

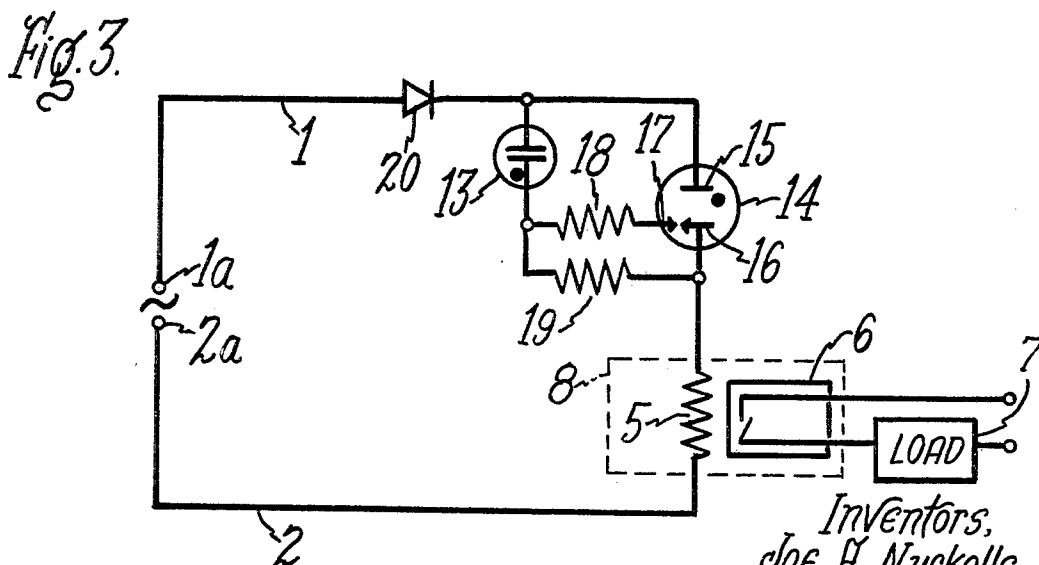
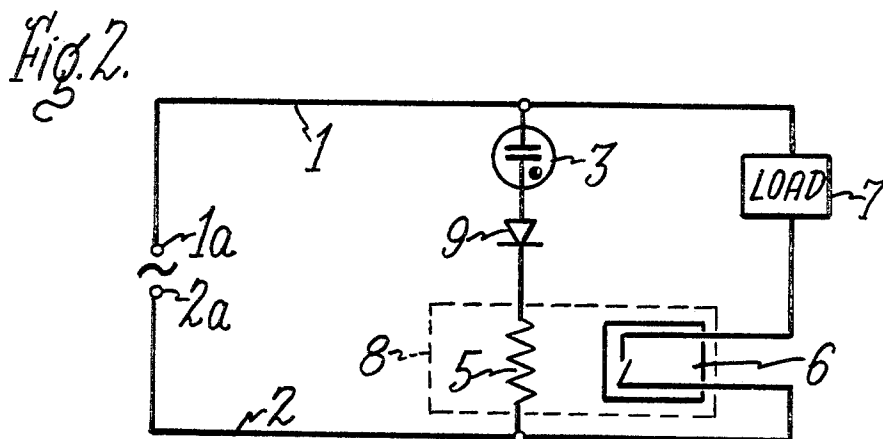
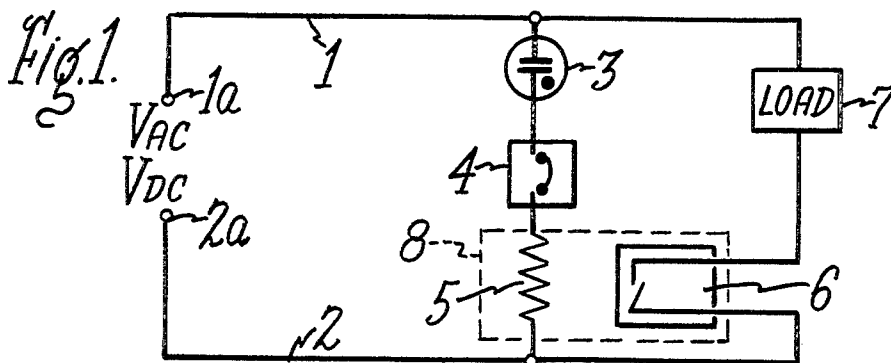
Dec. 9, 1969

J. A. NUCKOLLS ET AL
CONTROL CIRCUIT WITH VOLTAGE SENSITIVE
PHOTOELECTRIC GASEOUS DISCHARGE TUBE

3,483,430

Filed April 26, 1967

3 Sheets-Sheet 1



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Fig. 4.

