Jan. 13, 1942. E. C. DENCH 2,269,442

THERMALLY RESPONSIVE GAS-DISCHARGE DEVICE

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Fig. 1.

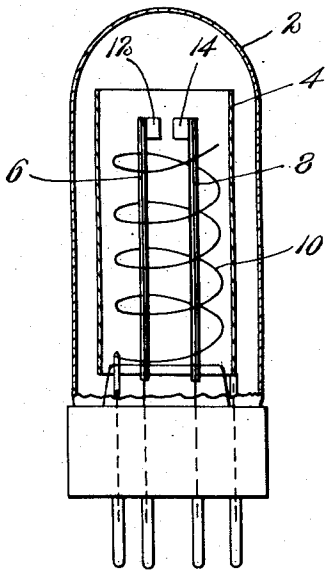

Fig. 2.

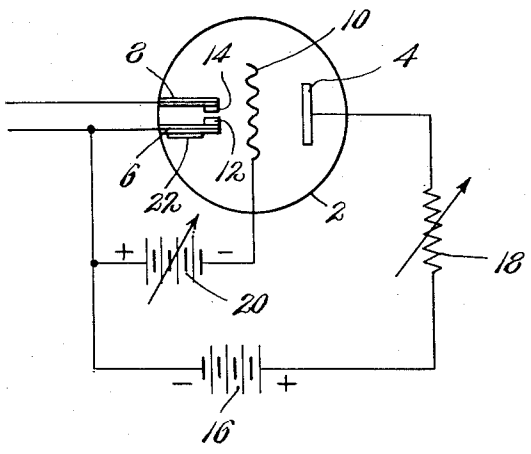

Fig. 3.

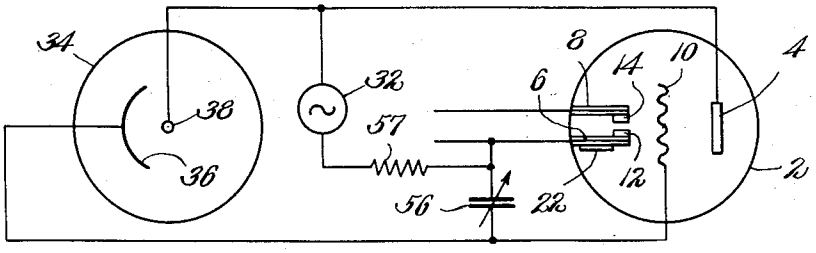

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Fig. 4.

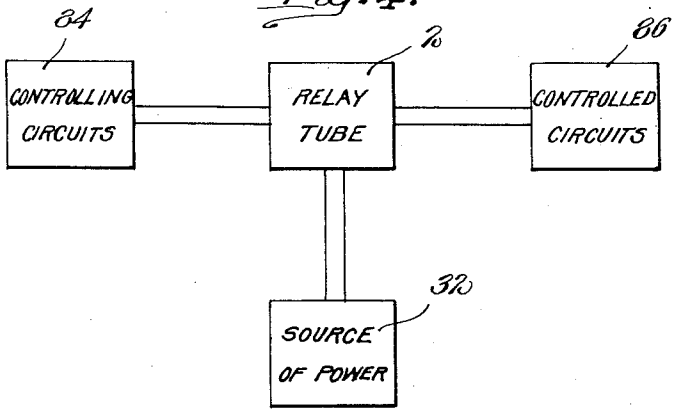

Fig. 5.

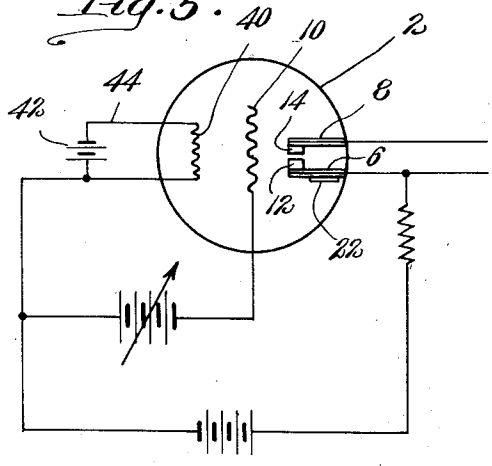

Fig. 12.

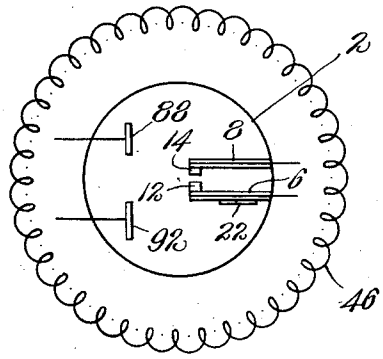

Fig. 6.

