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PHOTO ELECTROSTATIC RELAY

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FIG. 1

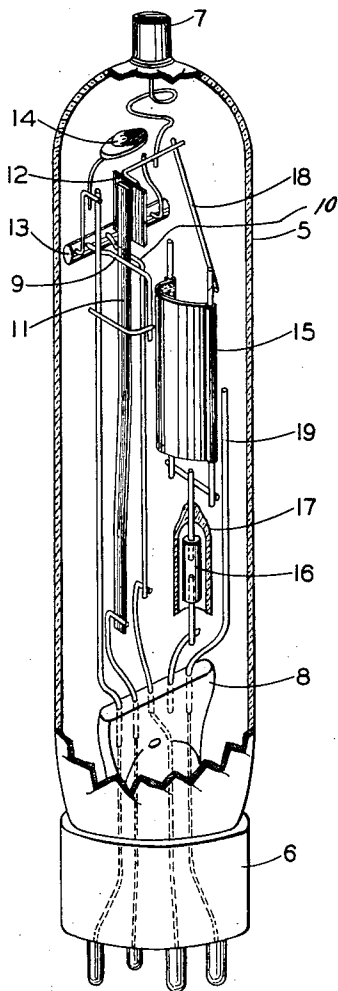


FIG. 2

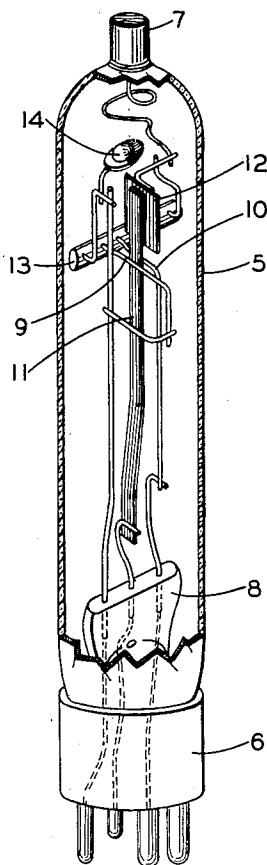


FIG. 4

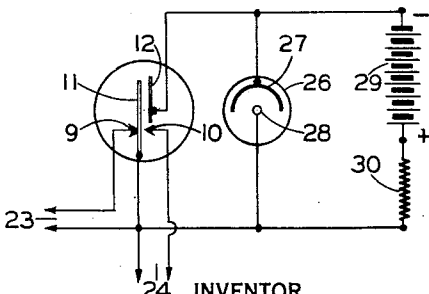
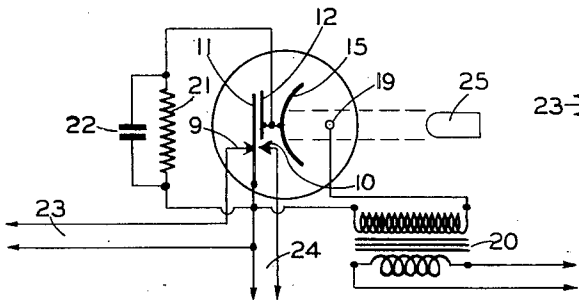


FIG. 3



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PHOTOELECTROSTATIC RELAY

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5 Claims. (Cl. 250—27.5)

My invention relates to electrical relays and similar devices and more particularly to circuit opening and closing relays which will respond to very small currents.

Electromagnetic relays for opening and closing a circuit may be made sufficiently sensitive to operate on small currents, but the expense of such relays increases and their ruggedness decreases so rapidly with increase in sensitivity that such relays designed to be operated by very small currents, less than a microampere, have not been commercially practical on account of high cost and lack of ruggedness.

One object of my invention is to provide a commercially practical relay which will control a work circuit and will respond to such small currents, for example, less than a microampere, that it may be operated by a device such as a photo-tube.

Another object is to provide a relay which may conveniently be mounted in a vacuum tube containing an electronic device for operating the relay and thus obtain a compact rugged device with the advantages of a vacuum make and break relay.

