Nov. 12, 1935. P. E. STOGOFF 2,020,917

RELAY

Filed Dec. 27, 1930

Fig. 1.

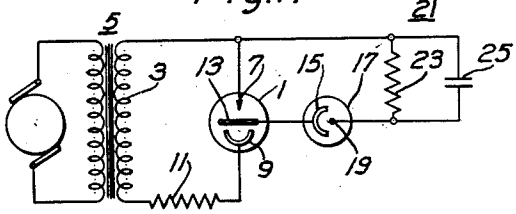


Fig. 2.

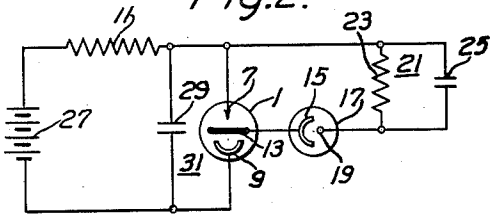


Fig. 3.

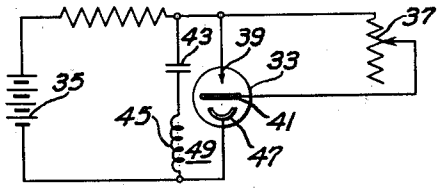


Fig. 4.

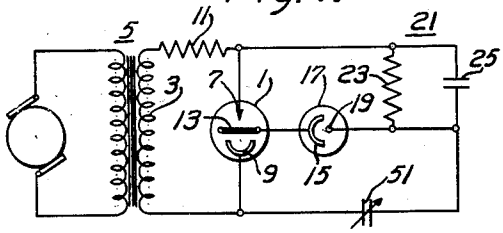


Fig. 5.

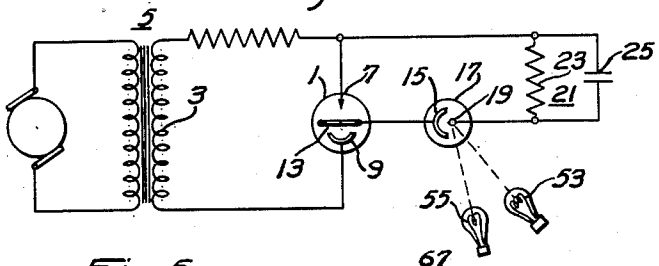
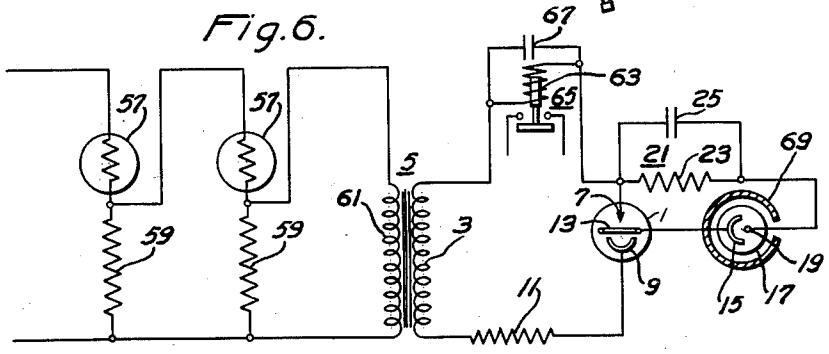


Fig. 6.



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UNITED STATES PATENT OFFICE

2,020,917

RELAY

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Application December 27, 1930, Serial No. 505,103

9 Claims. (Cl. 250—41.5)

My invention relates to relays and has particular relation to relays of the type wherein an electric-discharge device which is regulated by a photo-sensitive device is incorporated.

It is an object of my invention to provide a highly sensitive relay.

Another object of my invention is to provide a photo-sensitive relay that shall be responsive to a comparatively small light flux.

A further object of my invention is to provide a circuit including an electric-discharge device, the activity of which is regulated from a photo-sensitive device that is active for a comparatively small fraction of the time of activity of the circuit.

An ancillary object of my invention is to provide an electrical system for operating a photo-sensitive cell in the region of its glow point without any deleterious effects to the cell.

A further ancillary object of my invention is to provide, for a relay of the type including an electric-discharge device, a photo-sensitive trigger through which a disruptive discharge takes place, for a small period of time, under the influence of radiant energy.

An incidental object of my invention is to provide for a relay, of the type that locks itself in under the action of a trigger, a device for eliminating the lock-in characteristic.

