Jan. 11, 1944.

G. L. PEARSON

2,339,029

THERMOSENSITIVE RELAY

Filed Sept. 24, 1941

FIG. 2

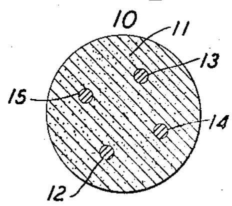


FIG. 1

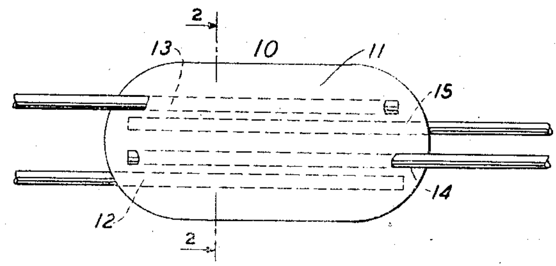


FIG. 3

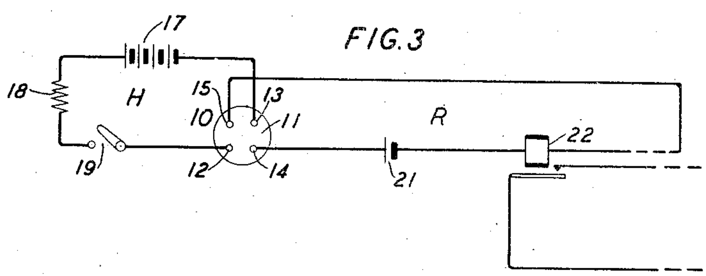


FIG. 4

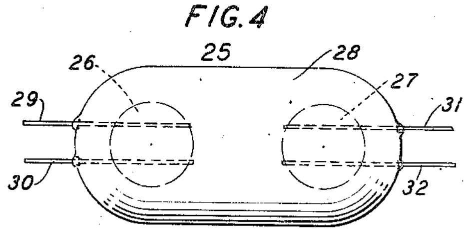
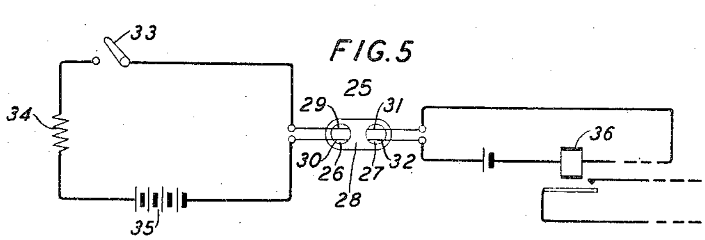


FIG. 5



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Patented Jan. 11, 1944

2,339,029

UNITED STATES PATENT OFFICE

2,339,029

THERMOSENSITIVE RELAY

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Application September 24, 1941, Serial No. 412,068

12 Claims. (Cl. 201—76)

This invention relates to electrical resistors having pronounced temperature coefficients of resistance and particularly to the use of these resistors for circuit controlling purposes.

An object of the invention is to provide an improved thermosensitive resistor that functions as a relay to operate a responsive circuit.

Another object is to provide an improved resistor for producing a time delay in the operation of an electric circuit.

It is well known that electric circuits may be operatively controlled through the use of directly heated resistors having a high negative temperature coefficient of resistance, wherein the resistor exhibits a high resistance at low temperatures and a low resistance at high temperatures. A resistor of this type usually comprises a heater conductor embedded within a minute bead of semiconductive substance having a high negative temperature coefficient of resistance, the two ends of the conductor being generally connected to an energizing circuit. The resistor of this type also includes two ends of a pair of conductors terminated in the semiconductive substance, the other ends thereof being connected to a responsive circuit. Upon energization of the heater circuit current flows through the heater conductor, and the heat generated thereby raises the temperature of the bead whereby the resistance thereof drops appreciably. This reduction of resistance in the bead consequently lowers the resistance of the responsive circuit and causes energization thereof, inasmuch as the material of the bead is in series with the ends of the conductors terminated therein. Control of the responsive circuit is therefore obtained through the heating effect of the heater conductor on the semiconductive material of the bead. This control, however, is limited because of the comparatively low impedance characteristic of the heater conductor and as a result necessitates substantial current drain in order to obtain the required heating effect.

