March 19, 1929. S. RUBEN 1,705,539

ELECTRIC CURRENT CONTROL APPARATUS

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Fig. 1,

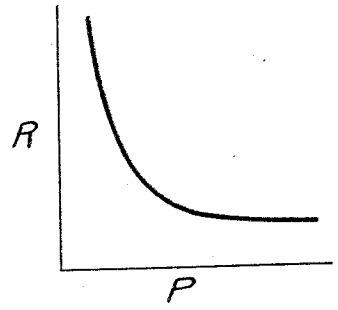
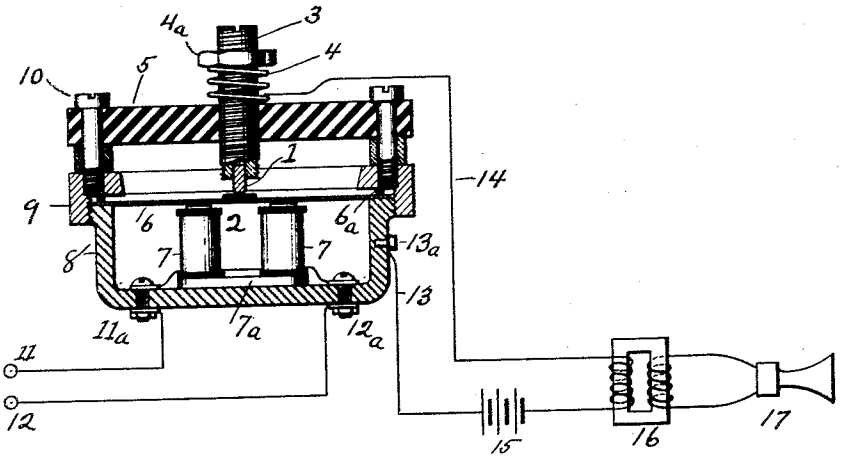


Fig. 2.



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Fig. 3.

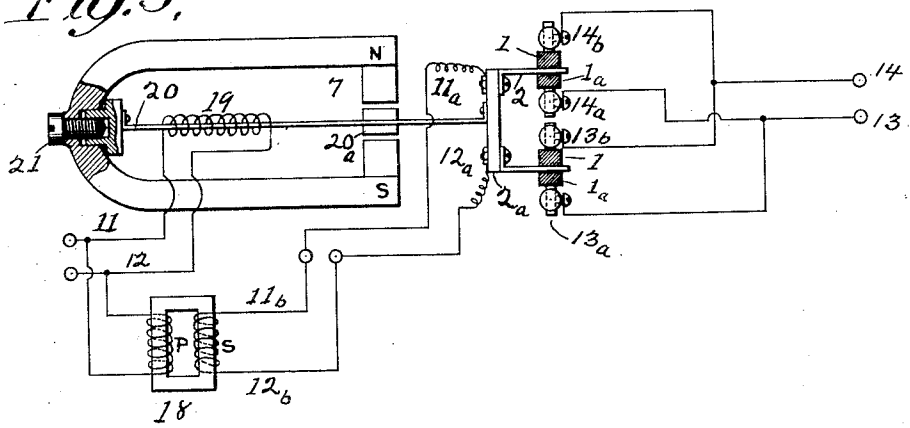
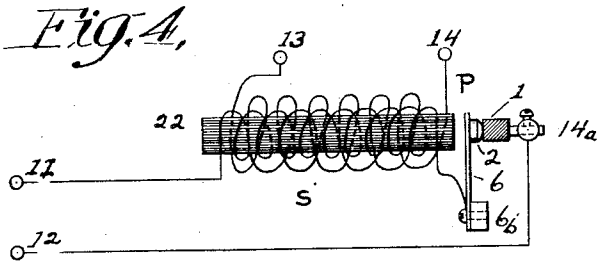


Fig. 4.



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Patented Mar. 19, 1929. 1,705,539

UNITED STATES PATENT OFFICE.

SAMUEL RUBEN, OF NEW YORK, N. Y.

ELECTRIC-CURRENT-CONTROL APPARATUS.

