Dec. 11, 1956 W. C. WHITE 2,774,015

PHOTOELECTRIC CONTROL APPARATUS

Filed April 23, 1953

Fig. 1.

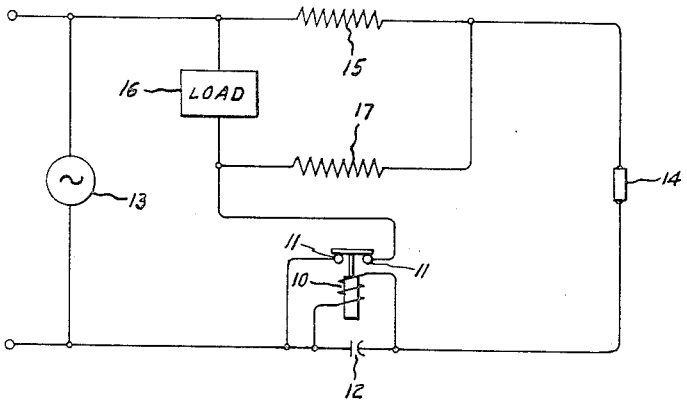
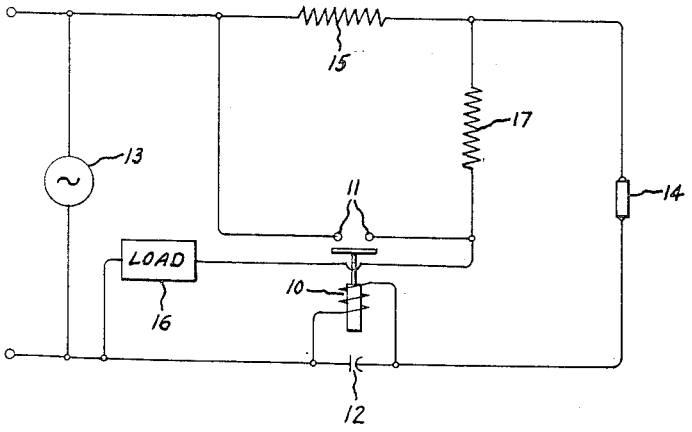


Fig. 2.



Inventor:
William C. White,
by Paul A. Frank,
His Attorney.

United States Patent Office 2,774,015
Patented Dec. 11, 1956

2,774,015

PHOTOELECTRIC CONTROL APPARATUS

William C. White, Schenectady, N. Y., assignor to General Electric Company, a corporation of New York

Application April 23, 1953, Serial No. 350,709

8 Claims. (Cl. 317—128)

This invention relates to a photoelectric control apparatus; more particularly, the invention relates to a photoelectrically controlled relay for use with alternating current.

Electrically-responsive, light-sensitive devices may be classed into three groups:

(1) *Photovoltaic.*—in this class, exposure of the cell to light generates an E. M. F. This is the type of device used in photographic light meters. Its output is so small that only very delicate relays can be used and its impedance and voltage output so low that amplification by means of an electron tube is not very practical. Therefore, this class of light-sensitive device has found little use for control functions, particularly in the industrial field.

(2) *Photo-emissive devices.*—In these devices the light produces an electron emission from a cathode and the resulting current is amplified for operation of an instrument or relay. These devices are usually called phototubes and are in common use for talking motion pictures and industrial applications. They are very satisfactory for these applications because their speed of response is very high and the need for amplification is not a serious drawback as the electrical characteristics of the phototube lend themselves easily to conventional amplifier circuits. The need for amplifiers, however, has introduced a cost element which has restricted their use to applications where the benefits gained justify the cost. The cost, size and necessity for operating amplifier tubes continuously together with their replacements have prevented their use in the home and similar applications.

(3) *Photo-resistive devices.*—In this class, which may also be defined photo-conductive devices, exposure to light changes the resistance of the element. The earliest photo-sensitive device, the selenium cell, falls into this classification. It has had only limited use since the development of the electronic phototube. The recently developed cadmium-sulfide crystal is in this same classification but it is small, tremendously more sensitive than the selenium cell and passes such relatively heavy currents that available sturdy relays can be operated without the need of any amplification.

The cadmium-sulphide crystal, when combined with certain circuit arrangements, permits the making of a very inexpensive photoelectric relay admirably suited for home use and other applications where a simple, small, low-cost device is a requirement.

There are a number of applications for the home. The most obvious is for the control of a porch, walk or vestibule light. In some cases, this is helpful in showing the street number of the house and in some localities all of the residents agree to leave these on all night and thus provide a low-cost form of street lighting. In many parts of the country, open car ports are replacing garages. A light in these car ports discourages theft and vandalism in connection with the car. Also a small

low-cost photoelectric relay finds usefulness inside the home where it is located on a window sill or table near a window to turn on a table or floor lamp near the window only when it gets dark. This makes it appear that the house is occupied.