An additional incidental object of my invention is to provide, for an electric-discharge device of a type operated from a direct-current source, a contrivance for automatically interrupting the activity of the discharge device.

A further incidental object of my invention is to provide a circuit, of a type including an electric-discharge device operated from a direct-current source, which does not have a lock-in characteristic.

More concisely stated, it is an object of my invention to provide a photo-sensitive relay that shall be responsive to a comparatively small light flux and that shall be adapted to be operated from direct-current or from alterating-current sources.

It has long been known that a gas-filled photo-cell acts as a luminous discharge device under the influence of proper voltage and illumination. That is to say, if the voltage between the electrodes of a cell is increased to a sufficiently high point to cause the electrons emitted from the cathode to have considerable kinetic energy, the electrons will produce sufficient ionization to cause a comparatively large current to flow in colliding with the atoms of the gas in the cell. The current may be so large as to be visible in the form of a purplish glow. When the cell is in the condition described above, it is said that a disruptive discharge is taking place between its electrodes and the cell is said to be disruptively energized.

Of course, a disruptive discharge is not introduced in a cell by the effect of the voltage alone. If the cell is not illuminated, the voltage has substantially no effect. Under the requisite gas pressure and sufficient voltage, the cell acts similar to an ordinary Geisler tube.

However, if a photo-cell is subjected to illumination of only a small intensity, the phenomenon of disruptive discharge immediately appears for only a moderate voltage impressed between its electrodes and has, furthermore, the property of maintaining itself in such manner that it persists and becomes an arc after the illumination has been removed. Experiment has shown that a photo-cell, under conditions wherein its potential is in the vicinity of its disruptive discharge potentials, may be energized by an extremely small light flux.

In experimenting with cells subjected to constant discharge of considerable magnitude, I have found that they have a short life since their electrodes are destroyed by the arc. In accordance with one feature of the present invention, I provide a system wherein the electrodes of a cell remain unimpaired by the comparatively heavy discharge that takes place between them.

According to my invention, I provide a photo-sensitive relay wherein the photo-cell is kept near its condition of disruptive discharge. However, under the influence of light, the disruptive discharge takes place for a period of time so short as not to affect the electrodes. The period of time of the discharge in the cell incorporated in a preferred embodiment of my improved system is of the order of

$$\frac{1}{10,000}$$

second, and the discharge does not become an arc and is, as a matter of fact, invisible to the eye.

My improved system comprises an electric-discharge device including a plurality of principal electrodes and a control electrode. The photo-sensitive device is connected between one principal electrode and the control electrode, and, connected in series with the photo-cell and the control electrode, is an impedance network having a comparatively low time constant. The

network includes a condenser that is adapted to discharge through the photo-cell when the latter becomes conductive by reason of its exposure to illumination.

The conductivity of the photo-cell produces a variation in the difference of potential between the principal electrode and the control electrode of the electric-discharge device which, in turn, causes the electric-discharge device to become energized or deenergized, as the case may be. I have found that a relay of the type described hereinabove responds to a light flux of only .00005 of a lumen. It is believed that this sensitivity is several hundred times the sensitivity of the ordinary photo-sensitive relay constructed as taught by the prior art.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of specific embodiments, when read in connection with the accompanying drawing, in which:

Figure 1 is a diagrammatic view showing a preferred embodiment of my invention,

Fig. 2 is a diagrammatic view showing the principal elements of the apparatus utilized when my invention is applied to a system wherein the electric-discharge device is operated from a direct-current source.

Fig. 3 is a diagrammatic view illustrating an incidental feature of my invention,

Fig. 4 is a diagrammatic view showing an embodiment of my invention wherein a device is provided for varying the sensitivity of the system.

Fig. 5 is a diagrammatic view showing a modified embodiment of my invention wherein another device is provided for varying the sensitivity of the system, and

Fig. 6 is a diagrammatic view of a still further embodiment of my invention.

The apparatus shown in Fig. 1 comprises an electric-discharge device 1 operated from the secondary 3 of a power-transmission transformer 5. The terminals of the secondary 3 of the transformer 5 are connected to the anode 7 and to the cathode 9 of the tube 1, and a current-limiting impedance 11 is incorporated in this circuit. It is understood that the exciting coil of a mechanical contactor (not shown) for controlling a circuit which it is desirable to operate may also be included in this circuit.