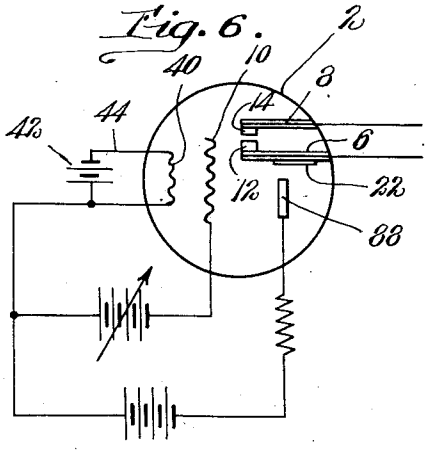

Fig. 13.

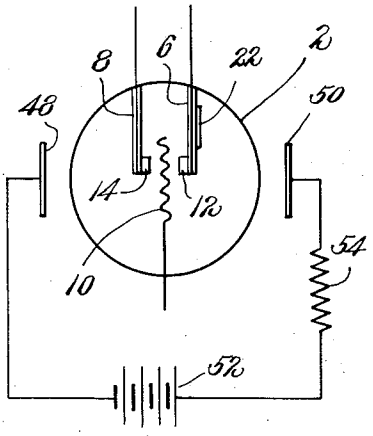

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Fig. 7.

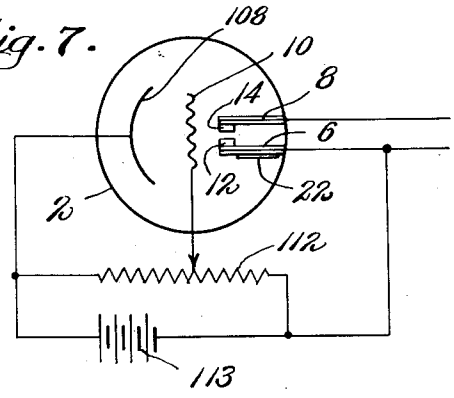


Fig. 8.

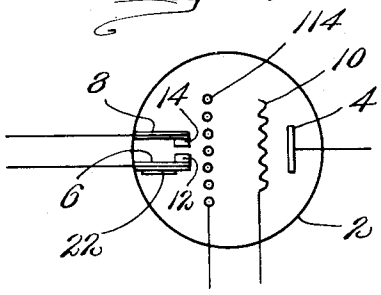


Fig. 9.

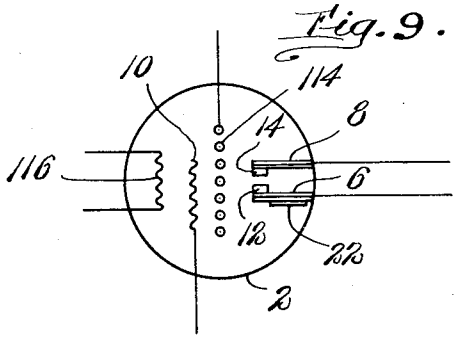
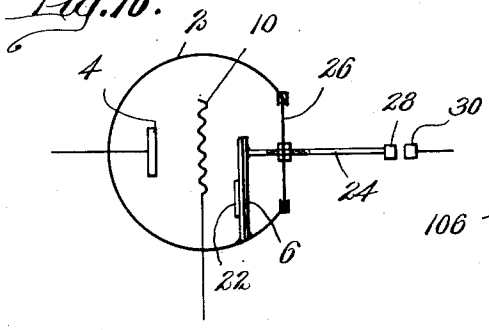


Fig. 10.



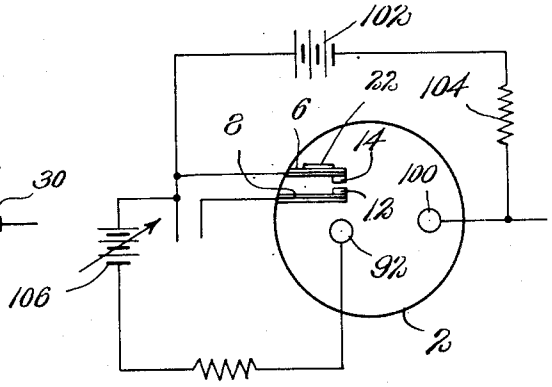


Fig. 11.

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UNITED STATES PATENT OFFICE

2,269,442

THERMALLY RESPONSIVE GAS-DISCHARGE DEVICE

Edward Charles Dench, Worcester, Mass.

Application March 14, 1939, Serial No. 261,786

22 Claims. (Cl. 250—41.5)

The present invention relates to electric-discharge control devices, and more particularly to devices wherein thermally responsive materials are utilized to effect electric control in response to their heating by the discharge. The invention is not restricted to the employment of materials that exhibit a mechanical reaction to heat, but includes also materials the electrical or magnetic or other properties of which may respond in accordance with their heating. The terms "thermostatic," "thermally responsive," "thermally sensitive," and the like will, therefore, be employed in the specification and the claims in this broad sense. The invention has particular application to gas tubes. The term "gas tube," "gas-containing tube," or its equivalent will be employed in the specification and the claims to include tubes or other devices containing gas, vapor, or a combination of a gas and vapor or a plurality of gases and vapors.

An object of the invention is to provide a new and improved electrical controlling device relying for its operation upon the heat of a gaseous discharge under the control of a grid or other control means.