Application filed May 5, 1925. Serial No. 28,106.

This invention relates to electric current control apparatus; and it relates more particularly to apparatus for the control of electric current by means of varying the surface contact pressure between an electrode of an electropositive material and a cooperating electrode of a relatively electronegative material. One of the objects of the invention is to provide devices, simple in design and durable and which by the variation of pressure between their contacting electrode members, noiselessly and steplessly amplify and otherwise control an electric current.

Current control by pressure, as employed in the prior art depends upon the variation of molecular contacting areas of conducting materials obtained by varying the physical pressure therebetween. The devices of this type in most general use comprise combinations of carbon or graphite elements with means for applying pressure, and known as carbon piles. The electrical resistance is varied by changing the pressure upon and therefore the extent of molecular contacting areas of the materials. These devices function independently of polarity and the members offer poor conductivity until well compressed.

I have found that in an electric circuit employing as cooperating contacting electrodes, an electropositive material as the anode, and a relatively electronegative material as the cathode, and varying the pressure therebetween with a negligible change of contacting area, the electric conductivity of the couple is an increasing function of the pressure applied to the contacting area. That is, as the surface pressure between the materials of these characteristics increases, the electrical resistance in the path between rapidly decreases, thereby permitting increasing current flow between the electrodes. But it is important that the voltage of the applied current shall be below that of the decomposition potential of the reaction product at the junction of the combination. A characteristic curve of such a combination under varying pressures, as an aluminum body in contact with cupric sulphide, respectively as the anode and cathode in an electric circuit, when a potential difference less than the break down value is employed, is illustrated by Fig. 1 of the accompanying drawings. Ordinate R represents the resistance and the abscissa P, represents the pressure applied. It will be observed that with a variation of pressure between these materials, there is a very wide change in the current discharge. This is due to the change of contact resistance, rather than to variation in areas of the molecular contacts as in the devices of the prior art, as is shown by the fact that these results are obtainable by the employment of these materials as pointed electrodes, the points only being in contact, and the materials used being substantially non-compressible under the applied pressures; and this characteristic is not obtained if the polarity of the employed source of potential is reversed.

That is, this pressure control of resistance does not apply when the electropositive material is the cathode in the circuit to some degree; the couple is unilaterally conductive, being dependent upon the polarity of the current applied. The unilateral conduction effect varies with the difference in the electro differences between the contacting materials according to a known constant. The greater the potential of the applied current the wider should be the difference in electrophysical characteristics of those materials; and if a potential is applied that is equal to or greater than the decomposition potential value of the combination at the junction, a break down occurs and the unit is short circuited. The break down voltage of this resistance value I have found is a function of the relative electrophysical characteristics of the cooperating materials, the more electropositive the anode and the relatively more electronegative the cathode, the greater the resistance value. Thus, the aluminum and cupric sulphide couple withstands a higher potential than a zinc and cupric sulphide couple. The pressure required between the cooperating electrodes at which the contact resistance decreases, I find, is also dependent upon the same characteristics that govern the potential break down value; thus, a couple of aluminum and cupric sulphide requires a higher pressure than one of zinc and cupric sulphide. The choice of materials in the combination, therefore, should be related to the nature of the use to which the couple is to be put; for instance, if high

sensitivity to pressure is desired, materials having smaller electrophysical differences between them are selected.

With any combination, for example, zinc and cupric sulphide, the current through the couple when the electropositive material is the anode in the circuit, is relatively low, increasing proportionally with the voltage applied, until it reaches the break down potential value, when the resistance of the unit suddenly falls to an extremely low value, and sparking occurs. When the potential is again reduced to the critical value the resistance suddenly rises to its high value. With a couple having contacting areas of one square centimetre, I have found the unit to have a resistance of 10,000 ohms, and when the potential is increased slightly above a maximum or break down value of the couple, the resistance dropped to .01 ohm. This value is unstable if the excess voltage is only a small amount because of sparking occurring between the surfaces which continues as long as the potential is maintained at the excess value, and increases with a greater excess value. This characteristic I have discussed in my copending application filed in the United States Patent Office October 6, 1924 bearing Serial Number 741,969.