The control electrode 13 of the electric-discharge device 1 is connected to the cathode 15 of a photo-electric cell 17, and the anode 7 of the device 1 is connected to the anode 19 of the cell 17, through a network 21 comprising a resistor 23 and a capacitor 25. The resistor 23, as well as the capacitor 25, have comparatively low magnitudes and, consequently, the product of these magnitudes, or the time constant of the system, is comparatively low.

It is a well known fact that the current, in a system wherein the time constant is low, rises rapidly to its maximum value under the influence of an electrical potential and falls rapidly when the potential is decreased. Hence, in the present case, a pulse of current passes between the electrodes of the cell for a comparatively small period of time when the potential between the electrodes attains a predetermined value. The pulse continues for the short time that the condenser is discharging and stops when the condenser is discharged.

I have found, however, that cells of all types do not give equally satisfactory responses. The reason for this phenomenon is not susceptible of a simple explanation. Suffice it to say that, according to my experience, gas-filled cells, wherein the pressure is in the proximity of 50 microns, give the most satisfactory results for a cold-cathode electric-discharge tube requiring from 300 to 400 volts between the principal electrodes. For satisfactory operation, I have found that the resistance in this case should be from ¼ to ½ meg-ohm, and the capacity should be from 6 to 25 micro-micro-farads. Moderate success has accompanied experiments with cells having a pressure of less than 50 microns.

The operation of a system such as is shown in Fig. 1 may also be explained from a consideration of individual elements thereof. In the absence of illuminating flux on the cathode 15 of the photo-sensitive device 17, the electric discharge device 1 is deenergized and the photo-sensitive device 17 is deenergized. If the control electrode 13 were perfectly insulated from the cathode 9 of the electric discharge device 1, the cathode 15 of the photo-sensitive device 17 would float. However, such is not the case.

Assume that at the instant under consideration the potential impressed from the secondary 3 of the transformer 5 is such that the anode 7 of the electric discharge device 1 is positive while the cathode 9 is negative. The electric discharge device 1 is a gas-filled device of the cold-cathode type and by reason of the potential impressed between its principal electrodes 7 and 9 a minute leakage electronic current drifts from the negative electrode 9 to the positive electrode 7 and a negative charge is impressed on the control electrode 13. The electrode 13 is thus brought substantially to the potential of the cathode 9 and the difference in potential between the anode 19 and the cathode 15 of the photo-sensitive device 17 is substantially equal to the difference in potential between the anode 7 and the cathode 9 of the electric discharge device 1. The photo-sensitive device 17 is of the gas-filled type and the potential impressed between its electrodes 15 and 19 in this manner is sufficient to cause it to become disruptively energized when a small illuminating flux impinges on its cathode 15. The capacitor 25 is normally uncharged and when the photo-sensitive device 17 is energized, it simulates a short circuit in cooperating with the photo-sensitive device and tends to quickly reduce the potential between the electrodes 15 and 19 of the photo-sensitive device 17 thus causing the device to become quickly deenergized.

Another factor which is of importance in tending to deenergize the photo-sensitive device 17 is the electric discharge device 1. As soon as the photo-sensitive device 17 is energized, the potential impressed between the anode 7 and the control electrode 13 of the electric discharge device 1 is decreased and the electric discharge device 1 is energized. However, when the electric discharge device 1 is energized, the negative charge impressed on the control electrode 13 is neutralized and, by reason of the positive ions generated in the electric discharge device 1, remains neutralized as long as the electric discharge device 1 remains energized. As long as the energized condition persists, therefore, the control electrode 13 of the electric discharge de-

vice 1 is at the potential of the anode 7; the potential impressed between the cathode 15 and the anode 19 of the photo-sensitive device 17 is zero and the device 17 is quickly deenergized.