A further object is to provide a new and improved electric relay, operating on the thermal principle, without the aid of a hot emitter, and that shall be simple and compact in construction and operation, and inexpensive to manufacture and operate.

An object of the invention is to provide a new and improved electrical controlling device of the discharge type that is controlled by the action of light or other radiant energy.

Still a further object is to provide a new and improved device of the above-described character controlled through the photoelectric control of the flow of electrons, or ionization, within the tube, which flow or ionization, in turn, communicates heat to the thermally-responsive element or elements.

A further object is to provide a new and improved photoelectric relay, operating on the thermal principle, and that shall be simple and compact in construction and operation, and inexpensive to manufacture and operate.

The invention will now be more fully explained in connection with the accompanying drawings, in which:

Fig. 1 is a longitudinal section, partly in elevation, of a tube embodying the invention;

Fig. 2 is a diagrammatic view of the same, shown connected in a circuit operable according to the present invention;

Fig. 3 is a circuit diagram similar to Fig. 2 of a modification;

Fig. 4 is a schematic diagram applicable to the circuit diagram of Fig. 3; and

Figs. 5 to 13 are views similar to Fig. 2 of further modifications.

The tube 2, as before stated, may contain gas, vapor, or other substance, or a combination of the same. A rare gas or vapor, such as neon, is preferred. The invention may be said to apply more particularly to gas tubes in which glow and arc discharges take place between cold electrodes in the gas tube.

Electric emission may be obtained from specified cold electrodes through their bombardment by positive ions. In the case of glow discharges, the cold cathode may emit sufficient electrons without bombardment at normal room temperatures. Depending upon operating conditions, however, bombardment may take place in addition. In devices of this character, the number of free ions present is normally insufficient to liberate very many electrons from the cold electrodes. Upon an increased number of ions colliding with the cold electrodes, however, they may liberate sufficient energy to heat the electrodes.

In certain embodiments of the invention, the tube may contain one or more cathodes, one or more anodes, and one or more control elements or other means of control, stabilizing elements, starting electrodes, and so on, all in the same container or tube 2. When properly associated in electrical circuits, these elements may produce useful results. The thermally responsive element or elements may be constituted of one or more anodes, cathodes, or control electrodes, or they may be provided in addition to these electrodes.

In Fig. 1, the tube 2 is shown provided with a plurality of normally spaced electrodes therein, namely, a cylindrical anode 4, two thermally responsive or thermostatic elements 6 and 8, and a control grid 10 disposed, in coiled or spiral form, between the anode 4 and the elements 6 and 8.

The elements 6 and 8 may each be constituted of a single unbent strip, as shown, or it may be in the form of a coil or any other configuration. It may be constituted of bimetallic material, each comprising two or more such strips, as shown. One of the strips 6 and 8, as will hereinafter appear, may constitute a cathode. The tube 2 of Fig. 1, therefore, contains at least an anode 4, a cathode 6 or 8, and a control grid electrode 10.

The strips 6 and 8 or other thermally responsive element or elements may each be provided with, or otherwise, control, an electric contact member, shown at 12 and 14, respectively. The contact members 12 and 14 are disposed so as to engage, for the purpose of closing an electric circuit, upon flexing of the elements 6 and 8, in response to heat. The heat from the discharge is thus employed to cause the thermally responsive element or elements to respond to effect engagement of the contact member or members. The contact members may, for example, be constituted of molybdenum.

The contact members 12 and 14 need not be mounted on the metallic strips 6 and 8. They may be positioned in the tube 2 separately from the strips 6 and 8, and operated by them through some insulating medium, as would be required in some cases, as where the controlling and the controlled circuits are required to be kept separately.

The adaptation of the invention to use as a thermal relay may, for example, be understood from Fig. 2, where the same gas-filled tube and the electrodes 4, 6, 8 and 10, illustrated in Fig. 1, are shown by the same reference numerals, but more diagrammatically. In this Fig. 2, the cathode bimetallic strip 6 is shown connected in circuit with a battery energy source 16 and a ballast resistor 18 to the anode 4, so as to impress a potential upon the anode 4 positive with respect to the cathode. The voltage of the battery creates a tendency to accelerate the electrons from the cathode bimetallic strip 6 toward the anode. A battery 20 connected between the cathode strip 6 and the grid 10 impresses a suitable potential upon the grid 10. By varying the potential of the battery 20, however, it is possible to vary this grid potential, thus causing the grid to control the discharge flow and the energy of the electrons between the cathode 6 and the anode 4. In this manner, it is possible to permit the electrons to have sufficient energy to ionize the readily ionizable medium, namely, the neon or other gas in the tube, the production of the positive ions being dependent upon the voltage impressed upon the control grid electrode. It is only when the voltage of the control electrode 10 exceeds a critical value that the cumulative production of the ions takes place. Because the gas ions will be attracted toward the cathode, a gaseous glow or arc discharge will be created between the anode and cathode, through the tube 2. This discharge will be under the control of the control grid 10, independently of the bimetallic cathode 6 and the anode 4. This discharge will effect ionization of the gas in the tube, and consequently the degree of heating of the bimetallic electrode. The molecular heat of bombardment of the ions of this discharge upon the thermostatic cathode strip 6 will effect heating of the cathode strip 6 and electron emission therefrom.