It is an object of the present invention to provide an inexpensive photoelectric relay satisfactory for home use.

It is another object of the present invention to provide a photoelectric relay operable from a source of alternating current.

It is a further object of the present invention to provide a photoelectric relay having positive operation of the relay contacts in response to slow changes in the light striking the photo-conductive device.

Briefly stated, in accordance with one of its aspects, the light-responsive control apparatus of this invention comprises an alternating current relay, a capacitor connected in parallel with the relay in tuned circuit relationship, a relatively low impedance photo-conductive device, a resistor, a first circuit connecting the resistor and photo-conductive device in series with the relay and capacitor, and a second circuit for connecting a load across the first resistor, photo-conductive device, relay and capacitor, the second circuit passing through the contacts of the relay.

Fig. 1 is a schematic diagram of one embodiment of this invention and Fig. 2 is a schematic diagram of an alternative embodiment.

This invention makes use of a crystal photo-conductive device. A light-sensitive crystal particularly suitable for use in applicant's apparatus is disclosed in application Serial No. 190,801, filed October 16, 1950, of John E. Jacobs, entitled "X-Ray Detection," now Patent No. 2,706,790, and consists of a cadmium sulfide crystal substantially free from lattice distortion. These crystals, consisting of hexagonal cadmium sulfide, may be synthesized from cadmium vapor and hydrogen sulfide. Other photo-sensitive elements are germanium semiconductors.

In the circuit illustrated in Fig. 1, a relay **10** having normally closed contacts **11** is connected in parallel with a capacitor **12**, the two elements combining to form a tuned circuit at line voltage frequency. A photo-conductive crystal **14** and resistor **15** preferably of about 20,000 ohms resistance, or less, are connected in series with the tuned circuit formed by the coil of the relay **10** and the capacitor **12**. This circuit is adapted to be connected to a source **13** of alternating current, which may be 120 volt 60 cycle alternating current available in most private residences.

A load circuit, indicated in block form at **16**, is connected across the circuit formed of the resistor **15**, crystal **14** and tuned circuit of the coil of relay **10** and capacitor **12** through the contacts **11** of the alternating current relay **10**. A resistor **17** is connected to shunt out the load **16** and resistor **15**.

Cadmium sulfide is a preferred material for the photo-conductive crystal **14**. The crystal may be about $\frac{3}{16}$" long and about $\frac{1}{16}$" in diameter. These dimensions are not critical but are set forth in order to show how small a crystal will function satisfactorily in the apparatus described herein. Smaller or larger crystals may also be used.

Photoelectric relays particularly of the alternating current type disclosed herein have a tendency to chatter at a certain light level due to the fact that operation of the relay changes the electrical characteristics of the circuit. The resistor **17**, which may have a resistance varying from about the same level as resistor **15** to a level $2\frac{1}{2}$ times its value, prevents chattering of the contacts **11**.

The function of the resistor 17 is to increase the current through the relay when the contacts first open and to accelerate the relay armature action once it has started to function. When the relay contacts 11 first start to close, there is an opposite but also beneficial action. Thus, regardless of how slow the current changes are through the winding of the relay 10 the relay action is definite. The resistor 17 may be omitted from the circuit where the apparatus is used in installations which are not subject to a slow fading or increase in the light level such as at dawn and dusk. Chattering is not a problem where changes in the level of light exciting the crystal 14 are large and rapid.

The capacitor 12 shunted across the coil of the relay 10 is given a value to partially tune with the inductance of the relay winding at 60 cycles in order to have the relay current heavier than the crystal current and thus improve the sensitivity of the apparatus. In addition to this the capacitor compensates to some extent for the difference in pull-in and drop-out current of the relay. When the relay armature is opened, the capacitance to tune with the inductance of the relay winding is higher than when the relay armature is closed. By choosing a capacitor having a capacitance value about mid-way between the two levels there is a cumulative effect whereby when the armature starts to close, the relay current due to increased resonance is raised and this increases this relay current still further to hasten the closing. When the armature starts to open, a reverse effect takes place which promotes further the initial opening of the armature.

In Fig. 1 the normally closed contacts 11 of the relay 10 will open the circuit of the load 16 when light impinging upon the crystal 14 passes a certain level. This circuit is intended particularly for use with an electric light as the load wherein the light is illuminated as daylight decreases below a particular level.

The circuit illustrated in Fig. 2 is similar to that illustrated in Fig. 1 except that the relay contacts are normally opened instead of normally closed. Since the elements of the circuit are otherwise analogous, they are given the same numerals for identification purposes. The resistor 15 protects the circuit by preventing overloads through the crystal and relay in case the crystal 14 is exposed to direct sunlight or to some other brilliant light source. With the circuit elements arranged as illustrated the control circuit draws very little energy. The relay 10 may be made operable with only a few milliamperes of relay current and in the embodiment illustrated in Fig. 1, when the contacts 11 are closed there is substantially no current passing through the relay coil when crystal 14 is not illuminated.