A further object is to provide a simple and compact photo relay which will open and close a controlled circuit in response to variations in light intensities, and which is a unitary device that may be utilized to replace the usual combination of photo-tube, amplifier, and electromagnetic relay.

In accordance with my invention a pair of relatively movable contacts connected in the circuit to be controlled are mounted in a sealed or evacuated bulb so as to be movable into and out of engagement in response to variations in the electrostatic field of an electrostatic actuator, such as a metal plate, which may be charged to such a potential that its electrostatic field is great enough to actuate the circuit controlling contacts. As the relay is essentially a voltage actuated device, the necessary operating voltage may be obtained from a current which is negligible as compared with the current required for the usual current operated electromagnetic relay. The relay may be connected externally to a photo-tube or similar device, but for most commercial purposes I prefer to combine the relay and the photo-tube into a simple compact and unitary device in which the circuit controlling contacts and the electrostatic actuator plate are mounted in the bulb of the photo-tube with the actuator plate internally connected to the photo-cathode so that a high

resistance or impedance in the output circuit of the photo-tube will produce on the actuator plate of the relay a voltage or charge which is dependent on the amount of photo current and, therefore, the electrostatic field of the charged actuator plate of the relay varies in accordance with the photo current. The photo-tube is of the vacuum type, and the control circuit is made and broken by contacts operating in a vacuum, hence the contact surfaces remain clean, and a very small amount of power is required to make and break the circuit. Such a relay is a unitary self-contained device which will automatically open and close the controlled circuit in response to variations in intensity of the light falling on the photo-cathode, and is sufficiently rugged for commercial use.

The novel features which are characteristic of my invention are set forth with greater particularity in the appended claims, but the invention itself will be better understood from the following description taken in connection with the accompanying drawing in which:

Figure 1 is a longitudinal section of a combined photo-tube and relay showing the operating parts in perspective and constructed in accordance with my invention; Figure 2 is a similar view of an electrostatic relay having an evacuated bulb; Figure 3 is a diagram of one type of circuit suitable for use with the combined photo-tube and relay shown in Figure 1; and Figure 4 is a diagram of a type of circuit suitable for use with the electrostatic relay shown in Figure 2 with external connections to a photo-tube.

The circuit opening and closing relay, which forms part of the preferred form of device shown in Figure 1, has, as shown in Figures 1 and 2, an evacuated bulb 5, with a four prong base 6 at one end and a contact cap 7 at the other end, enclosing the electrodes which are mounted on the usual press 8. The relatively movable contacts for making and breaking the controlled circuit comprise two fixed contacts 9 and 10, such as two parallel nickel wires, and a cooperating movable contact 11, which may conveniently be a thin resilient strip or blade of nickel mounted at its lower end on the press to project between the two fixed contacts. This nickel strip 11 is mounted with its sides parallel to the fixed contacts, and is tensioned to normally engage one of the fixed contacts, such as the contact 9.

The movable contact or strip of nickel 11 is moved relatively to the fixed contacts by an elec-

trostatic actuator, such as a metal plate 12 mounted parallel to the strip 11 and close enough to it so that the upper end of the strip acts as a plate armature parallel with and close to the actuator plate and of such area that the strip will be moved from the contact 9 into engagement with the contact 10 in response to the electrostatic attraction exerted on the armature by the actuator plate when the plate is charged.

The actuator plate 12 is electrically connected to the contact cap 7, and is preferably held in proper relation to the contacts by some kind of an insulating spacer, such as a glass bead or rod 13, which may conveniently carry a getter capsule 14 for holding a mixture for developing caesium vapor for sensitizing the photo-cathode. I have obtained good results with such a relay in which the flat strip 11 is of resilient nickel, about two thousandths of an inch thick, about one-eighth of an inch wide, and about six inches long, and a flat sheet nickel actuator plate 12, about one-half inch square. The area of such an actuator plate will ordinarily be sufficient so that the relay operates satisfactorily.