The bimetal strips 6 and 8 are so constructed that they will flex in the same direction under heat. This insures that they shall not touch each other, and thus cause a permanent set, during manufacture. In operation, however, a relatively high temperature is developed along the bimetal strip 6 only through the impact agitation of the ions. As the bimetallic strip 8 remains cool at this time, it will remain stationary or unflexed. The flexing of the bimetallic strip 6 will, therefore, effect closing of the electrical contact members 12 and 14. The contact members 12 and 14 will therefore close a relay or other circuit for controlling any desired apparatus, such, for example, as an electric-light illumination circuit.

Bimetallic thermally responsive strips are particularly adapted to this relay because they are readily deformable mechanically in response to temperature changes. The contact member 12 or 14 is controlled by this deformation of the bimetallic electrode 6 or 8.

Once thus closed, the circuit will remain closed, and the relay will operate, independently of the grid, very much as takes place in a grid-glow tube. By suitable adjustment, by appropriate means, however, the grid may be caused to stop the discharge.

The control electrode or electrodes or other means for regulating the discharge, therefore, and the degree of heat applied to the thermally responsive element or elements, control the operation of the contact member or members.

The contact members 12 and 14 at the ends of the bimetal strips may be so constructed that when the bimetal is subjected to the high temperatures necessary properly to manufacture the device, the contact members 12 and 14 shall be allowed to cross over, one with respect to the other, thus tending to prevent any permanent deformation of the bimetal during the manufacture.

If a cross-over principle for the contact members is employed during manufacture, to prevent the formation of a permanent set, the strips 6 and 8 may be disposed so as to move toward each other. In that event, it would be possible so to design the tube that heat from one of the strips, as the strip 6, may be caused to heat also the other, as the strip 8. This would result in quicker engagement of the contact members 12 and 14. In either case, after the parts are properly positioned, the tube is exhausted, treated and filled with the desired gas or vapor.

Only one bimetallic strip need act as the cathode, connected into circuit. Two strips 6 and 8 may be used to secure ease of manufacture, and to provide convenient support for the contact members 12 and 14. A single bimetallic cathode strip 6 may operate against a rigid support 8 serving as a stationary contact member.

A more convenient way of using this relay is to supply the grid and the anode with alternating potential supplied, say, from a generator 32. The discharge will then automatically stop at each zero point or some other low value in the alternating-current cycle. During the application of the alternating voltage to the circuit, the anode 4 will first be positive with respect to the cathode 6. Electrons will, therefore, be driven off from the bimetal strip 6 toward the anode 4. These electrons will cause ionization, depending upon the potential of the grid or other control means. Ionization will stop at low values of the current and as the current passes through zero. On the other half of the cycle, the cathode will be positive with respect to the anode. As the anode is not electron-emissive, the tube will not break down on this other half of the cycle. In accordance with the alternations of the voltage source, therefore, when the grid or control means permits it, the electrons, in their traverse through the gas, will ionize the gas. From that point on, the operation is as before described.

Whether the tube should be operated from direct or alternating voltage will depend upon

such factors as the use, the construction and the associated circuits.

A novel sensitive thermal relay of the cold-cathode type is thus provided, adapted for quiet operation on either direct or alternating current, with little consumption of power from the controlling circuit, at normal potentials. Though adapted to control comparatively large currents, it is relatively inexpensive and requires a relatively small amount of equipment. It may be adapted for many uses, such as in telephone systems, particularly in bell-ringing circuits, oil-burner control, counting devices and radio or other electronic-tube circuits, illumination control, burglar alarms, door openers, capacity operated relays, smoke indicators, time delay relays and other controls.

As an illustration, the electrodes 6 and 8 (Figs. 2, 3, 5 to 9 and 11) may be connected to any desired external circuit or circuits, the closing (or opening) of which it is desired to control by the closing (or opening) of the contact members 12 and 14. Such external circuit may contain any desired load, such as a bell or any of the other devices before mentioned, in series with a source of energy. The anode and the cathode are connected to the source of energy 16 (Fig. 2), 32 (Fig. 3), 113 (Fig. 7) or 102 (Fig. 11) for energizing the gaseous-discharge tube 2.

In Fig. 3, the generator 32, as a source of power, is illustrated as connected between the cathode strip 6 and the anode 4, and a photoelectric cell 34 in the position occupied by, replaces, the variable battery 20 in Fig. 2. The grid 10 is shown connected to the cathode 36 of the photoelectric cell 34, and the anode 4 to the anode 38 of the photoelectric cell 34.

The contact members 12 and 14 may here serve as a relay to control a contactor for such purposes as controlling street lights. The street lights will become illuminated when darkness sets in, as determined by the photoelectric cell 34. The invention is also applicable to other lamps desired to be turned on and off by the action of light falling on the photoelectric cell 34, such as illuminating billboards, and for turning on lights at airports or beacon stations upon the arrival of nightfall.