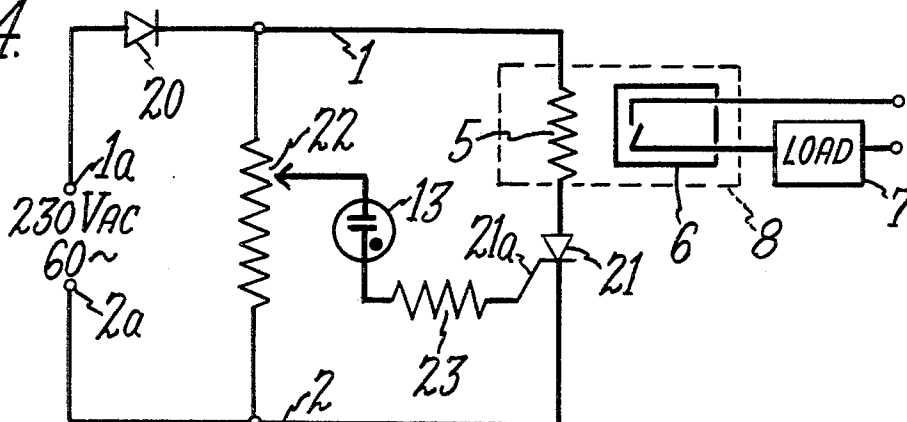


Fig. 5.

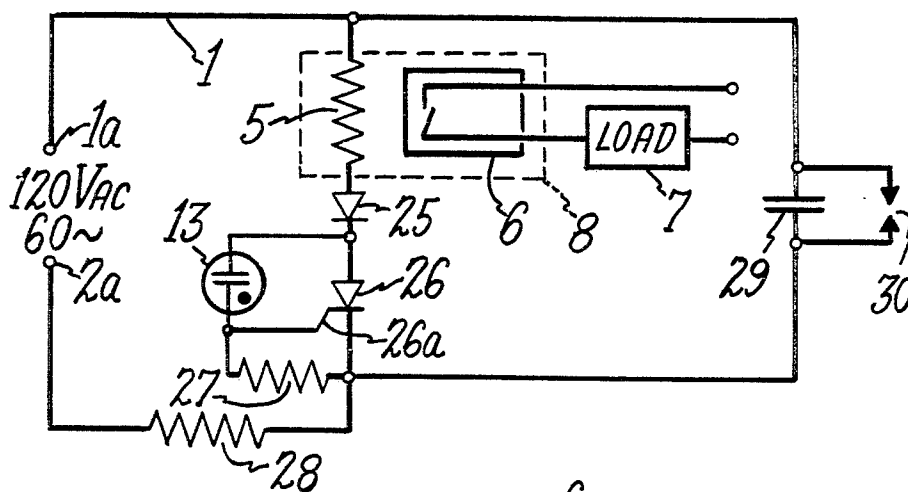
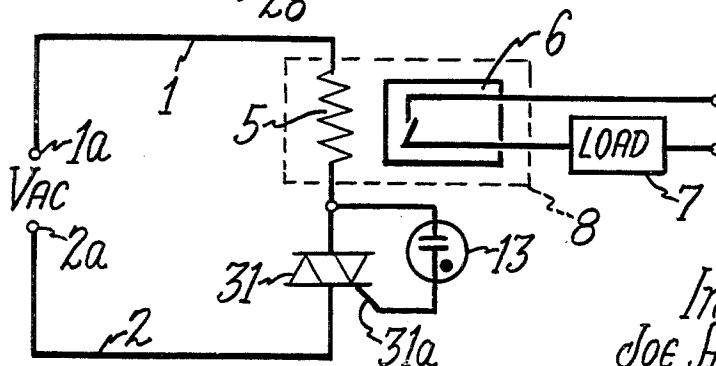


Fig. 6.



