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PHOTOCELL CIRCUIT CONTROL ARRANGEMENT

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2 Sheets-Sheet 1

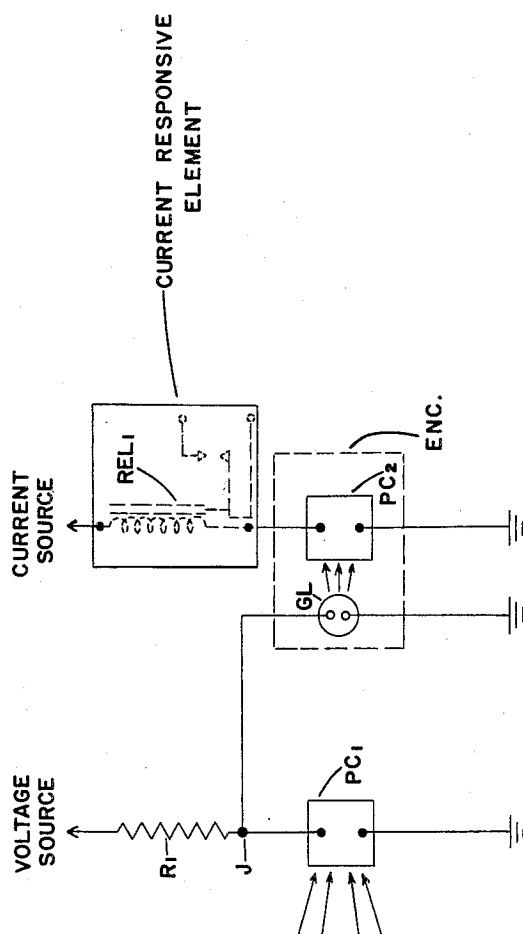


FIG. 1

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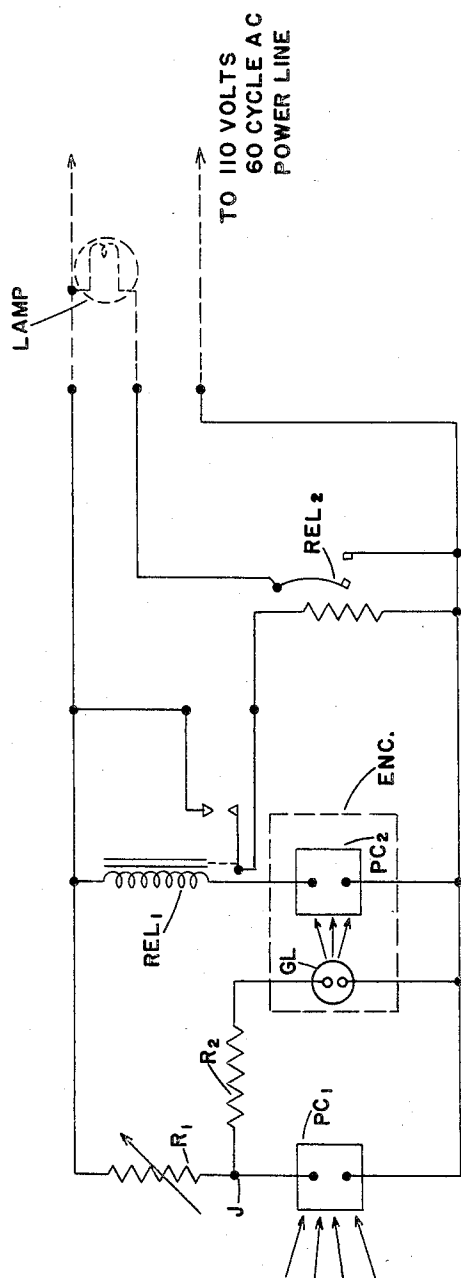
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PHOTOCELL CIRCUIT CONTROL ARRANGEMENT

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This invention relates to photocell circuit control arrangements and is particularly directed to such arrangements using photoconductive cells of high luminous efficiency and capable of handling appreciable current.