The circuit diagram of Fig. 4 illustrates schematically circuit diagrams like the diagram of Fig. 3, the controlling circuits 84 being represented by the photo tubes and the controlled circuits 86 by the external circuit under the control of the contact members 12 and 14.

Though the thermally responsive element or elements may be disposed wherever desired in the tube, it is preferred to position it or them near a cathode; or better still, as illustrated in Figs. 1 and 2 and other figures, to have it or them constitute, or form part of, the cathode. If it constitutes, or forms part of, the cathode, it will operate as a cold cathode, substantially unheated by the passage of current therethrough, in the neighborhood of 200° C., as distinguished from hot cathodes, operating in the neighborhood of 800° to 2000° C. To facilitate cold-cathode operation, and improve cold-cathode characteristics, the strip 6 may, if desired, be coated with substances, such as barium and strontium oxides, conducive to the emission of electrons, diagrammatically illustrated at 22, thereby providing for a more copious emission of electrons. This, however, is not essential; and the unheated strip 8 need not be coated at all. As a further modification, the bimetallic strip may itself be constituted of materials conducive to the emission of electrons, such as copper and magnesium together.

In order to assure rapid heating and cooling of the bimetal, furthermore, it may be blackened, to increase its heat-absorbing and radiating properties. This may be effected in any desired way, as by carburizing, or by the use of platinum black.

The electric contact members 12 and 14 need not necessarily be disposed within the tube or other container 2. As illustrated in Fig. 10, for example, a single bi-metallic cathode strip 6 may be provided, connected at 24, through a diaphragm 26 communicating with the interior of the tube 2, to a contact member 28 outside of or external to the container tube 2, which may be made of metal, as well as glass or any other suitable substance. The contact member is here too, controlled by the bimetallic electrode 6; it is adapted, in response to thermal flexing of the bimetallic strip 6, under the control of the grid 10, to engage a cooperating contact member 30 to close a relay or other external circuit.

The control means is not necessarily in the form of a control electrode or electrodes, such as a grid or grids; and it is not essential that the grid, if employed, be of spiral form, or that it surround the bimetallic strips 6 and 8, as shown in Fig. 1. Other control means, such as a magnetic or electrostatic field or fields, or photoelectric effects, may be employed. The control means may be in the form of an anode or other means for initiating the discharge, and it may be employed not only to delay the gaseous discharge, to permit the discharge to take place at the proper time, as above described, but also to increase it, initiate it, or stabilize the action of the device. Instead of having the relay contact members close an external circuit, they may be arranged to interrupt a circuit, or to control any desired combination of make-and-break circuits.

As illustrative of the fact that the means for controlling the relay contact members need not necessarily be electric, the gaseous discharge in the tube 2 is illustrated in Fig. 12, for example, under the control of the magnetic field produced by a winding 46. The operation may be on a principle similar to that of the magnetron, the electrons emitted from the cathode 6 being diverted by the magnetic field so as to travel along more or less circular paths. The electrons in the gaseous tube 2 will not ionize the gas and will not cause the normal discharge to take place because their mean free path will be shorter than the normal free path of an electron in the gas. If the magnetic field is reduced or changed or removed, however, the electrons will be permitted to travel between the cathode and the anode so that ionization shall be produced. The thermostatic cathode will then cause the electrical contact members to become closed.

In Fig. 13, the gaseous discharge of the tube 2 is shown controlled by an electrostatic field between two electrostatic electrodes 48 and 50, outside the tube 2, subjected to a difference of potential by a battery 52, this potential difference being regulated by the potentiometer 54. The effect of the electrostatic field may be likened to that of a grid for its controlling influence. It is possible also to introduce electrostatic fields that will control the discharge in the discharge space from an external source rather than from an internal source.

The magnetic field illustrated in Fig. 12, the

electrostatic field illustrated in Fig. 13, or any combination of these fields, with or without the use of control electrodes, may be employed in connection with the electrode arrangements in any of the figures of the drawings. These may be regarded as representing any medium for controlling the ionization and consequent heating of the thermally sensitive material.

The starting and stopping or the control of the gaseous discharge may be effected also by the insertion, in the space, of elements that are photo-sensitive, or coated with a photo-emissive material that, upon being subjected to radiant energy, will emit electrons that will cause fields to be set up. The control of the discharge may here, too, be likened to the control exerted by a grid. The grid itself, indeed, might be covered with such photo-emissive material. Starting and stopping or control of the discharge may, in this case, be effected by the degree of illumination or radiant energy falling upon such a special precoated electrode as in Figs. 15 and 16, coated with a photo-sensitive substance. Electrons emitted from this electrode under the influence of the radiant energy will cause a field to be set up which will determine the control of the gaseous discharge within the space. The cold cathode, before described, may also be made of photo-sensitive material. The discharge will then be initiated by the action of light upon the cathode, rather than through control secured by the action of light on a control element.