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3 Sheets-Sheet 3

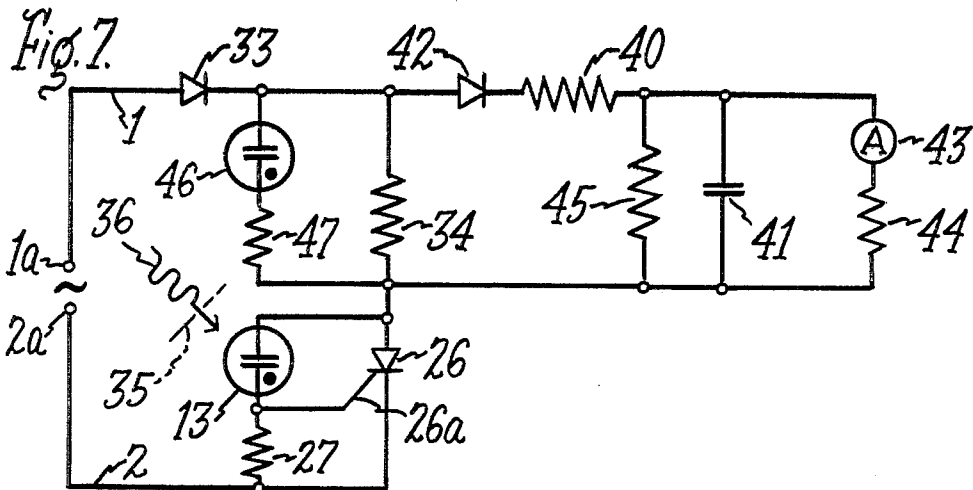
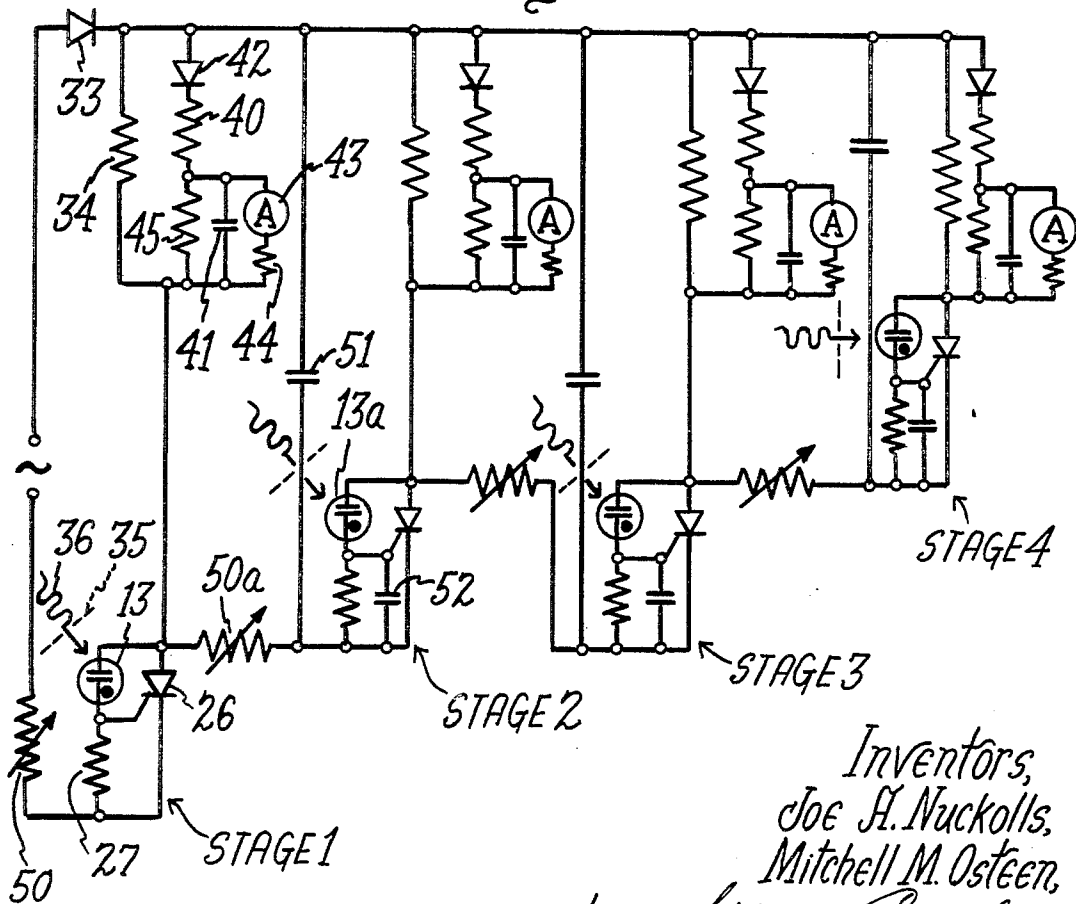


Fig. 8.