While wide use is now made of photocell controlled circuits, there are a number of applications where the complexity, cost, and limited life and reliability of known arrangements have barred their employment up to the present. For instance, in automatically controlled street lighting systems it would be very desirable to operate each lamp by connecting it directly to the general power system which supplies the area rather than to install a separate supply line network solely for street lighting purposes. To do this obviously calls for individual ambient light responsive switching controls for each street lamp which, in view of the cost and complexity of known photocell circuit control arrangements, has hitherto been of dubious practicality. The recent advent of photoconductive cells of such luminous efficiency and current handling capacity that they will operate a standard relay directly would seem to offer a simple solution to the above problem. One such type of cell is the cadmium sulfide cell having a relatively large area of specially processed cadmium sulfide and an extensive electrode structure. A typical cell of this type has a dark resistance in the order of megohms and a resistance in direct sunlight of some tens to hundreds of ohms. The permissible wattage dissipation is a function of the cell size, and may readily be made to be in the order of 1 watt or more.

However, despite these attractive properties of such cells, in applications such as the street lighting control system above where a wide range of light intensities are encountered, and where it may be desired to adjust the ambient light level operating point, the apparently obvious circuit combination of a power source, a photoconductive cell of the above type, and a relay is not as simple or economical as may be expected.

A suitable relay for use in such a system might have a resistance of, say 10,000 ohms. Now, as noted above, the photoconductive cell in darkness has a resistance of several megohms, and in full daylight a resistance of possibly one hundred ohms or so, because of this resistance mismatch to the relay little power is dissipated in the cell either at night or in full daylight. However, during a considerable period of time at both dusk and dawn, and possibly on cloudy days, the cell resistance might well be of the same order as that of the relay. Under such conditions much more power must be dissipated by the cell than under what might be considered as being normal conditions. Thus to avoid overload of the cell it would be necessary to employ one having many times that power rating sufficient for operation during the major portion of the operation time cycle.

In the above arrangement, also, it is often necessary to provide for operation of the relay at different light levels. For example, it might be desired to provide for operation at any level between, say, 5 foot candles and

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1 foot candle. The cell resistance will be in the order of 20,000 ohms at 5 foot candles and 100,000 ohms at 1 foot candle. If our relay is to operate in this range of light levels without making adjustment of its sensitivity for each different setting of the operating point, it will be necessary to adjust the total series resistance in the circuit in each case to bring the overall resistance to the same value, which in this instance would be 110,000 ohms. If we assume that relay operation within a current differential of 10 percent must be allowed for, a resistance variation of 10 percent of 110,000 ohms, or 11,000 ohms must be anticipated. Now this is over 50 percent of the photoconductive cell resistance of 20,000 ohms which obtains at the operating point of 5 foot candles but only 11 percent at 1 foot candle. Therefore the possible light intensity differential will vary over a range of 5 to 1. If this very undesirable change in operating differential for different operating points is to be avoided it would be necessary either to provide a relay of adjustable sensitivity, or to provide a power source of adjustable potential and low internal resistance—that is, a transformer, or a high current potentiometer. Neither of these expedients is simple or economical.

A further point of consideration in the operation of such a control as the above is that the chosen light intensity operating point will usually be passed through very slowly with the gradual change of daylight. If an alternating current relay is used there will be corresponding periods, possibly of many minutes, where it will "chatter." This chattering, which results in rapid contact wear, would be quite impermissible in such a service. At first thought it might be considered advisable to go to the expense and complication of providing a direct current power supply for the relay circuit. Here, however, we encounter a property of known suitable photoconductors which effectively bars this obvious method of operation in an arrangement that is required to have long-time stability and freedom from the necessity of even infrequent adjustment. Photoconductors of the type mentioned when operated for some time on a fairly high direct current, as they would do in sunlight in the postulated arrangement, frequently exhibit a phenomenon akin to polarization which, amongst other things, results in a shift of the resistance versus illumination characteristic curve. In the type of circuit under consideration even a small change in characteristics would result in a serious shift of the operating point. Frequent inspection, adjustment, and possibly replacement of the photoconductive cell would therefore be required. The magnitude of the necessary maintenance schedule that would be involved in a street lighting system or the like is obvious, and effectively rules out the possibility of using direct current operation of this type of circuit in such cases.

An object of the present invention, therefore, is to provide a circuit arrangement which will permit economical and reliable use of photoconductive cells in ambient light responsive circuit control systems.

A further object of the invention is to provide a circuit arrangement employing photoconductive cells in ambient light responsive circuit control systems wherein the operating point, in terms of ambient light intensity, may be readily adjusted.

Another object of the invention is to provide a circuit arrangement employing photoconductive cells in ambient light responsive circuit control systems wherein an alternating current relay may be operated without chattering despite slow variations of light intensity around the desired operating point.