Photoelectric relays made in accordance with this invention may occupy a very small volume. The size of the crystal 14 has previously been described. The relay 10, resistors 15 and 17, and capacitor 12 may also be made to occupy a very small space. All components may readily be fitted into a container 1½" thick by about 2" square. The apparatus is provided with a cord for plugging in to house current and with a receptacle adapted to have a load plugged thereinto. After the apparatus has been plugged into a source of alternating current and a load has been connected thereto it is merely necessary to position the crystal in a location where it has access to light to which it is intended to respond and is shielded from other light sources.

While the present invention has been described with reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the invention. Therefore, I aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A control apparatus comprising a load circuit for connection across a power supply and including in series a pair of contact terminals and a pair of load input terminals for connection to a load, electrical current responsive means to selectively connect together and to disconnect said contact terminals, a first current limiting resistance, an impedanced evice having an impedance variable in accordance with an external stimulus, said means, said device, and said first resistance being connected in a series circuit in the order named across said load circuit, and a second resistance connected at one end to said load circuit between said terminals and said contacts and at the other end to said series circuit between said device and said first resistance to provide for positive action of said apparatus to control the energization of said load relative to a predetermined magnitude of said stimulus.

2. A control apparatus as defined in claim 1 in which the impedance device includes a cadmium sulfide crystal.

3. A light sensitive control apparatus comprising a load circuit for connection across a power supply and including in series a pair of contact terminals and a pair of load input terminals for connection to a load, a relay including electrical current responsive means to selectively connect together and to disconnect said contact terminals, a first current limiting resistance, a light sensitive element the resistance of which varies in response to incident light variation, said means, said element, and said first resistance being connected in a series circuit in the order named across said load circuit, and a second resistance connected at one end to said load circuit between said terminals and said contacts and at the other end to said series circuit between said element and said first resistance to provide for positive action of said apparatus.

4. A light sensitive control apparatus as defined in claim 3 in which the light sensitive element includes a cadmium sulfide crystal.

5. A light sensitive control apparatus comprising a load circuit for connection across an alternating current power supply and including in series a pair of contact terminals and a pair of load input terminals for connection to a load, a relay including an inductive coil and an armature movable to selectively connect together and to disconnect said contact terminals in response to the magnitude of current through said coil, a capacitor connected in parallel with said coil to form therewith a tuned circuit at the frequency of said power supply, a first current limiting resistance, a light sensitive element the resistance of which varies in response to incident light variation, said coil, said element, and said first resistance being connected in a series circuit in the order named across said load circuit, and a second resistance connected at one end to said load circuit between said terminals and said contacts and at the other end to said series circuit between said element and said first resistance to provide for positive action of said apparatus.

6. A light sensitive control apparatus comprising a load circuit for connection across an alternating current power supply and including in series a pair of contact terminals and a pair of load input terminals for connection to a load, a relay including an inductive coil and an armature movable axially of said coil selectively to a first position connecting said contact terminals together and to a second position whereby said contact terminals are disconnected in response to the magnitude of current through said coil, a capacitor connected in parallel with said coil to form a tuned circuit therewith at the frequency of said power supply, the capacitance of said capacitor being between the capacitance required for resonance with the inductance of said coil at the frequency of said power supply when said armature is in said first position and the capitance for said resonance when said armature is in said second position, and a light sensitive element the resistance of which varies in response to incident light variation, said

element and said tuned circuit being connected in series across said load circuit to control the energization of said load relative to a predetermined level of said incident light.

7. A light sensitive control apparatus comprising a load circuit for connection across an alternating current power supply and including in series a pair of contact terminals and a pair of load input terminals for connection to a load, a relay including an inductive coil and an armature movable axially of said coil selectively to a first position connecting said contact terminals together and to a second position whereby said contact terminals are disconnected in response to the magnitude of current through said coil, a capacitor connected in parallel with said coil to form therewith a tuned circuit at the frequency of said power supply, the capacitance of said capacitor being between the capacitance required for resonance with the inductance of said coil at the frequency of said power supply when said armature is in said first position and the capacitance for said resonance when said armature is in said second position, a first current limiting resistance, a light sensitive

element the resistance of which varies in response to incidence light variation, said tuned circuit, said element, and said first resistance being connected in a series circuit in the order named across said load circuit, and a second resistance connected at one end to said load circuit between said terminals and said contacts and at the other end to said series circuit between said element and said first resistance to provide positive control for the energization of said load relative to a predetermined level of said incident light.

8. A light sensitive apparatus as defined in claim 7 in which the light sensitive element includes a cadmium sulfide crystal.

References Cited in the file of this patent

UNITED STATES PATENTS

Re. 19,199	Knowles	June 5, 1934
1,345,586	Coblentz	July 6, 1920
1,878,010	Spahr	Sept. 20, 1932
2,089,830	Grohndahl	Aug. 10, 1937