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CONTROL CIRCUIT WITH VOLTAGE SENSITIVE PHOTOELECTRIC GASEOUS DISCHARGE TUBE

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17 Claims

ABSTRACT OF THE DISCLOSURE

Photoelectric control device for switching loads on and off, such as street lights, comprises the combination of a photosensitive gaseous discharge tube for sensing desired radiation, a current interrupter for de-ionizing the gas tube to permit renewed radiation-sensing, and an integrating switch such as a thermal switch for operating the load in response to actuation of the gas tube by radiation of the desired intensity and wavelength.

It is an object of the invention to provide a photoelectric control device of the above type which is operated by external or ambient radiation, which may be of selected wavelength and intensity.

It is another object of the invention to provide a control device of the above type which may be operated by alternating or direct current at relatively low voltage levels.

Still another object of the invention is to provide a control device of the described type which is characterized by high current capacity for operating the integrating switch, while still retaining adequate sensitivity of the gas discharge tube to radiant energy.

Other objects and advantages will become apparent from the following description and the appended claims.

With the above objects in view, the present invention in a broad aspect relates to a photoelectric control device for controlling the operation of a load comprising a photosensitive gaseous discharge tube having a predetermined breakdown voltage, the gaseous discharge tube becoming conductive at the breakdown voltage by incidence thereon of radiant energy, means for connecting the gaseous discharge tube to a power supply for applying the breakdown voltage thereto, means operatively associated with the gaseous discharge tube for interrupting condition of current therethrough, and switch means responsive to the operation of the gaseous discharge tube for controlling operation of the load.

The invention will be better understood from the following description taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a circuit diagram showing the photoelectric control device of the invention in its broad aspects;

FIGURE 2 is a circuit diagram of an embodiment of the FIGURE 1 control device operated from an alternating current source;

FIGURE 3 is a circuit diagram of another embodiment of the control device which incorporates a plurality of different gaseous discharge tube devices;

FIGURE 4 is a circuit diagram of another embodiment of the control device incorporating a power amplifying device in a circuit arrangement which may be used with a relatively high voltage supply;

FIGURE 5 is a circuit diagram of an embodiment of the control device incorporating a modified current interrupting and power amplifying arrangement and employed with a voltage supply of conventional level;

FIGURE 6 shows still another embodiment of the control device having a different power amplifying device;

FIGURE 7 is a circuit diagram of another embodiment of the control device including a radiation counting means; and

FIGURE 8 shows a modification of the FIGURE 7 circuit embodying a multi-stage counting device of increased range.

Referring now to the drawings, and particularly to FIGURE 1, there is shown a photoelectric control arrangement of the invention connected to supply lines 1 and 2 having terminals 1a, 2a for connection to a suitable power supply, which may be either alternating or direct current. A gas tube 3, having the characteristics more fully described below, is connected across the power supply in series with a current interrupter 4 and a heating resistor 5. Arranged adjacent to the heating resistor 5 is thermal switch 6 which is connected in series with a load 7 connected to supply lines 1, 2. In a typical application of the described control device, load 7 is a street lighting luminaire. Although the circuit comprising thermal switch 6 and load 7 is shown connected to supply lines 1, 2 it will be understood that this circuit, as well as the load circuits in the other arrangements shown in the drawings, may alternatively be connected to other power sources if desired.