In accordance with this invention, a novel directly heated resistor, comprising a bead of high negative temperature coefficient of resistance, is utilized as a relay for controlling the operation of an electric circuit, wherein the semiconductive material itself replaces the heater conductor as the heating element. By employing the comparatively high impedance semiconductive material, rather than a continuous conductor, as a heating element applicant has provided a more flexible and economical means for controlling subsidiary circuits, since a smaller value of current can be applied. Use of the semiconductive material as a heating means is obtained by terminating the heater circuit conductors individually therein, so that the semiconductive material is serially connected with the heater conductors.

In arrangements where more than one pair of conductors has been terminated in a semiconductive substance, it has been heretofore difficult to direct current flow through the proper channels. As far as applicant is aware, resistors of high negative temperature coefficient having more than two conductors embedded within a semiconductive substance are limited to the type wherein the heating element comprises a continuous conductor embedded within the material. Applicant has overcome this limitation, in one embodiment, by spacing four conductors conjugately with respect to each other. The conjugate relationship existing among the conductors, disregarding thermal effects, is such that a change in the impressed electromotive force in one circuit does not produce a change in the current of another circuit. This is based on the well-known theory that equipotential planes of varying magnitude exist between two conductors of a circuit. In this instance, assume an imaginary line between the two heater conductors terminated in the semi-conductive substance. Equipotential planes of varying magnitude exist along this line and at right angles thereto. As the two conductors of the responsive circuit are conjugately placed with respect to the heater conductors they are therefore positioned along one of the equipotential planes. Consequently, there is no potential difference between the responsive circuit conductors and as a result current is not induced in the responsive circuit by flow of current in the heater circuit. Furthermore, the heater current continues through the semiconductive material between the heater conductor terminations rather than circuitously through the responsive circuit.

In another embodiment applicant has paired the quadruplex conductors and has terminated each pair in an individual bead of semiconductive material having a high negative temperature coefficient of resistance. Both beads are then embedded in a thermal medium such as glass. Current flow through the proper circuit is thereby assured and the delaying action of one circuit upon another may also be increased.

A feature of this invention therefore resides in a high negative temperature coefficient resistor having a pair of activating circuit conductors and a pair of responsive circuit conductors terminated conjugately in a bead of semi-conductive material.

Another feature resides in a high negative temperature coefficient resistor having a pair of heater circuit conductors and a pair of responsive circuit conductors terminated in individual beads of semiconductive material while both beads are thermally interconnected by glass or glass-like material.

A clear understanding of the invention may be obtained from a consideration of the following detailed description read in connection with the accompanying drawing in which:

Fig. 1 illustrates one embodiment of the invention in which a resistor bead having a high negative temperature coefficient of resistance has terminated therein four conductors spaced at conjugate points;

Fig. 2 illustrates a sectional view of the resistor taken along line 2—2 of Fig. 1;

Fig. 3 illustrates a circuit application of Fig. 1 as a delaying device;

Fig. 4 illustrates another embodiment of the invention in which a pair of resistor beads, each having a pair of conductors terminated therein, are interconnected by a thermal medium; and

Fig. 5 illustrates a circuit application of Fig. 4 as a delaying device.

High negative temperature coefficient resistors exemplified as time delay relays herein may be made from combinations of metal oxides as taught in the application of Richard O. Grisdale, Serial No. 274,114, filed May 17, 1939, now Patent 2,258,646, issued October 14, 1941. By the employment of proper proportions of the oxide for the resistance material, series of units may be made having a wide range of specific resistance but always in a comparatively narrow range of high resistance temperature coefficient. It has been found that mixtures of nickel and manganese oxides when properly heat treated combine to produce a resistance material having particularly desirable resistance characteristics.

Referring to the drawing and particularly to Figs. 1 and 2, a resistor bead 10 comprises a selected semiconductive material 11 such as disclosed, for example, in the aforementioned Grisdale application, which material has a high resistance to current flow at ordinary room temperatures while a low resistance to current flow at high temperatures. Within the material 11 are terminated conducting leads 12, 13 and 14, 15 in conjugate relationship therewith. By placing the conductors 12, 13, and 14, 15 conjugately, current flow is directed through the desired circuit; for example, if we consider conductors 12, 13 connected to a primary circuit and conductors 14, 15 connected to a secondary circuit, an electromotive force impressed across conductors 12, 13 will cause current to flow from conductor 12 serially through the semiconductive material and thence to conductor 13 without passing through the secondary circuit conductors 14, 15. This phenomenon of conjugate conductors can be explained by the above example wherein the electromotive force impressed across conductors 12, 13 creates a potential gradient therebetween; which gradient may be considered as consisting of a series of equipotential planes of varying magnitude, one plane of which intercepts conductors 14, 15. Since a difference in potential is required to produce a flow of electric current and since the intercepting plane herein has but one potential, a current flow is therefore not produced in the circuit comprising conductors 14, 15.