From the above-set-forth considerations, it will appear that the disruptive discharge in the photo-sensitive device 17 will persist for only a minute interval of time. This interval may be so short that the electrodes 15 and 19 of the device 17 are not deleteriously affected. After the electric discharge device 1 has been energized, it remains energized as long as the potential between its principal electrodes is maintained at a sufficient value to support the discharge between the electrodes. The charge on the capacitor 25 on the other hand is quickly removed by the resistor 23. However, since the electric discharge device 1 remains energized, the potential impressed between the electrodes 15 and 19 of the photo-sensitive device 17 is low and the photo-sensitive device remains deenergized. As soon as the potential impressed between the principal electrodes 7 and 9 of the electric discharge device 1 is sufficiently reduced, the electric discharge device is deenergized. This situation does not occur until substantially a negative half cycle of potential is impressed between these electrodes and during this interval the potentials impressed between the electrodes 15 and 19 of the photo-sensitive device 19 are of such polarity that the photo-sensitive device remains deenergized. However, as soon as the subsequent positive cycle of potential is impressed between the principal electrodes 7 and 9 of the electric discharge device 1, the potentials impressed across the other elements of the system are again of proper polarity for operation and if the cathode 15 of the photo-sensitive device 17 is still under the influence of illumination, the above set forth steps are repeated.

It often happens that it is desirable to utilize a relay of the type incorporated in my invention in a locality where alternating current is not available. There are, moreover, a number of applications of my invention, such as in portable photometers, for example, wherein the system can only be used with direct-current sources.

It is a well known fact that an electric-discharge device of the type described here has a property of locking itself in when it is once energized, as in the present case, by a trigger.

In Fig. 2, a system of the type, wherein the locking in characteristic is eliminated, is illustrated. The system of the type shown in this view is similar to the system shown in Fig. 1. However, the alternating-current source of the system of Fig. 1 is replaced by a direct current source 27, and a capacitor 29 is connected between the electrodes 7 and 9 of the electric-discharge device.

The condenser 29 coacts with the discharge in the tube, causing an oscillatory current to flow in the network 31, including the capacity 29 and the ionized path in the tube 1, and, hence, producing a variation in polarity of the potentials impressed upon the electrodes of the tube. By reason of the variation in polarity of the potentials, the discharge in the tube is interrupted when the grid 13 is reverted to its original electrical condition, after having been given a potential favorable to discharge between the electrodes 7 and 9 of the tube 1.

In Fig. 3, this particular feature of the system is illustrated in its general form. The apparatus shown in this view comprises an electric-discharge device 33 operated from a direct-current source 35. The activity of the device is regulated from a variable impedance 37 connected between one principal electrode 39 and the control electrode 41 of the device 33. A capacitor 43, in series with an inductor 45 connected between the principal electrodes 39 and 47 of the device 33, provides the external elements of oscillatory circuit 49, whereby a discharge between the electrodes 39 and 47 of the electric-discharge device 33 is interrupted when the control electrode 41 attains a condition unfavorable to the persistence thereof.

The system of the type illustrated in Fig. 4 is similar to the system illustrated in Fig. 1 but includes, in addition, a capacitor 51 connected between one principal electrode 9 of the electric-discharge device 1 and the anode 19 of the photo-sensitive cell 17. By varying the magnitude of the capacitor 51, the sensitivity of the system is varied. It is apparent that variation of the sensitivity of a device, responsive to as small intensities as the device hereinabove described, is an important matter.

It is a well established fact that the velocity of the electrons emitted from the cathode of a photo-sensitive cell is dependent upon the potential impressed between the electrodes. The number of electrons emitted from the cathode, on the other hand, is dependent upon the illumination impinging on the cathode. It is apparent then that a disruptive discharge may be produced in a gas-filled cell by a combination of illumination and potential.

In Fig. 5, a system of a type, wherein I have applied this principle, is illustrated. The relay is substantially the same as the relay of the type illustrated in Fig. 1. However, the photo-cell is under the influence of a permanent source of illumination 53, the intensity of which may be varied by some well known external means. By regulating the radiation emitted by the permanent source 53, the sensitivity of the system is regulated. A second source 55, that is provided for regulating the activity of the relay, is also shown. The source 55 is similar to the sources that are utilized in the devices assembled above and is only active when it is desirable that the relay be active. The source 53 may be regarded as a primary source.

Relays of the type illustrated in Fig. 6 include several important features that are, at times, necessary in the operation of control systems.

The voltage is supplied to the power-transmission transformer through a bank of ballast tubes 57, or other voltage-regulating devices, associated with a plurality of resistors 59. In this manner, the current through the primary 61 of the transformer 5 is maintained at a constant value and, consequently, the voltage across the secondary 3 is constant.