Gas tube 3 is of a type which responds to radiant energy of some form, and in the application of the device for turning the street lighting luminaire on and off at desired light levels, gas tube 3 is sensitive to wavelengths of ambient light, such as those of visible or ultraviolet light. Such photosensitive gas tubes typically comprise a glass envelope enclosing an ionizable gas such as neon and a pair of spaced electrodes. The gas tube has a characteristic voltage breakdown level, and when that level is reached and selected radiation is incident on the gas tube to cause photoemission of electrons from the cathode, the gas becomes ionized, resulting in condition of current through the tube. A difficulty which arises in connection with the use of conventional forms of such tubes, also known as glow lamps, is that once the tube is ionized it continues to conduct current as long as the applied voltage does not fall below its breakdown level, whether or not the selected radiation is still present. This difficulty is overcome by the present invention by the provision of means, which may take various forms, for interrupting the current through the tube. By such means the gas tube is de-ionized at intervals such that it can recover to a condition in which it is capable of detecting subsequent photoemitting or photoionizing radiations.

A current interrupting means for this purpose is represented in FIGURE 1 by circuit breaker 4. The latter may be any of known devices of this type which is normally closed, but which opens at predetermined intervals during the time when it is actuated. It may, for example, be a current sensitive or a thermo-sensitive circuit breaker device. In operation, when radiation is detected by gas tube 3, current flows to heating resistor 5 through circuit breaker 4. The latter opens after a predetermined time, at which time, if no radiation is present, the circuit is de-energized. If continued radiation is sensed, gas tube 3 will immediately re-ionize upon the closing of the circuit breaker, and resistive heater 5 will eventually actuate thermoswitch 6, thus energizing load 7. Thermoswitch 6 thus has an integrating effect on the circuit, which avoids sporadic operation of the load such as would be caused by normal fluctuations of the light intensity at the low lighting levels at dusk and dawn. Once thermoswitch 6 has closed or opened, its thermal lag or differential is adequate to hold it in that position until a substantial variation in temperature occurs to change its

position. In the use of the described device for operating street lighting luminaires, the contacts of thermoswitch 6 would normally be closed during the hours of darkness when gas tube 3 is not actuated by light rays, and the contacts would be open during the daytime due to the effect of heat thereon produced by integrating resistor 5 which results from conduction by gas tube 3 when daytime light rays are incident thereon. In practice, resistor 5 and thermal switch 6 are preferably mounted within a suitable enclosure 8 so that the integrated heating effect of the resistor on the thermal switch is not unduly dissipated. The time required for closing and opening thermal switch 6 may, of course, be varied as desired by selection of an appropriate heating resistor or thermal switch having the desired heating or response characteristics.

The light sensitive gaseous discharge tube employed in the invention is similar in form to conventional glow lamps commonly used as indicator lamps. It differs significantly from such conventional lamps, however, in that it is kept as free as possible from additives of low effective work function which have been used in known glow lamps to assure a plentiful supply of avalanche-initiating electrons other than photoemitted electrons. Such additives are used in the prior art to facilitate breakdown of the glow lamp and minimize the so-called "dark effect." In the present invention such as "dark effect" is emphasized in order to make the gas tube more selectively responsive to radiations. A particular gas tube design found satisfactory in practicing the invention comprised nickel electrodes, a penning gas mixture of 99% neon-1% argon at a pressure of 50-80 torr, and a lead glass envelope. Low work function materials such as caesium, barium, strontium, and their oxides are avoided, as well as radioactive additives. Further, it is desirable to avoid oxide films on the electrodes, since these can promote field emission of electrons after conduction has once started. The electrodes may be made of metals other than nickel, such as molybdenum, tungsten or any electrode metal which has an effective work function greater than 3.5 electron-volts. The gas in the tube is preferably a neon-argon gas mixture with a range of about .1-1% by volume of argon.

The gas tube may be made selective to radiation of desired wavelengths by various means. For example, a suitable element may be added to the tube which has an ionization potential such that radiation of particular wavelengths impinging thereon will cause photoemission of electrons. Thus, to make the photocontrol device sensitive only to ultraviolet radiation, a voltage potential is applied across the gas tube which is less than the field emission breakdown voltage, but higher than the holding voltage, the gas tube having electrode metals therein having an effective work function between about 3.0 and 4.0 electron-volts, corresponding to about 400-300 millimicron (ultraviolet) radiation. Alternatively, optical filters passing the desired wavelengths could be used in conjunction with the gas tube, or the glass envelope of the tube may be selected to have the desired light filtering properties.