As before stated, the thermally responsive element or elements need not necessarily be of the bimetallic form shown. In any form, however, the material, suitably shaped, will be of such nature as to change, in response to the reactions developed in the gaseous discharge, one or another of its physical characteristics, mechanical, electrical or magnetic, upon the application of heat. Among the mechanical characteristics that may be so altered may be displacement, volume, position, flexure, softness, springiness, hardness, and the like. These mechanical changes, as already explained, may be utilized to control contact members. The electric or magnetic characteristics include resistance, dielectric constant, inductance, permeability, susceptance and conductivity. Among the thermally responsive materials that may be employed are substances having positive or negative resistance coefficients.

When the material is connected to an electric circuit, and electric changes are depended upon for the action of the device, the physical change may be of such nature as to produce a change in an electric or other circuit that is associated externally with the material in the tube, which changes its electrical characteristics according to heating. Such change may involve a change in circuit constants to perform predetermined operations, as through the medium of altered voltages or currents in the controlled circuits due to a controlled electron flow or ionization preferably in a gas.

Magnetic circuits, too, may be controlled similarly through the medium of a grid-controlled gaseous discharge. Materials changing magnetic qualities according to heat may be used to alter circuit characteristics in a magnetic circuit which, in turn, may be associated with electric circuits the constants of which are to be variable according to variation of magnetic characteristics of the material placed in the tube.

The novel relay of the present invention consumes little power in its operation, approximating two to five watts, more or less. Due to the fact that it is operated with a cold cathode, no power is required to keep it ready for service during stand-by periods and over long periods of time.

Though preferred, the bimetallic strip or strips need not necessarily constitute the cathode, or be positioned near the cathode. In Fig. 5, one of the bimetallic strips is shown as constituting the anode electrode. The cathode may then be a hot electrically heated cathode, such as a thermionic filament, or a cold cathode.

The cathode **40** of Fig. 5 is shown as a cold cathode, constituted of a material, such as tungsten, having a high temperature coefficient of resistance. The gaseous-discharge tube **2** and the controlling electrode **10** may be of the same character as heretofore described. The high-temperature-coefficient resistor **40** may or may not be supplied with energy from any desired source, illustrated as a battery **42**; in practice, it may be connected to an external circuit, indicated at **44**, the circuit being controlled by changes in resistance of the resistor **40**, as it is heated or cooled according to the action of the gaseous discharge between the resistor **40** and anode in the tube, under the control of the grid **10**. In this case a conventional anode replaces the bimetal. Other materials than tungsten may be used; for example, carbon, which has a negative coefficient of resistance, silver sulphide, which has an abrupt change in resistance due to temperature changes, silver iodide, silicon, boron, zirconium oxide, and other substances responsive similar to changes in the nature of resistance changes. Certain alloys that change their magnetic properties due to temperature change may also be employed or other materials changing electrical or magnetic properties.

In Fig. 10, however, the bimetal is not necessarily present, for the tube may contain a cold coated cathode of the materials above described, a control means and an anode. The anode may be made of the said material, and a common cold or hot cathode may be employed. Assuming the circuit of Fig. 10 to be provided with a conventional anode, for example, the element **40** may be the said material, replacing the contact members **12** and **14**. The battery **40** is omitted. Variations of resistance or other electrical properties due to heating may change the electrical constants of the circuits in which the material is connected, and this variation may be controlled by controlling the discharge in the tube. The material **40** may be replaced also by a material changing its magnetic properties and may be used to vary a magnetic circuit in accordance with the controlled discharge in the tube. The element **40** may be situated anywhere in the tube in the same manner as the bimetal of the tubes discussed previously may be moved about.

In Fig. 6 the thermionic filament **40** cooperates with an anode **88** of conventional type. The strips **6** and **8** are provided in addition, in any part of the tube, and will operate when heated as before described.

In Fig. 11, too, the anode **88** may be of conventional type. The bimetallic-strip cathode **6**, and the support for the contact member **14** are provided, in combination with a starting anode **92** which may be connected into circuit as shown in Fig. 11. In this tube, the bimetallic cathode may be placed close to the starting anode **92**, and a third electrode **100**, positioned at a considerable distance away, may serve as a running anode.

A potential may be established between the cathode 6 and the running anode 100 by means of a battery 102 through an impedance 104. This potential should not be sufficient to ionize the gas or cause the discharge to take place. A variable-control potential provided by a battery 106 may be applied between the starting anode 92 and the cathode 6. When this potential is adjusted to a certain value, break-down will occur between the cathode and starting anode, due to their proximity. The presence of the ions introduced into the space by this break-down will cause a break-down to take place between the cathode and the running anode 100. The original break-down will not necessarily cause the contact members 12 and 14 to close, but the secondary discharge between the cathode and the running anode 100 will be of sufficient magnitude to cause these contact members to close.

In Fig. 13, the cathode may be constituted of one of the bimetal strips, as shown at 6, and the anode of the other, shown at 8. The grid 10, acting as a control electrode, is interposed between them. The operation is similar to that described above in connection with Fig. 2. These may both be constructed as cathodes and alternating current applied to them.

