as the rectification of lower frequency alternating currents than those employed in wireless telegraphy.

The invention consists in the features indicated hereinafter and in the accompanying drawings, in which—

Figure 1 is a complete assembly of the crystal rectifier device, Fig. 2 an edge view of a modified form, Fig. 3 a broadside view of another modified form, Fig. 4 a diagrammatic view of certain circuit arrangements; and Fig. 5 is a diagram illustrating the conductance of a crystal of carborundum, and the critical values of voltage between which greatest efficiency was obtained.

The invention involves certain of the electrical properties of conducting crystals, which I have investigated. In an article written by me and published in the *Electrical Review*, vol. 48, p. 994, dated Nov. 24, 1906, a description of some of these properties appears. This article describes that portion of my investigations dealing with a certain crystal used as a local current varying detector for wireless telegraphy, that crystal being the artificial product silicid of carbon, known in the art as carborundum, and forming the subject matter of United States patent to Acheson, No. 492,767 of 1893, and disclosed as a wireless telegraphy detector in United States patent to Dunwoody, No. 837,616 of 1906, when used as a concrete mass or body of crystals. There are various other known crystals which possess properties similar to silicid of carbon and which are included within this invention.

In the course of my investigations, I made various observations which showed that carborundum in the form of true crystals, was comparatively inefficient when used in a mass or body of crystals having the conducting leads secured to the mass of crystals as by being twisted or bound around the body. For these various reasons the carborundum was used in the following manner, which greatly improved results, particularly as a detector for wireless telegraphy, both as to greater constancy of action and as to increased sensitiveness.

A mass of crystals of silicid of carbon and impurities, as a substance of commerce, was crushed, in order to separate out the individual crystals, having a thin, nearly completely hexagonal form. Those of such crystals which were found to produce excellent results were those selected as being most nearly translucent or transparent, and therefore having a minimum of impurities, and having a diameter of about a tenth of an inch and a thickness of about one fiftieth of an inch. Each crystal was electrolytically metal-plated on at least one of two contiguous edges, as with copper or other suitable metal, and so that the plating would make good contact with the edge or two different contiguous edges of the crystal. The plating serves to reduce resistance and provide means for establishing good contact at the contact which is to be the neutral or ineffective contact. This plated crystal may be employed in all uses of the invention in good contact between any suitable electrodes; or the crystal alone, without plating, may be used by having the crystal in good contact in the circuit, but one edge being directly connected to an electrode, as D in Figs. 2 and 4, the other edge being connected to the circuit in any suitable manner; reliance being placed in such case on the accidental occurrence of a larger aread contact at the latter connection which thereby becomes the neutral or effective contact. Fig. 2 provides an example of a case where the crystal contact with either C or D may be the effective contact, according to the accidents of adjustment, because each contact is an edge contact with an electrode. In order to secure maximum sensitiveness, one of the areas of contact between the crystal and the electrode is very small; otherwise, if the crystal edges be buried in or have large aread contact with both the electrodes as by great pressure or soft electrodes, the area of contact will be so large as to decrease the resistance and effective action. When used without electro-plating, the apparent resistance is over a megohm for a current of a few tenths of a microampere, while for a current of 300 microamperes the apparent resistance is as low as only 500 ohms.

In Fig. 1 the insulating base B has a super-base C of conducting material, as copper, secured to it by a screw S. As stated above, the plating is not necessary, this being because the support for the rectifying conductor will naturally have a contact with it of larger area (thereby becoming the neutral or ineffective contact) than the effective small contact between the rectifying conductor and its coöperating electrode. Thus, for example, no plating is shown in Fig. 2. The fusible metal M of Fig. 3 is the electrical equivalent of the plating P of Fig. 1, each having for its function to insure the continued existence of such conditions as will not tend to oppose the useful action at the effective contact, which is the small-aread contact with electrode D. The coating P or fusible metal M may be replaced by any other equivalent (provided that the rectifying conductor has its effective small good contact with its coöperating electrode D, as by a conducting edge of the crystal shown) which may be such as to insure the continued existence at the other circuit contact with the rectifying conductor, (irrespective of accidental changes in adjustments, or of breakage of the rectifying conductor), of such larger aread contact than that with the coöperating electrode D, as will not tend to substantially oppose the useful action at the smaller contact. The crystal (shown in edge view at X in Fig. 2) has its lower edge electro-plated as with copper, at P, which rests on the super-base C. The base B carries a conducting standard E, screw-threaded to receive the delicately-threaded adjusting contact-screw D, a portion of the lower end of which makes the effective edge contact with the edge or minute conducting portion of the crystal X.