I have experimented with various electropositive materials, such as calcium, magnesium, aluminum and zinc, in combination with an electronegative element, tellurium, of the sixth periodic group and compounds of other elements of that group, such as cuprous and cupric sulphids, fused iron oxid, copper oxid, silver, bismuth, lead, molybdenum, iron and stanneous sulphids, antimony, lead peroxid, vanadium and manganese oxids, and have found such combinations to be suitable for this purpose.

The principle of unilateral conduction between contacting substantially non-compressible materials of certain electrophysical characteristics which I have discovered to be applicable to the control of resistance in the electrical path between them, by the variation of the pressure between their contacting surfaces, and the arrangement of the elements according to the terms of my invention, have many applications, among which are audio frequency relays, current control devices, alternating current rectifiers, oscillators and telephone transmitters.

In order to afford a full understanding of the principles of the invention, embodiments thereof in especially desirable practicable forms are illustrated in the accompanying drawings, and are hereinafter described in detail for the sake of concrete examples, but it is to be understood that the invention is not to be limited to these particular arrangements.

In the drawings referred to, Fig. 1 represents a characteristic curve of two elements in contact under varying pressures. Fig. 2 is a sectional view of a telephone receiver equipped with a pressure current controlling arrangement as an audio frequency relay connected to control an amplified current discharge to a telephone device. Fig. 3 shows an arrangement of the pressure current controlling device for effecting alternating current rectification. Fig. 4 represents an oscillator without the employment of a gap between the electrodes, equipped with the pressure current control arrangement.

Referring more particularly to Fig. 2, showing an audio frequency relay, at 1 is a cupric sulphide cathode with a convex surface in contact with aluminum plate as the anode 2, in an electric circuit, and affixed to metal diaphragm 6, resting upon metal casing 8 of the telephone receiver and held in place by washer 6_a and cap 9. Electrode 1 is mounted in screw 3 passing through insulator plate 5, affixed to cap 9 by screws 10. Mounted upon screws 3 are spring 4 and nut 4_a. At 7 are the poles of an electromagnet mounted on insulator base 7_a, and the field of which is controlled by current discharging through input conductors 11 and 12, through insulated screw connections 11_a and 12_a. The controlled current from battery 15 discharges through conductors 13 and 14, connecting respectively with electrodes 2 and 1, to transformer 16 and to receiver or loud speaker 17.

When the pressure between the cupric sulphide cathode rod 1, and the aluminum plate anode 2 is adjusted to the critical value, that is, to the point at which, although contacting a negligible current discharges therebetween, as current is applied at audio frequency through conductors 11 and 12, the strength of the electromagnet (7) field varies, causing a displacement or movement of diaphragm 6, with its attached anode plate 2, at like frequencies, and a like variation of pressure and therefore, surface resistance between electrodes 1 and 2. With those resistance variations current as supplied by battery 15 of higher intensity, discharges between the electrodes and through conductors 13 and 14 and transformer 16 to receiver 17, at which the current oscillations at amplified values are translated into sound. In this way, signal oscillations of very low intensity impressed upon the input circuit can be translated with minimum distortion into signals of relatively great intensity.

In the rectifier shown in Fig. 3, 1 represents a cupric sulphide cathode connected with conductor 14, 1_a representing another cupric sulphide electrode connected with conductor 13, both continuously in contact with aluminum anode plates 2, mounted on insulator base 2_a supported on spring 20 car-

rying armature 20_a, and supported on a permanent magnet. Mounted on spring 20 is polarizing coil 19, connected to an input alternating current through conductors 11 and 12. In shunt with alternating current circuit through transformer 18, conductors 11_b and 12_b connect at 11_a and 12_a with aluminum anode 2.