An embodiment of this invention as a time retardation relay is exemplified in Fig. 3, which discloses a responsive circuit R activated through a four-terminal thermal resistor relay 10, of the above-described design, by a heating circuit H. The activating or heating circuit H contains a high voltage battery 17, current limiting resistance 18, and key 19 connected serially through the semiconductive material 11 to two opposite conductors 12, 13 of the thermal resistor relay 10. The responsive circuit R comprises a low voltage battery 21 and an electroresponsive relay 22 connected in series to the other two conductors 14, 15. The battery voltage 21 is lower than the maximum voltage of the thermal relay 10 characteristic so that under normal conditions only a small current flows in this circuit. This normal current, however, is insufficient to operate relay 22.

The invention will be most readily understood from a detailed description of the operation.

Normally key 19 is open so that the supply of current to the semiconductive material 11 is disconnected. By closing key 19, however, the high voltage of battery 17 heats the semiconductive material 11, in a circuit already traced, until the maximum voltage of the thermal relay 10 is less than the voltage of battery 21. In other words, the heater current flow through the semiconductive material 11 raises the temperature and in turn lowers the resistance thereof. It is to be noted that the main heating element herein comprises the semiconductve material itself and not the conductors 12, 13. When the maximum voltage of relay 10 is less than the voltage of battery 21, the responsive circuit R becomes unstable and current in the responsive circuit R increases to a value which is more than sufficient to operate relay 22. The operation of relay 22 closes the lower front contact springs thereof and initiates a circuit operation, which forms no part of the invention and which is therefore not shown in the drawing. When the key 19 is again opened, current cntinues to flow, however, in the responsive circuit R until its circuit is opened. Circuit opening means for the responsive circuit R is not shown as it also forms no part of the invention.

It is advantageous in some applications to have one circuit in a four-terminal thermal resistor insulated electrically from the other circuit while at the same time both circuits are coupled thermally. This type of unit may be constructed by sealing two spaced beads of semi-conductive substance having a high negative temperature coefficient of resistance in a glass rod or other suitable thermal means. Each bead also includes a pair of conductors terminated therein for connection to the external circuit.

As shown in Fig. 4, resistor 25 comprises a pair of spaced high negative temperature coefficient of resistance beads 26, 27 disposed within a glass rod 28 or other suitable thermal means. The separation of the beads 26, 27 is determined by the time delay desired, the retardation effect being greater the further apart the beads are placed. Each bead comprises a pair of conductors embedded therein, bead 26 including conductors 29, 30 and bead 27, conductors 31, 32.

Fig. 5 illustrates an application of the resistor 25 to an electric circuit arrangement similar to that described in Fig. 3. In this arrangement when key 33 is closed, current is provided for heating resistor bead 26 in a circuit traced from key 33, through current limiting resistance

34, battery 35, conductor 30, across semiconductive substance 26 to conductor 29, and thence back to key 33. The initial current, which is determined by the cold resistance of the bead 26, is small and rises slowly at first, then more rapidly as the bead becomes hot. The final current, which continues to flow until the circuit is opened, is limited by the resistance 34. The heat from bead 26 is transferred along the glass rod 28 to bead 27, which after a predetermined time interval heats sufficiently to lower its impedance to a value which causes sufficient current flow to energize relay 36 in an obvious circuit. Key 33 may be opened upon energization of relay 36, which continues energized until opened externally (not shown).

While this invention has been shown and described as embodying certain features, merely for the purpose of illustration, it will be understood that it can be used in many other widely varying fields without departing from the spirit of the invention and scope of the appended claims.

What is claimed is:

1. A resistor comprising semiconductive substance having a pronounced temperature coefficient of resistance, and two pairs of conductors having individually spaced ends thereof terminated within said substance, said pairs of conductors being so disposed that energization of one of said pairs renders said substance conductive to effect a low resistance path in the other pair of conductors.