A suitable spacing between the actuator plate and the metal strip is about ten one thousandths of an inch. In this relay a potential of from 400 to 500 volts on the actuator plate exerts sufficient pull by electrostatic attraction to move the strip 11 over against the contact 10, which acts as a stop to prevent the armature coming into contact with and discharging the actuator plate.

The electrostatic charge for actuating the make and break contacts may be impressed on the actuator plate 12 from an external source through the contact cap 7 in the simple relay shown in Figure 2, or may be derived from a photo-tube comprising a photo-cathode and a cooperating anode enclosed in the bulb 5 to form part of the photo relay shown in Figure 1. The photo-tube may be of various forms, but I have shown a conventional type of two electrode photo-tube comprising a semi-cylindrical photo-cathode 15 supported from the press on a low leakage insulator comprising a glass bead 16, which is to advantage protected by an insulating skirt 17. The photo-cathode 15, preferably of the caesiated type, may have on its concave side a surface of oxidized silver coated with caesium developed from a caesium compound in the getter capsule 14, in accordance with the usual practice in making photosensitive surfaces of this type. One of the photo-tube electrodes, preferably the photo-cathode 15, is connected to the actuator plate 12 and to the top cap 7, preferably by a connector 18 inside the bulb. The photo-tube anode may be a straight rod anode 19 mounted on the press at about the center of curvature of the semi-cylindrical photo-cathode.

Figure 3 shows diagrammatically an application of the photo relay shown in Figure 1 as a device for counting or indicating interruptions of a beam of light. A source 20 of potential, preferably alternating, has one terminal connected to the photo-tube anode 19 and the other terminal to the photo-cathode 15 and actuator plate 12 through a high impedance, such as a grid leak 21 of about 5000 megohms resistance, shunted by a mica condenser 22 of about 100 micromicrofarads capacity and of as high leakage resistance as feasible. The fixed contacts 9 and 10 are connected to controlled circuits

23 and 24, respectively. A light source 25, such as an incandescent lamp, produces a light beam which falls on the concave surface of the photo-cathode 15. When the light beam is uninterrupted and the photoelectric current is large, the voltage drop across the impedance in the output current of the photo-tube is large enough to charge the actuator plate to a voltage at which its electrostatic field causes the nickel strip 11 to be pulled away from contact 9, opening the circuit 23 and closing circuit 24. When the light beam is interrupted, the photo current from the photo-cathode drops, the voltage across the impedance drops correspondingly, and the electrostatic charge on the actuator plate also drops, whereupon the nickel strip 11 is released and swings back into contact with the fixed contact 9, closing circuit 23 and opening circuit 24. I have found that with this circuit the strip 11 is attracted and circuit 23 opened when the photo-tube current exceeds about one-tenth of a microampere and is released and returns to its normal position when the photo-tube current drops to about six-hundredths of a microampere or less.

Figure 4 is a diagrammatic illustration of how the electrostatic relay of Figure 2 may be used in conjunction with an external phototube 26 of the conventional type having a photo-cathode 27 and an anode 28. A battery 29 of a voltage which will charge the actuator plate 12 to a potential sufficient to operate the relay has its negative terminal connected to the photo-cathode 27 of the photo-tube and also through the top cap 7 to the actuator plate 12 of the relay. The positive terminal of the battery 29 is connected through a grid leak resistor 30 to the anode 28 of the photo-tube and to the movable contact for the nickel strip 11. Circuit 23 is closed as long as the potential across the photo-tube 26 is less than the critical potential at which the electrostatic attraction exerted by the actuator plate 12 on the strip 11 is sufficient to overcome the tension of the strip and move it away from the contact 9. When the critical potential is exceeded, the strip 11 is pulled toward the actuator plate and into contact with the fixed contact 10, closing circuit 24. I have found that in this arrangement with a battery 29 of about 500 volts and of a resistor 30 of about 5000 megohms resistance, the critical potential across the photo-tube 26 at which the strip 11 is pulled over to the actuator plate is about 430 volts, and that when this critical potential drops to about 350 volts the strip 11 is released and resumes its original position. In this arrangement the actuator plate 12 is charged high enough to attract the strip 11 and break the circuit 23 when the photo-tube current decreases below about fourteen-hundredths of a microampere, and its potential decrease to a point at which it releases the strip 11 when the photo-tube current increases to about twenty-eight-hundredths of a microampere.