In Fig. 7, a cold cathode 108 is shown constituted of photosensitive material. The anode is constituted of the bimetal strips 6 or 8. A battery energy source 113 connects the anode and the cathode. A grid 10 or grids or stabilizing elements may be interposed between the cathode and the anode, and may be connected to a potentiometer 112 connected across the battery 113. The impedance element 18 of Fig. 2 may, of course, be connected into circuit in Fig. 7, between the battery source 113 and the anode 6, 8. Electrons will be emitted from the cathode 108, and the starting of the discharge will be effected under the influence of radiant energy. These electrons will be accelerated toward the anode 6 or 8, causing ionization of the gas and consequent heating of the bimetal, which will effect operation of the electrical contact members 12 and 14.

Fig. 8 corresponds to Fig. 2 with the addition of a further control element 114, which may be coated with photosensitive material. Fig. 9 is similar to Fig. 8, except that the tube is provided with a hot emitter 116, and the bimetal serves as the anode.

In Fig. 8, for example, when light or other radiant-energy rays impinge upon the photoelectric grid electrode 114, electrons will be released therefrom, which will travel toward the more positive anode 4. This electron current will produce a potential change of the grid electrode 114, which will result in connecting the battery source 113 (Fig. 7), the thermally-sensitive electrode 6 and the non-thermally-sensitive electrode 4 into circuit, to produce a glow discharge between the anode 4 and the cathode 6 in the tube 2. Adjustment of the potentiometer 112 (Fig. 7) or other grid-bias source will determine the value of illumination for which the gas in the tube 2 becomes conducting. Positive gas ions are produced, when the gas becomes conducting, for striking the deformable bimetallic electrode 6 to heat it and consequently deform it. The heating of this bimetallic electrode is thus controlled by the discharge under the control of the photosensitive electrode.

A thermostatically operated switch 14, 15, is thus provided, under the control of the photosensitive electrode 114, that controls the gas discharge the action of which controls the heating of the thermostatic device.

In some cases, as in Figs. 7, 8 and 9, the tube may be either a gas tube or it may be a high-vacuum tube. In some constructions, secondary emission may be used to aid in the operation of the device. The cold cathode 108 (Fig. 7) and the photosensitive electrode 114 (Figs. 8 and 9), for example, may be coated with an electron-emission coating for supplying a flow of electrons when subjected to the action of radiant energy.

A novel tube is, therefore, provided, operated by the heat caused by ions, in which the thermostatic material may be used as cathode, anode, or other electrode. The tube operates very quickly, without being critical or delicate, it is not expensive and it has a long life.

Further modifications will occur to persons skilled in the art and all such are considered to be within the spirit and scope of the invention, as defined in the appended claims.

What is claimed is:

1. A device of the character described having, in combination, a gas tube having a non-thermally-sensitive electrode and a plurality of cooperating thermally-sensitive electrodes one of which is electron-emitting, and means for causing the electron-emitting electrode to emit electrons to energize the gas of the tube to cause one of the thermally-sensitive electrodes to become heated.

2. A device of the character described having, in combination, a gas tube having a non-thermally-sensitive electrode and a plurality of thermally-sensitive electrodes, one of which is electron-emitting, and means for connecting the electron-emitting electrode and the non-thermally-sensitive electrode into circuit to cause the electron-emitting electrode to emit electrons to ionize the gas particles between the electron-emitting and the non-thermally-sensitive electrodes and to cause the ionized gas particles to strike the said electron-emitting electrode to heat it.

3. A tube having an anode, a grid and a cathode comprising a plurality of cooperating thermally-sensitive elements.

4. A tube having three electrodes, namely, an anode, a cathode and a grid, one of the electrodes comprising a plurality of cooperating thermally-sensitive elements one of which is electron-emitting.

5. A gaseous-discharge tube having an anode, a cold cathode, a grid and an electrode comprising one or more cooperating thermally-sensitive elements.

6. A tube having an anode, a starting electrode, and an electrode comprising a plurality of cooperating thermally-sensitive elements.

7. An electric system having, in combination, a tube having an anode, a grid and a cathode comprising a plurality of thermally-sensitive elements one of which is electron-emitting, a source of energy, means connecting the source, the anode and the electron-emitting element into circuit to cause the electron-emitting element to emit electrons, means for controlling the grid to control the electrons emitted by the electron-emitting element, and means controlled by the emitted electrons for heating the said one thermally-sensitive element.

8. A device of the character described having, in combination, a gaseous-discharge tube having a plurality of electrodes comprising an anode and

a cathode, one of the electrodes being bimetallic, and means controlled by the heat of the discharge for heating the bimetallic electrode, one of the electrodes comprising a control electrode disposed between the anode and the cathode for controlling the discharge.

9. A device of the character described having, in combination, a gaseous-discharge tube having a plurality of electrodes one of which is bimetallic, means for producing a discharge between the bimetallic electrode and another electrode, means independent of the bimetallic electrode and the said other electrode for controlling the discharge, a contact member external to the tube, and means controlled by the bimetallic electrode for controlling the contact member.