2. In a resistor, a unit comprising a semiconductive material having a high negative temperature coefficient of resistance, and four conductors having individually spaced ends thereof so disposed within said unit that said material is circuitously connected with said conductors, one pair of said conductors adaptable for connection to an energizing circuit for heating said material, the other pair adaptable for connection to a responsive circuit, characterized by this that upon energization of the first pair said material increases in temperature and correspondingly decreases in resistance until said material is rendered conductive to effect a low resistance path in the other pair of conductors thereby energizing the responsive circuit.

3. A resistor comprising electrical semiconductive material having a negative temperature coefficient of resistance, and four conductors terminated within said material, said conductors being terminated at conjugate points.

4. A resistor unit comprising a bead of semiconductive material having a high negative temperature coefficient of resistance, and four conductors having ends thereof embedded and terminated within said bead, said conductors being spaced symmetrically and being terminated at conjugate points.

5. A resistor unit comprising an electrical insulating, heat conducting medium, a plurality of beads of semiconductive material having a high temperature coefficient of resistance included within said medium, and a plurality of conductors terminated in each of said beads.

6. A directly heated resistor unit comprising a pair of beads of semiconductive material having a high negative temperature coefficient of resistance, a glass medium in which said beads are embedded in spaced relationship, and a pair of conductors terminated in each of said beads, whereby said pairs of conductors are electrically insulated and thermally coupled.

7. A circuit controlling device comprising two pairs of conductors connected respectively to a primary and secondary circuit, an electrical semiconductive substance having a high temperature coefficient of resistance, said pairs of conductors having ends thereof individually embedded in the substance and spaced to introduce a time element in the influence of the primary circuit over the secondary circuit, means in said primary circuit for rendering said substance conductive, and means in said secondary circuit responsive to the conductivity of said substance.

8. A resistor comprising four conductors connected respectively to the two terminals of a primary and secondary circuit, a semiconductive material having a high negative temperature coefficient of resistance, said conductors having ends thereof individually terminated within said material at conjugate points, means in said primary circuit for rendering said material conductive, and means in said secondary circuit responsive to the conductivity of said material.

9. A directly heated resistor comprising semiconductive material having a high resistance temperature coefficient, a plurality of spaced conductors having ends thereof individually terminated within said material, said conductors being grouped into pairs and spaced so that the resistance between the conductors of each pair is less than that between the conductors of separated pairs, a normally open primary circuit connected in series with one pair of said conductors, a normally closed secondary circuit connected in series with another pair of said conductors, a source of energy in said secondary circuit normally insufficient to cause effective current flow through said material, and a source of energy in said primary circuit to render said material conductive, whereby the energy of said secondary circuit is rendered effective.

10. In combination, a primary circuit and a secondary circuit, a device coupling said primary circuit to said secondary circuit, said device comprising electrical semiconductive material having a high temperature coefficient of resistance, a pair of spaced electrical conductors having ends thereof embedded in said material and connected to said primary circuit, a second pair of spaced electrical conductors embedded in said material and connected to said secondary circuit, the resistance between the conductors of each pair being less than that between the conductors of separated pairs, a source of potential in said secondary circuit, said potential being insufficient normally to circulate effective current through said secondary circuit because of the normally high resistance of said semiconductive material, and a source of energy in said primary circuit to render the material conductive, whereby the potential of said secondary circuit is rendered effective to cause current flow therein.

11. A circuit controlling device comprising a pair of beads of electrical semiconductive substance having a high negative temperature coefficient of resistance, a pair of spaced conductors individually terminated within each of said beads, a glass rod enclosing said beads in spaced relationship with said conductors extending through the glass rod, a heating circuit connected to one pair of said conductors, a responsive circuit connected to another pair of the conductors, means in said heating circuit for raising the temperature of said substance to render same conductive, and means in said re-

sponsive circuit energized by reason of the conductivity of said substance.

12. A resistance bead comprising semiconductive material having a high negative temperature coefficient of resistance, a pair of conductors having spaced ends thereof terminated within said material, a source of energy for supplying a potential to said conductors, whereby equipotential planes of varying magnitude are produced in the material between said terminated conductors, and a second pair of conductors having ends thereof terminated within said material, said second pair of conductor ends being terminated along one of said equipotential planes.

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