The exciting coil 63 of a contactor 65 is illustrated in this modification of my invention, and a capacitor 67 is shown connected between the terminals of the coil 63. The capacitor 67 tends to prevent the contactor 65 from chattering when it is energized. In the embodiment of my invention described in this view, the sensitivity of the system is regulated by a shield 69 that is rotated relative to the cell 17 and thus controls the area of the cathode 15 that is illuminated. This sensitivity-regulating device has the advantage that it increases the life of a cell when only moderate sensitivity is required, since it involves the use of only a section of the cathode.

In the above discussion, my invention has been illustrated as applied to a system of a specific type, and electric-discharge devices of the cold-electrode type have been shown as incorporated therein. It is apparent that my invention is not restricted to the particular modifications illustrated nor is it restricted to be utilized with a discharge device of a particular type.

My invention may be utilized, for example, with grid controlled glow tubes of the hot-electrode type, with thermionic tubes, with grid-controlled mercury discharge tubes, and with other tubes of like nature.

It is, furthermore, to be noted that, while my invention has been specifically applied to relays of the type wherein the electric-discharge device is rendered active by the excitation of the photo-cell, it is also applicable to relays of the type wherein the electric-discharge device is rendered inactive by the excitation of the photo-cell.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. A relay including a photo-sensitive device having at least a sensitive electrode and another electrode to cooperate with said sensitive electrode, said electrodes being immersed in a gaseous medium having a pressure of the order of 50 microns of mercury, a source of voltage for impressing a potential between said electrodes of said photo-sensitive device that is of such magnitude that said photo-sensitive device is deenergized in the absence of radiant flux impinging on said sensitive electrode and becomes disruptively energized when radiant flux impinges on said electrode, a gaseous electric discharge device having a current path, which does not include said photo-sensitive device, connected to said source and controlled by said photo-sensitive device when it is so energized and which tends to by-pass current flowing from said source to said photo-sensitive device a short interval of time after it has been so energized.

2. A relay including a photo-sensitive device having at least a sensitive electrode and another electrode to cooperate with said sensitive electrode, said electrodes being immersed in a gaseous medium having a pressure of the order of 50 microns of mercury, means for impressing a potential between said electrodes of said photo-sensitive device that is of such magnitude that said photo-sensitive device is energized in the absence of radiant flux impinging on said sensitive electrode and becomes disruptively energized when radiant flux impinges on said electrode, a gaseous electric discharge device having a current path which does not include said photo-sensitive device to respond to said photo-sensitive device when it is so energized, means to respond to said photo-sensitive device when it is so energized for deenergizing said photo-sensitive device a short interval of time after it has been so energized and after said electric discharge device has responded thereto.

3. A relay including a photo-sensitive device having at least a sensitive electrode and another electrode to cooperate with said sensitive electrode, said electrodes being immersed in a gaseous medium having a pressure of the order of 50 microns of mercury, means for impressing a potential between said electrodes of said photo-sensitive device that is of such magnitude that said photo-sensitive device is deenergized in the absence of radiant flux impinging on said sensitive electrode and becomes disruptively energized when radiant flux impinges on said electrode, a gaseous electric discharge device having a current path which does not include said photo-sensitive device to respond to said photo-sensitive device when it is so energized, means incorporating an element which is substantially independent of said potential-impressing means to respond to said photo-sensitive device when it is so energized for deenergizing said photo-sensitive device a short interval of time after it has been so energized and after said electric discharge device has responded thereto and a capacitor for varying the magnitude of the radiant flux for which said photo-sensitive device becomes disruptively energized.

4. A relay comprising an electric discharge device having a control electrode and a plurality of principal electrodes, means for impressing potentials between the electrodes of said device to maintain said device in a predetermined condition of excitation, a photo-sensitive device having a sensitive electrode and an electrode to cooperate with said sensitive electrode, means for coupling the electrodes of said photo-sensitive device between the control electrode and a principal electrode of said electric discharge device and to said potential supply means, to impress potentials between the electrodes of said photo-sensitive device that are of such magnitude that said photo-sensitive device is deenergized when the sensitive electrode thereof is not impinged by radiant energy and becomes disruptively energized, when radiant energy impinges on said sensitive electrode, and means to respond to said photo-sensitive device when it is so energized for deenergizing said photo-sensitive device a short interval of time after it has been so energized and said electric discharge device has responded thereto.