According to the invention there is provided a radiant energy responsive circuit control arrangement comprising, a source of given electrical potential, a resistor of

predetermined resistance value, a first photoconductive cell, means to connect said resistor and said first photoconductive cell serially across said source of potential, means to so mount said first photoconductive cell that it is exposed to said radiant energy, a glow discharge tube having a striking potential less than said given potential connected between the junction of said resistor and said first photoconductive cell and one side of said source of potential, a second photoconductive cell, a light impervious enclosure, means to mount said glow discharge tube and said second photoconductive cell within said enclosure in such relation that radiant energy produced by said glow discharge tube is directed upon said second photoconductive cell, a source of current, a current responsive circuit controlling element, and means to serially connect said second photoconductive cell and said current responsive element across said source of current.

The invention will be described with reference to the accompanying drawings in which,

Figure 1 is a schematic diagram illustrating the principles of the invention, and

Figure 2 is a preferred embodiment of the invention applied to a street lighting control system.

In Figure 1 a photoconductive cell, PC_1 , and a resistor, R_1 , are connected in series across a potential source. The cell is so mounted and located as to receive the illumination in accordance with which control action is to be exercised. It will be seen that R_1 and PC_1 constitute a potentiometer, the potential at the junction J being a function of the relative resistances of R_1 and PC_1 . By proper selection of R_1 it is possible to obtain at J a potential which, very closely, is any desired fraction of the potential of the source at any given light intensity incident on the photoconductive cell.

Across one arm of the potentiometer circuit (in the present instance, the photoconductive cell arm) is connected a glow lamp GL having a striking voltage within the range attainable at J . The glow lamp GL is mounted together with a second photoconductive cell, PC_2 , inside a light tight enclosure ENC in such a manner that radiant energy from the glow lamp when struck is directed on the cell PC_2 .

A current responsive element, such as the actuating coil of a relay REL_1 , is connected in series with the second photoconductive cell PC_2 to a source of current. The switching contacts of REL_1 may be made available for connection to a circuit which is to be controlled in response to variations in the intensity of light falling on cell PC_1 .

The action of the arrangement of Figure 1 is as follows. Let it first be considered that the voltage source supplying the potentiometer circuit of R_1 and PC_1 is a direct current source. Starting with maximum light intensity incident on PC_1 , the resistance of this cell will then be low, and hence the voltage at J will be below that necessary to cause conduction of the glow lamp GL . With the glow lamp non-conducting the resistance of the cell PC_2 will be high since it will receive no radiation, being completely shielded from light by the light tight enclosure ENC . The high resistance of PC_2 prevents the flow of any appreciable current in the coil of relay REL_1 and hence said relay is not actuated.

Now let the intensity of light incident on the photoconductive cell PC_1 gradually diminish. The resistance of this cell, and concomitantly the value of the potential at J , will rise until the point is reached when the glow lamp is fired. Thereupon the resistance of the photoconductive cell PC_2 , now being adequately illuminated, falls to a low value and permits a flow of current through the relay coil thus actuating the relay REL_1 . It will be seen that the action is a triggered one, the cell PC_2 being either dark or fully illuminated, and thus having either a very high or a very low resistance.

Direct current relays normally have very appreciable backlash—that is, after having been actuated by a given

minimum current, upon reducing the current the relay will hold this actuated position until the current through the coil drops to possibly as low as 50 percent of the current value initially required to actuate it. With the present invention, by using a glow tube which has an extinguishing potential very little less than the striking potential, this common drawback of direct current relays is very substantially eliminated. Some backlash remains, dependent upon the difference between the striking and extinguishing voltages of the glow tube, but a small amount is often very desirable to ensure stable operation when there is the possibility of small fluctuations of light intensity around the operating point.

It will be realized that adjustment of the operating point is not subject to variations in operation differential. When a change in the operating point is required the value of R_1 is changed to correspond with the new resistance of the photoconductive cell at this new point. The ratio of resistances in the two arms of the potentiometer remains the same, and hence the same percentage differential of incident light intensity on the photoconductive cell at any chosen operating point will always result in the same percentage differential of the potential at J .