FIGURE 2 shows a photoelectric control device similar to that of FIGURE 1 except that a rectifying diode 9 is used in place of circuit breaker 4, the circuit being connected to an alternating current supply. Diode 9 serves as a de-ionizing or voltage-recovery means by removing the applied voltage on alternating half-cycles, thus permitting gas tube 3 to de-ionize each half-cycle at a 60 cycle per second frequency and thus return to a condition for resensing the selected radiation. Such an arrangement would be useful under high cosmic radiation conditions. While the diode is shown as a separate component, it could be incorporated in the gas tube structure.

FIGURE 3 shows a modification of the photocontrol device in which two different types of gas tubes are used in order to permit the device to conduct high currents

for actuation of the thermoswitch while still having good sensitivity to selected radiation. It was found that the passage of relatively high currents through the radiation detecting gas tube led to difficulties in returning the tube to the desired non-conducting de-ionized state. In the FIGURE 3 arrangement, a sensitive radiation-detecting gas tube 13 of low current capacity is connected via rectifying diode 20 to an alternating current supply in parallel with a second gas tube 14 which has a high current carrying capacity and is designed to be self-quenching at the end of each half cycle. Diode 20 serves as a current interrupting device to assist de-ionization of gas tubes 13 and 14 similarly to diode 9 previously described. Gas tube 14 comprises main electrodes 15 and 16 and a triggering electrode 17 connected to detecting gas tube 13 through series-connected resistance 18. Electrodes 16 and 17 have closely spaced ends which are preferably pointed in order to cause high field stresses even when the voltage drop therebetween is very low. The current passing between these electrodes, although of the order of only micro-amperes, is sufficient to ionize the gas in gas tube 14 to initiate the main flow of heavier current between electrodes 15 and 16 which passes to thermoswitch heating resistor 5. Resistance 19 arranged in series between gas tube 13 and heating resistor 5 serves to force all the line voltage to be applied to gas tube 13 so that the latter attains the necessary breakdown voltage level. Resistance 18 functions to keep gas tube 13 from drawing excessive current when electrode 17 is triggered. Thus, light-sensing gas tube 13 carries very little current and quickly returns to a non-conducting state, and high current-carrying gas tube 14 must be triggered each time it conducts. In effect, gas tube 14 serves as a triggered switch.

FIGURE 4 shows a modified photocontrol arrangement which may be employed, wherein a power amplifying device such as a controlled rectifier is used in conjunction with the radiation sensing gas tube. The illustrated circuit also shows a voltage reduction arrangement which may be used to avoid application of high voltages to the gas tube which would tend to cause breakdown of the latter by field emission rather than by the desired photoemission. In this circuit, heating resistor 5 is connected by supply lines 1, 2 to a 230 or 440 volt alternating current supply, and in series therewith is arranged a silicon controlled rectifier (SCR) 21 having a control electrode 21a. Detecting gas tube 13 is connected on one side to an adjustable voltage-divider 22 connected across the power source, whereby the voltage applied to the gas tube may be reduced to a desired level, e.g., 120 volts. On the other side, gas tube 13 is connected to the control electrode 21a of SCR 21 through resistor 23 which typically is of the order of 10K ohms and serves to limit the current passing through the gas tube 13. In the operation of this circuit, SCR 21 is triggered into conduction through its control electrode when gas tube 13 is actuated by selected radiation as previously described, and as a result the line current passes through heating resistor 5 for operating thermoswitch 6. SCR 21 thus serves as a switch means which acts in connection with thermoswitch 6 for controlling the operation of load 7.

FIGURE 5 shows a further embodiment of the control device using the gas tube and silicon controlled rectifier combination in a different arrangement. In this circuit, heating resistor 5, diode 25 and SCR 26 are connected in series across a power supply of 120 volts AC. Detecting gas tube 13 is connected in shunt with SCR 26 via resistor 27, and control electrode 26a of SCR 26 is connected to the junction of gas tube 13 and resistor 27. Resistor 28 connected to the line in series with SCR 26 is a surge voltage protective means, and typically has a value of about 56 ohms. SCR 26 is used as a current amplifying device for the signal generated by gas tube 13. Before SCR 26 is gated on by conduction of gas tube 13, it serves as an open switch, leaving gas tube 13 in

series with heating resistor 5, resistor 27, and surge resistor 28. Diode 25 will permit current conduction through this series circuit during alternating half cycles. In this arrangement sufficient voltage is applied to gas tube 13 to support breakdown thereof, which will occur as soon as an electron is photoemitted from its cathode. When gas tube 13 does break down, it immediately draws current which establishes a potential across resistor 27, which is the SCR gate-to-cathode resistor. SCR 26 quickly responds to such a voltage pulse and permits line current to flow therethrough. When SCR 26 is gated on, the cathode to anode voltage drops to a very low value, e.g., 1.5 volt, and accordingly the time in which gas tube 13 conducts current is very short, e.g., 100 microseconds for each cycle in which it fires, because the voltage drop across it cannot be greater than that across SCR 26. As a result, gas tube 13 has a low duty cycle, which contributes to long life of this component in the described arrangement.