5. A relay comprising an electric discharge device having a control electrode and a plurality of principal electrodes, means for impressing potentials between the electrodes of said device to maintain said device in a predetermined condition of excitation, a photo-sensitive device having a sensitive electrode and an electrode to cooperate with said sensitive electrode, means for coupling the electrodes of said photo-sensitive device between the control electrode and a principal electrode of said electric discharge device and to said potential supply means, to impress potentials between the electrodes of said photo-sensitive device that are of such magnitude that said photo-sensitive device is deenergized when the sensitive electrode thereof is not impinged by radiant energy and becomes disruptively energized, when radiant energy impinges on said sensitive electrode and means including a capacitor coupled between an electrode of said photo-sensitive device and an electrode of said electric discharge device to respond to said photo-sensitive device when it is so energized for deenergizing said photo-sensitive device a short interval of time after it has been so energized and said electric discharge device has responded thereto.

6. In combination, a photo-sensitive device having at least a sensitive electrode and another electrode cooperating therewith, said electrodes being immersed in a gaseous medium, a source of voltage and means for impressing a potential between said electrodes of said photo-sensitive device that is of such magnitude that said photo-

sensitive device is deenergized in the absence of radiant flux impinging on said sensitive electrodes but becomes disruptively energized when radiant flux impinges on said electrode and means controlled by said photo-sensitive device when it is so energized to form a by-pass of a type conductive to direct current from said source around said photo-sensitive device after it has been so energized.

7. In combination an electric discharge device having an anode, cathode and control electrode immersed in a gaseous medium, means for impressing potentials between the electrodes of said device to normally maintain it in a deenergized condition, a photo-sensitive device having an anode and a cathode immersed in a gaseous medium, means for coupling the cathode of said photo-sensitive device to the control electrode of said electric discharge device and the anode of said photo-sensitive device to the anode of said electric discharge device, thereby to maintain the difference in potential between the anode and cathode of said photo-sensitive device substantially equivalent to the difference in potential between the anode and cathode of said electric discharge device, when it is deenergized, and in the absence of radiant energy impinging on the cathode of said photo-sensitive device to maintain said photo-sensitive device deenergized, means for transmitting radiant flux to the cathode of said photo-sensitive device to disruptively energize said device and thereby to energize said electric discharge device and a capacitor coupled between the anode of said photo-sensitive device and the anode of said electric discharge device, to be charged by the current transmitted through said photo-sensitive device and thereby to deenergize said photo-sensitive device in such a short interval of time that the cathode thereof is not deleteriously affected by the disruptive discharge.

8. In combination an electric discharge device having an anode, cathode and control electrode immersed in a gaseous medium, means for impressing potentials between the electrodes of said device to normally maintain it in a deenergized condition, a photo-sensitive device having an anode and a cathode immersed in a gaseous medium, means for coupling the cathode of said photo-sensitive device to the control electrode of said electric discharge device and the anode of said photo-sensitive device to the anode of said electric discharge device, thereby to maintain the difference in potential between the anode and cathode of said photo-sensitive device substantially equivalent to the difference in potential between the anode and cathode of said electric discharge device, when it is deenergized, and in the absence of radiant energy impinging on the cathode of said photo-sensitive device to maintain said photo-sensitive device deenergized, means for transmitting radiant flux to the cathode of said photo-sensitive device to disruptively energize said device and thereby to energize said electric discharge device, a capacitor coupled between the anode of said photo-sensitive device and the anode of said electric discharge device, to be charged by the current transmitted through said photo-sensitive device and thereby to deenergize said photo-sensitive device in such a short interval of time that the cathode thereof is not deleteriously affected by the disruptive discharge and a resistor coupled across said capacitor to discharge said capacitor after it has been so charged and to thereby render said photo-sensitive device responsive to variations in the radiant energy impinging on the cathode thereof.

9. A relay including a photo-sensitive device having at least a sensitive electrode and another electrode to cooperate with said sensitive electrode, said electrodes being immersed in a gaseous medium, a source of voltage for impressing a potential between said electrodes of said photo-sensitive device that is of such magnitude that said photo-sensitive device is deenergized in the absence of radiant flux impinging on said sensitive electrode and becomes disruptively energized when radiant flux impinges on said electrode, a gaseous electric discharge device having a current path, which does not include said photo-sensitive device, controlled by said photo-sensitive device when it is energized and which tends to by-pass current flowing from said source to said photo-sensitive device a short interval of time after it has been energized.

PETER E. STOGOFF.