Other advantages are obtainable with the invention. Since the photoconductive cell PC_1 functions as a part of a potentiometer, and thus is not required to handle any appreciable current, a small size high resistance type may be employed. Such cells are less expensive than those required to handle appreciable currents. Because of the high resistance of the type of cell PC_1 which may be used, the resistance of R_1 will also be high. The maximum possible current through the glow lamp will therefore be limited. This action may be augmented if desired by the addition of a current limiting resistor connected between the junction J and the glow lamp. By this means, if so desired, the current flow through the glow lamp after striking may be made almost constant in value despite wide variations of resistance in the cell PC_1 . Therefore the light incident upon the photoconductive cell PC_2 may be made essentially constant. With this effected the type of photoconductor cell used for PC_2 may be chosen for maximum efficiency at this particular light intensity. There is no necessity for providing power dissipation capacity in excess of that just adequate to ensure reliable operation.

Another important advantage accrues to the arrangement of the invention. As above noted the polarization effects occurring in photoconductor cells is a function of the amount of current flowing through them. Since cell PC_1 may be used in a very high resistance circuit the current it is required to carry will then be low, and polarization effects will be negligible. This system, therefore, may be operated on direct current.

Let us now consider the operation of the invention when an alternating current source of voltage is used to supply R_1 , PC_1 , and GL , and wherein, as before, the current responsive element is a relay. As the resistance of cell PC_1 increases with the lessening of illumination, the voltage at J builds up until at the peaks of the alternating current cycle the voltage is just sufficient to strike the glow lamp GL . Unless the glow lamp has a very long de-ionization time it will conduct after being struck only until the voltage falls in the cycle to the extinguishing point, whereupon conduction will cease until the following voltage peak.

Consequently, as the operating point is reached and slowly passed, the glow lamp will begin to emit a train of light pulses whose duration, per cycle of the alternating current source, is dependent upon the difference between the striking and extinguishing potentials of the glow lamp. The photoconductive cell PC_2 may be so chosen in relation to the amount of energy in the light pulses as to provide a triggering type of action just as in the case where direct current is used, but the back-

lash property possessed by the system under direct current operation is no longer present in this part of the circuit.

It might also appear at first glance that, since the cell PC_2 is intermittently illuminated, it would cause pulses of current to flow in the relay coil, and that some smoothing means might possibly be required to prevent chatter of the relay. However, a characteristic of photoconductor cells of the type suitable for use here is such that this difficulty does not occur. Intrinsically such cells have a long time constant—that is their response to light stimuli is sluggish. So, when exposed to a train of light pulses, a photoconductive cell will reduce its resistance gradually and smoothly within a period of several cycles. The possibility of relay chatter is therefore not present in the arrangement of the invention.

In Figure 2 is shown an embodiment of the invention in the form of a control for a lamp such as might be used for street lighting or for an outdoor advertising sign. Those components corresponding to like components of Figure 1 are similarly designated. In Figure 2 the source of voltage for the potentiometer and glow lamp, and the source of current for the relay, is here provided by an alternating current power line source of 110 volts, 60 cycles, and R_1 is made adjustable. As discussed above in relation to the operation of the arrangement of Figure 1 a current limiting resistor, R_2 , is serially connected with the glow lamp. The preferred type of glow lamp for this application is a miniature neon tube of the type frequently used to indicate the energization of circuits. Such neon tubes are available having a striking voltage of about 75 volts and emitting adequate radiation in the visible and infra-red region, when passing a current of only a fraction of a milliampere, to reduce the resistance of the photoconductor cell PC_2 to a sufficiently low value to effect positive actuation of a standard relay. Such neon tubes are long lived, rugged, cheap, and of such small size that the light tight enclosure housing such a glow tube and photoconductive cell occupies a bulk of less than one cubic inch.

In the arrangement of Figure 2 the switching contacts of relay REL_1 are used to connect or disconnect from the power lines the heater winding of a thermostatic relay REL_2 . This second relay in turn controls the actual lamp circuit. While it would be entirely feasible to use a relay at REL_1 having the ability to switch the lamp directly, it has been found in practice that the double relay system shown here has a lower overall cost and improved reliability. A less sensitive and less expensive relay, and one that imposes less stringent requirements on the photoconductor cell PC_2 may be used for relay REL_1 in the preferred arrangement. The thermostatic relay REL_2 is simple, cheap, rugged, and capable of handling large currents. Its relatively indefinite time delay of operation is no drawback in this service.

In a commercial version of the invention shown in the embodiment of Figure 2 the various components, as shown by the full lines, are assembled in a water tight glass covered case fitted with a three prong plug. The unit is then connected to the lamp and power line circuits, shown by the dashed lines, simply by plugging it in to an appropriately located socket.