10. An electric system having, in combination, a gaseous-discharge tube having a plurality of electrodes one of which is bimetallic, the electrodes comprising an anode, a cathode and a control electrode, a contact member controlled by the bimetallic electrode, means for connecting the anode and the cathode into circuit to effect a discharge through the tube to effect ionization of the gas in the tube in order to heat the thermostatic electrode by ionic bombardment, thereby to effect control of the contact member, means for connecting the control member to control the discharge, and an external circuit controlled by the contact member.

11. An electric system having, in combination, a tube having a plurality of electrodes comprising an anode, a grid and a cathode, the electrodes comprising a photo-sensitive electrode and a plurality of thermally-sensitive elements one of which is electron-emitting, a source of energy, means connecting the source, the anode and the electron-emitting element into circuit to cause the electron-emitting element to emit electrons, means for controlling the photosensitive element to control the electrons emitted by the electron-emitting element, and means controlled by the emitted electrons for heating the electron-emitting element.

12. A gaseous-electric-discharge device for connecting a load to a source of electrical energy comprising a container provided with an ionizable medium therein, normally spaced electrodes in said container connected, respectively, to said source and to said load, and a photosensitive element provided with an electron-emissive coating for supplying a flow of electrons when subjected to the action of radiant energy, at least one of said electrodes comprising a bimetallic element.

13. A device of the character described having, in combination, a gas tube having a plurality of thermally-sensitive and non-thermally-sensitive electrodes, a source of energy, and means comprising a photosensitive electrode for connecting the source, one of the thermally-sensitive electrodes and one of the non-thermally-sensitive electrodes into circuit to energize the gas of the tube to cause one of the thermally-sensitive electrodes to become heated.

14. A device of the character described having, in combination, a gas tube having an anode, a photoelectric grid and a thermally-sensitive cathode, a source of energy, and means for connecting the source, the grid and the cathode into circuit to energize the gas of the tube in response to energization of the grid by energy rays to cause the cathode to become heated.

15. The combination of a gaseous electric-discharge device containing a readily ionizable medium and provided with electrodes one of which is photo-sensitive, a source of electrical energy for energizing said device, an impedance element connected to said source and to said device, and means controlled by the photo-sensitive element for producing a discharge between the electrodes, one of the electrodes comprising a bimetallic element adapted to become heated by the discharge.

16. An electric system having, in combination, a gas-containing tube having a plurality of electrodes one of which is deformable in response to temperature changes, the electrodes comprising at least an anode, a cathode, and a control electrode, a contact member controlled by the deformation of the deformable electrode, means for connecting the anode and the cathode into circuit to produce between the anode and the cathode in the tube a discharge of electrons for bombarding the gas particles in the tube, thereby to produce positive ions for striking the said deformable electrode to heat it, means for impressing a voltage upon the control electrode, and means controlled by the voltage impressed upon the control electrode for controlling the production of the ions, thereby to control the degree of heating of the deformable electrode.

17. An electric system as defined in claim 16 in which the contact member is disposed within the tube.

18. An electric system as defined in claim 16 in which the contact member is disposed external to the tube.

19. An electric system having, in combination, a gas-containing tube having a plurality of electrodes one of which is thermally sensitive, the electrodes comprising at least an anode, a cathode and a control electrode, means for connecting the anode and the cathode into circuit to produce a discharge between the anode and the cathode in the tube, means controlled by the discharge for heating the thermally-sensitive electrode, means for impressing a voltage upon the control electrode, and means controlled by the voltage impressed upon the control electrode for controlling the discharge, thereby to control the degree of heating of the thermally-sensitive electrode.

20. An electric system having, in combination, a gas-containing tube having a plurality of electrodes one of which is bimetallic, the electrodes comprising at least an anode, a cathode and a control electrode, means for connecting the anode and the cathode into circuit to produce a discharge between the anode and the cathode in the tube, means controlled by the discharge for heating the bimetallic electrode, means for impressing a voltage upon the control electrode, and means controlled by the voltage impressed upon the control electrode for controlling the discharge, thereby to control the degree of heating of the bimetallic electrode.

21. An electric system having, in combination, a gas-containing tube having a plurality of electrodes one of which is bimetallic, the electrodes comprising at least an anode, a cathode and a control electrode, means for connecting the anode and the cathode into circuit to produce between the anode and the cathode in the tube a discharge of electrons for bombarding the gas particles in the tube, thereby to produce positive ions for striking the bimetallic electrode to heat it, means for impressing a voltage upon the control electrode, and means operable when the voltage impressed upon the control electrode exceeds a critical value to control the production of

the ions, thereby to control the degree of heating of the bimetallic electrode.

22. An electric system having, in combination, a gas-containing tube having a plurality of electrodes comprising at least an anode, a thermally-sensitive cathode and a control electrode, means for connecting the anode and the cathode into circuit to produce a discharge between the anode and the cathode in the tube, means controlled by the discharge for heating the thermally-sensitive cathode, means for impressing a voltage upon the control electrode, and means controlled by the voltage impressed upon the control electrode for controlling the discharge, thereby to control the degree of heating of the thermally-sensitive cathode.

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