The cupric sulphide cathodes 1 and 1_a are adjusted by screws 13_b and 14_b so that their surfaces are in sensitive contact with anode plates 2. These plates vibrate with the armature movement in response to the alternating current cycles, without losing contact with either surface of the cathode elements, alternating between increasing and decreasing the contacting pressure between the cooperating electrodes. Upon the application of alternating current through conductors 11 and 12, through polarizing coil 19, the armature 20_a is alternately attracted to and repelled by each pole of the permanent magnet, the arms of electrode 2 having corresponding movement with respect of their contacting electrodes 1 and 1_a, causing variations of pressure and surface resistance therebetween and alternately preventing and permitting the discharge of the waves of the input alternating current through connections at 11_a and 12_a to the circuits of the co-operating electrodes 1 and 1_a.

The resultant effect of the polarized magnetic movements of armature 29 carrying anode 2 is the complete wave rectification of the applied alternating current, so that the output current through conductors 13 and 14 is a pulsating direct current.

In the oscillator shown in Fig. 4, the cupric sulphide electrode 1 is adjustably mounted on a support at 14_a with respect of contact with aluminum electrode 2 mounted on vibrating armature 6, supported on fixed base 6_b. Input current is carried by conductors 11 and 12 through a primary coil about iron core 22. Conductors 13 and 14 represent the output connection in which a secondary coil is wound about core 22. When current is applied to the primary coil by connection with lines 11 and 12, the core is magnetized; this serves to attract armature 6 to the core, reducing the contact pressure between electrode 2 and electrode 1 and causes the current flow in the primary circuit to decrease and, the field density to decrease. With the decreasing magnetic field density the armature returns to its initial contact pressure and effects a reestablishment of the conductive path, allowing continuous oscillations to be maintained without physically breaking the contact between the electrodes. The variations in the primary field current density, in turn induce a potential in the secondary connected to the output conductors 13 and 14. The cycle is repeated with the movement of electrode 2 and the variation of the current flow. I have found that such an arrangement functions at audio frequency at rates as high as 3,000 cycles, ordinarily difficult of obtaining, with a marked degree of steadiness and with no break in the contact.

What I claim is—

1. A device for controlling the flow of current in an electric circuit comprising, in combination, an anode of said circuit, and a cooperating electrode composed of a compound of copper and an element of the sixth periodic group, said anode being composed of a material electropositive with respect to the material of the cooperating electrode, and means for varying the contact pressure between said electrodes by the dynamic effects of current discharges from a source of energy in another electric circuit.

2. A device for controlling the flow of current in an electric circuit, comprising, in combination, an aluminum electrode arranged to be connected as an anode in said circuit and a cooperating electrode composed of a compound of copper and an element of the sixth periodic group, and means for varying the contact pressure between said electrodes by the dynamic effects of current discharges from a source of energy in another electric circuit.

3. A device for controlling the flow of current in an electric circuit, comprising, in combination, an aluminum electrode, arranged to be connected in said circuit as the anode and a cooperating electrode composed of a compound of a metal electronegative with respect to aluminum and an element of the sixth periodic group and means for controlling the electrical resistance between said electrodes by varying the pressure between said electrodes.

4. In a variable electrical resistance device, an anode, electropositive with respect to elements of the sixth periodic group, and a cooperating cathode composed of an element of the sixth periodic group which is maintained in surface contact with the anode by a flexible member, in combination with another member, the movement of which, in response to variations in electrical oscillations in another electrical circuit varies the stress upon said flexible member and the pressure between the surfaces of said non-compressible bodies.

5. In an electrical circuit, a variable electrical resistance device having an aluminum anode and a cooperating electrode of a compound of copper and an element of the sixth periodic group, maintained in contact with said anode by a spring member, and means for varying the pressure upon said spring member by the dynamic effects of current discharges from a source in another electrical circuit.

6. A device for controlling the flow of current in an electrical circuit, comprising, in combination, an electrode composed of a material electropositive with respect to elements of the sixth periodic group, in surface contact with a cooperating electrode composed of an electrically conductive crystalline compound of an element of the sulphur group, means for varying the pressure between said electrodes by the dynamic effects of current discharges from a source of energy in another electrical circuit.

In testimony whereof, SAMUEL RUBEN has signed his name to this specification, this 14th day of April, 1925.

SAMUEL RUBEN.