The combination of glow lamp and photoconductive cell in a light tight enclosure as used in the invention possesses some characteristics that are not immediately apparent. Due to the possibility of shift of photoconductor cell characteristics under high light intensity and high current as previously noted, it is often imperative, as in the embodiments described, to limit the current flow in photoconductor cells exposed to a wide range of light intensity. If such cells are required to control a current responsive device such as a relay, it is necessary to provide some form of current amplification. In the embodiments described this function is performed by the encapsulated neon tube—photoconductor cell combina-

tion where a current gain of 10 to 1 is readily achieved. The invention, in fact, acts very much like a photo transistor with a very large light sensitive area and a low impedance output.

It will be noted that the energizing sources for the two photoconductor circuits may be entirely independent. A direct current source for PC_1 and an alternating current source for PC_2 , or vice versa, may be used. If independent sources are used the possibility of feedback from the output to input circuits via a common source impedance is not present.

It will be realized that the invention may be practised using current responsive elements other than relays controlled by the second photoconductor PC_2 . The scheme of cascading increasingly larger glow lamp-photoconductor assemblies at once suggests itself, as does the use of magnetic amplifiers actuated by the current flow in the second photoconductive cell. One of the simplest current responsive elements would, of course, be a current indicating meter, the arrangement then providing a measure of light intensity above a predetermined threshold level.

Whereas the invention has been described for the most part with reference to its use in a system which imposes a particular combination of operational difficulties upon photoconductive cells, it will be realized by those skilled in the art that the invention provides solutions to problems arising in a wide variety of applications of such cells. The scope of the invention is therefore not to be considered as being confined to the embodiments set forth in the disclosure but is to be judged in the light of the appended claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A radiant energy responsive circuit control arrangement comprising, a source of given electrical potential, a resistor of predetermined resistance value, a first photoconductive cell, means to connect said resistor and said first photoconductive cell serially across said source of potential, means to so mount said first photoconductive cell that it is exposed to said radiant energy, a glow discharge tube having a striking potential less than said given potential connected between the junction of said resistor and said first photoconductive cell and one side of said source of potential, a second photoconductive cell, a light impervious enclosure, means to mount said glow discharge tube and said second photoconductive cell within said enclosure in such relation that radiant energy produced by said glow discharge tube is directed upon said second photoconductive cell, a source of current, a circuit controlling element responsive to the flow of electric current, and means to serially connect said second photoconductive cell and said current responsive element across said source of current.

2. A circuit as claimed in claim 1 wherein a current limiting resistor is inserted in the connection between the junction of said resistor and said first photoconductive cell and said glow discharge tube.

3. A circuit as claimed in claim 1 wherein said circuit controlling element responsive to the flow of electric current is a relay.

4. A circuit as claimed in claim 1 wherein said resistor of predetermined value is an adjustable resistor.

5. A circuit as claimed in claim 1 wherein said source of electrical potential and said source of electrical current are constituted by a common source.

6. An ambient light actuated circuit switching arrangement comprising, a source of electrical power having a given potential, an adjustable resistor, a first photoconductive cell, means to serially connect said adjustable resistor and said first photoconductive cell across said source of power, means to so mount said photoconductive cell that it is exposed to said ambient light, a glow discharge tube having a striking potential less

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 than said given potential, a current limiting resistor, means to serially connect said glow discharge tube and said current limiting resistor between the junction of said adjustable resistor and said first photoconductive cell and one side of said power source, a second photoconductive cell, a light impervious enclosure, means to mount said glow discharge tube and said second photoconductive cell within said enclosure in such relation that radiant energy produced by said glow discharge tube is directed upon said second photoconductive cell, a relay having an actuating coil and switching contacts, means to serially connect said relay actuating coil and said second photoconductive cell across said power source, and a working circuit connected to the switching contacts of said relay and under the control thereof.

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 7. A circuit as claimed in claim 6 wherein said electrical power source is a standard 110 volt lighting supply source and wherein said glow discharge tube is a miniature neon tube having a striking voltage of the order of 75 volts.

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 8. A circuit arrangement as claimed in claim 6 wherein said working circuit is constituted by a further relay operable from said power source, said further relay controlling the energization of a further working circuit.

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 9. A circuit arrangement as claimed in claim 6 wherein said working circuit is constituted by a further relay operable from said power source, said further relay controlling the energization of a further working circuit and wherein said further working circuit is comprised of a lamp load, and wherein the elements of said circuit exclusive of said lamp load and said source of power are enclosed within a waterproof unitary mounting structure.

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