Tests have shown that my electrostatic relay will handle satisfactorily at the circuit controlling contacts 9 and 11 currents as high as 3 amperes at 6 volts, and that the relay is sufficiently rugged to be satisfactory for ordinary use, although in some cases it may be desirable to shield the relay from mechanical vibration.

While I have indicated the preferred embodiment of my invention of which I am now aware and have also indicated only one specific appli-

cation for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

What is claimed as new is:

1. A unitary photo relay comprising a highly evacuated bulb having a press at one end and enclosing a fixed contact mounted on said press, a resilient blade mounted at one end on said press and tensioned to normally engage said fixed contact, a support wire projecting from said press into said bulb alongside said blade, a low leakage insulator on the inner end of said support, a sheet metal photocathode supported on said insulator beside said blade and sensitized to light on its surface opposite said blade, a rod anode mounted on said press parallel to and on the sensitized side of said photocathode, an insulating spacer mounted on said press adjacent the upper end of said photo-cathode, an actuator plate mounted on said spacer near the free end of said blade parallel to the side of said blade, and an electrical connection between said photocathode and said actuator plate and extending through the other end of said bulb.

2. A unitary photo relay comprising a highly evacuated bulb having a press at one end and enclosing an insulating spacer on and parallel to said press, a fixed contact mounted on said insulating spacer, a cooperating movable contact mounted on said press to engage said fixed contact and comprising a plate armature, an actuator plate mounted on said insulating spacer adjacent and parallel to said plate armature, a low leakage insulator mounted on said press, a curved sheet metal photocathode mounted on said insulator beside said movable contact with the concave surface facing away from said contact and sensitized to light, a cooperating anode mounted on said press on the concave side of said photo-cathode, an internal electrical connection between said actuator plate and said photo-cathode and extending through the other end of said bulb, leads in said press connected to said contacts and to said anode, and a support for said insulator embedded in and projecting from said press.

3. A unitary photo relay comprising a highly evacuated bulb having a press at one end and

enclosing a fixed contact, and a cooperating movable contact mounted on said press, said movable contact comprising a plate armature, a photo-tube assembly comprising a curved sheet metal photo-cathode sensitized to light on its concave side and mounted beside said movable contact with its convex side toward said contact and an anode mounted on the concave side of said photo-cathode, a glass bead spacer mounted on said press adjacent said contacts and said photocathode and rigidly connected to said fixed contact and to said photo-cathode, an actuator plate mounted on said glass bead spacer adjacent and parallel to said plate armature, a photocathode support comprising a low leakage insulator mounted on a support in said press and carrying said photocathode, and an electrical connection between said actuator and said photocathode and extending through the other end of said bulb.

4. A unitary photo relay comprising a highly evacuated bulb having a press at one end and enclosing a fixed contact, an actuator plate, an insulating spacer for spacing said fixed contact and said actuator plate, a resilient blade mounted at one end on said press with the other end adjacent said fixed contact and with its side parallel to said actuator plate, a sheet metal photocathode mounted beside said blade with its surface opposite said blade sensitized to light, and a cooperating anode mounted adjacent said sensitized surface, a support on said insulating spacer for said photo-cathode, an electrical connection electrically connecting said actuator plate and said photocathode to a terminal at the other end of said bulb, and a photocathode support comprising a low leakage insulator mounted on a support in said press.

5. A photoelectric relay comprising a highly evacuated envelope enclosing an electrostatic relay including an actuator plate and a cooperating movable electrode, a photo-cathode comprising a metal sheet mounted beside said movable electrode and sensitized to light on the surface facing away from said electrode, an anode adjacent said sensitized surface, an insulating support for said actuator plate, a rigid metallic conductor connecting said actuator plate and said photo-cathode, and a conductor extending through the wall of said envelope and electrically connected to said actuator plate and said photocathode.

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