In Fig. 2 the lower edge of the crystal X engages directly with super-base C without any plating; and in Fig. 3 the super-base C' is cup-shaped and contains fusible metal M in which the crystal X is supported. This individual crystal of silicid of carbon, when used as specified, has a very marked rectifying effect upon alternating electromotive forces, as discovered in the course of my investigations and observations. Also, the change in conductivity as the potential across the edge-contact terminals of the individual crystal is varied, is characteristic, as the curve of conductance (for the particular crystal used in some of my tests) has a critical portion between one volt and one and one-tenth volts, where an increase of ten per cent. in the electromotive force causes a change in the conductance of more than 100 per cent. For this reason, although the rectifying action of the individual crystal is operative as a wireless telegraph detector without a local source of electromotive force, I devised a circuit arrangement for the crystal possessing said peculiar property, which included not only a local battery, (A, Fig. 4) but also a potentiometer R, (with conducting rod 1 and slide 2), in order to quite accurately control the voltage in the local circuit when the crystal is used as a wireless telegraphy detector, in order that the crystal may be operated on the steepest part of the conductance curve, and therefore with maximum efficiency. I find that in practice a battery and an adjustment of the potentiometer which produces a difference of potential across the terminals of the crystal of between one volt and three volts, depending of course upon the characteristics of the particular crystal used, produces the best results.

In Fig. 5 is shown a conductance curve of a particular crystal of carborundum used in some of my work, wherein appear the critical values of voltage between which greatest efficiency was obtained. This curve is taken from the publication above referred to. It is important to note that this curve is not precisely representative of all crystals, even of the same substance, with respect to the quantitative relations between impressed voltage and conductance; and that in some unusual cases the critical value may extend to approximately as high as three volts, or as low as one volt and even less, but in the latter case the efficiency is usually greatly impaired. The shape of the curve, however, is characteristic of all specimens of carborundum tested by me.

With the particular rectifying conductor herein disclosed, the positive (carbon or copper) pole of the battery (indicated as usual by the longer vertical line, at the left, Fig. 4) is connected to the coöperating conducting member D, in order to apply the low auxiliary electromotive force, so as to cause an auxiliary current to flow into the rectifying conductor X in a direction from its effective contact with the coöperating member D, which is the same direction as that of the currents rectified by the conductor X when the latter is of carborundum. This connection shown in the drawing insures the optimum working of the rectifying conductor with respect to its optimum conductance in combination with the requisite value of auxiliary source of direct electromotive force, that is to say, insures operation of the rectifier at the steepest part of its curve of conductance for the rectified current. When used as a detector, and with a local source of electromotive force provided with means to control the same within the limits of the steepest part of the conductance curve of the crystal, the individual crystal device seems to owe its efficiency not only to the high positive coefficient of conductivity of the material, useful under the influence of heat caused by the oscillations, but also to the comparative smallness of the effective edge contact which limits the action to and concentrates it at a very small volume of the crystal, while providing a good and effective contact at the best-conducting exterior portion of the crystal. In a commercially sensitive detector, the operative portion of the crystal is a little pyramidal mass, a thousandth of an inch or so on an edge and containing about a billionth of a cubic inch of material. The area of edge contact with the electrode is also extremely small, being of the order of a few millionths of a square inch. This of course refers to effective electrical contact, and not physical contact, which may be many times larger. Of course, various forms of mechanical holders may be employed with the invention.

When used as a rectifier of oscillations of lower frequency than those commonly used in wireless telegraphy, the action of the same individual crystal device, with the edge contacts, or conducting edge contacts as by metal-plating the neutral contact, is more efficient, particularly with the very low frequency currents of the general art. The action of the same device is possible however as a rectifying detector of wireless telegraphy oscillations, without a battery, but this arrangement is not as efficient commercially as with the battery and potentiometer, and not so readily controllable, unless crystals be used of other substances than carborundum and possessing the same property in greater degree, and which may be obtained by arbitrary trial of various substances or by their known and tabulated or measurable properties.

It is not yet established as to what property of the crystal contributes to its rectifying effect, or whether or not heat enters into this, or in precisely what way the auxiliary electromotive force aids the rectifying effect, except that at a particular potential, herein specified for one rectifying conductor, such as carborundum, there is a corresponding steepest portion of the conductance curve, which is characteristic of the particular conductor, at which portion the rectifying efficiency of such conductor is greatly enhanced; that is to say, the rectifying conductor is operated at the steepest part of its curve of conductance for the rectified current. The fact remains, however, as I have discovered, that the device is an efficient rectifier or rectifying detector as well as a controlling detector for a local battery circuit.

The device herein described, consisting of an individual crystal held firmly and in good contact at its edges or at least one edge between two flat copper-faced electrodes, is much more sensitive and reliable in operation than a mass or body of crystals, connected in circuit either by a wire winding or by contacts pressing against the mass. The actual advantage of the individual crystal-edge may be due to the possible fact that while the body of the crystal is conducting, the surface is insulating even to some extent covering the edge, so that only a minute part of the edge is conducting. The use of the substance in a controlled circuit supplied with electromotive force from a local source, is best adapted for wireless telegraphy purposes, in that it permits operation within narrow limits at the steepest part of the conductance curve, which is much more efficient than the rectifying effect alone, in the case of crystals not having the rectifying property in a higher degree than silicide of carbon. The use of an individual crystal, with edge contacts or with at least an effective contact with one edge, in such a controlled circuit, provides a device which is commercially operative. In brief, the invention concerns, irrespective of all else, the individuality of contact with at least one crystal edge, which thereby constitutes the effective and useful contact.

In rectification, the individual crystal is useful in that it provides limited conductivity and small area of contact points. The crystal has clearly defined edges, and some crystals have limited conductivity along planes. In some cases, as in that of silicide of carbon, or carborundum, the surfaces of the crystal are of higher resistance than the edges, which permits the making of very small aread contacts. Laminar conductivity may exist in some crystals, which yet further constricts the current path.

The pressure by the screw D (Fig. 1) will vary in accordance with the particular crystal of which X is composed, but in all cases will be such as to produce good contact. The best crystals are those which, in addition to the other desired properties, will withstand high temperature without injury. Also the crystals should be stable in air, that is, as free as possible from oxidation; or else they should be placed in oil or vacuum when in use, or otherwise protected from oxidation.

I claim:

1. As an element of a means for receiving intelligence communicated by electromagnetic waves, an individual conducting crystal.

2. As an element of a means for receiving intelligence communicated by electromagnetic waves, an individual crystal of low conductivity, and having a conducting body and conducting edges.

3. Means for receiving intelligence communicated by electromagnetic waves, which comprises an individual conducting crystal of low conductivity, and an electrode having good but minute contact with the edge of the crystal.

4. A rectifier of alternating electromotive forces, which comprises an individual conducting crystal of low conductivity.

5. A rectifying device for alternating electromotive forces, which comprises an individual conducting crystal of low conductivity and having a metallic deposition upon it.

6. Means for receiving intelligence communicated by electromagnetic waves, which comprises a conducting crystal having a high positive conductivity coefficient, a local source of electromotive force, and means for operating said crystal within the limits of the steepest part of the conductance curve of the crystal.

7. Means for rectifying alternating electromotive forces, which comprises an individual conducting crystal having a metallic deposition upon its edge.

8. Means for rectifying the alternating electromotive forces of electrical oscillations in wireless telegraphy, which comprises an individual conducting crystal, and an electrode in good contact with the edge of the crystal.

9. Means for receiving intelligence communicated by electromagnetic waves, which comprises a conducting crystal having a high positive coefficient of conductivity, and a local source of electromotive force therefor of suitable proportions to operate the crystal within the limits of the steepest part of its conductance curve.

10. As a means for receiving intelligence communicated by electromagnetic waves, the combination with an individual conducting crystal of carborundum having a high positive coefficient of conductivity and conducting edges; of an electrode having a minute good contact with the conducting edge of the individual crystal: a local source of electromotive force connected to said electrode and crystal; and means for limiting the electromotive force of said local source between one volt and three volts.

11. A rectifying device for alternating electromotive forces, which comprises a conducting crystal of extremely low conductivity, and having a metallic deposition on one edge; in combination with an electrode of conducting material in good contact with another edge of the crystal.

12. A rectifying apparatus for alternating electromotive forces, which comprises a conducting solid having extremely low conductivity and possessing the property of rectification, in combination with an electrode of conducting material in good electrical contact with a good-conducting portion of said rectifying conductor, said contact being effectively minute; and means for applying a direct electromotive force across said rectifying conductor to operate it substantially within the limits of the steepest part of its curve of conductance for the rectified current.

13. In an apparatus for rectifying alternating electromotive forces, useful, for example, in receiving intelligence communicated by electromagnetic waves, the combination with a conducting solid having extremely low conductivity and possessing the property of rectification, of means for applying a direct electromotive force across said conductor to operate it substantially within the limits of the steepest part of its conductance curve.

14. A wireless telegraph detector, which comprises a rectifying conducting crystal, a coöperating conductor operatively in small-aread electrical contact with a conducting surface of said rectifying crystal, and means for applying across said conductors an electromotive force of a critical value for operating said rectifying conductor substantially within the limits of the steepest portion of its conductance curve.

15. A wireless telegraph detector, which comprises a rectifying conducting crystal of carborundum, a coöperating conductor operatively in small-aread electrical contact with a conducting edge of said carborundum crystal, and means for applying across said conductors an electromotive force of a critical value for operating said rectifying conductor substantially within the limits of the steepest portion of its conductance curve.

16. A rectifying apparatus for alternating and oscillating electromotive forces, which comprises a conducting substance possessing the property of rectification; a coöperating conductor having an operative small-aread contact with a conducting surface of said rectifying substance; and means for applying across said coöperating conductors in a definite direction with respect to their operative contact, a direct electromotive force of characteristic voltage for operating said rectifying conductor within the steepest part of its conductance curve.

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Witnesses:

EDWARD H. ROWELL,

MYRA S. ROWELL.