Resistor 27, which may typically be in the range of 200-1000 ohms, contributes to the life and stability of SCR 26 by effectively lowering its input impedance, thus eliminating the over-sensitiveness of the gate circuit. Resistor 27 can be omitted with some types of SCR's.

Diode 25 not only serves as a current interrupter for de-ionizing gas tube 13 as previously described, but also bears the principal burden of holding off reverse voltage so as to protect SCR 26.

Resistor 5, which may typically be 2000 ohms in the illustrated circuit, serves to limit the current through SCR 26 as well as functioning as a thermal integrator in conjunction with thermoswitch 6, as previously described.

Surge and transient voltage protection for the circuit is provided by parallel-connected capacitor 29 and spark gap 30 which are arranged in shunt with the above-described circuit components and in series with resistor 28. In this arrangement capacitor 29 effectively short-circuits high frequency voltage transients, and spark gap 30 clamps power voltage surges of longer duration as the series resistor 28 provides the series voltage dropping element across which the transients and surges appear.

The thermoswitch 6 used in this or any of the other disclosed circuits may be any of several which are commercially available. A particular type which has proved satisfactory is one incorporating a Spencer bi-metal disc which has an effective snap-action. This device exhibits long life while switching heavy loads, such as 1000 watt incandescent lamps of 1800 volt-ampere inductive loads.

In the further modification shown in FIGURE 6, a symmetrical semiconductor switch 31, such as a triac, is used in place of the silicon controlled rectifier of the FIGURE 5 device. A "triac" is an alternating current semiconductor controlled switch having a single control electrode which, when gated, causes the switch to conduct current in the direction as indicated by the forward bias condition of the semiconductor. A triac may also be described as a bi-directional triode for gate control of alternating current power. In this arrangement, gas tube 13 is connected to the control electrode 31a of triac 31 and thereby triggers the latter for conduction alternately in each direction. Since only non-catastrophic forward breakover can occur, the need for surge and transient voltage protection may be largely dispensed with. Since this device now utilizes the full sine-wave of the applied voltage, a diode is no longer employed. However, adequate time for quenching gas tube 13 is still provided since the latter is in the conducting stage for only a small percentage of the time even when responding to radiation on every half cycle.

It will be understood that although particular components, such as diode or circuit breaker, are provided in the disclosed circuits for interrupting the current to assist in de-ionization and recovery of the radiation sensing gas tube, the means for effecting this function may

form a part of the gas tube structure itself. For example, the electrodes of the gas tube may be made of different metals having different effective work functions. Thus, an electrode of nickel or molybdenum, which have effective work functions in the range of about 3 to 4 electron-volts, may be used in combination with an electrode of tungsten or copper, which have effective work functions in the range of about 5 to 6 electron-volts. When such electrode combinations are used with an alternating current supply, the electrode of the higher work function metal will tend to interrupt the current flow when it becomes the cathode, since greater energy is required for causing emission of electrons from such cathode metals, as compared to the electrode metals of lower work function. Thus, such combinations of electrode metals in the gas tube will function in a manner somewhat equivalent to the diode and circuit breaker components, and in certain cases the latter components may therefore be entirely dispensed with.

While the invention has been described above mainly as applied to controlling the operation of street lighting luminaires, it will be understood that it may find application for a variety of other uses. For example, the sensing gas tube may be used for detecting the presence of a flame in a burner or furnace, and my thermoswitch 6 actuate the associated device which it is desired to operate in dependence on the presence or absence of such a flame.

It has also been found that gas tubes of the above-described type are responsive to the photons of high-energy radiations such as X-rays and gamma rays. Such high-energy photons generate free electrons and ions by collision with the metal electrodes or the gas in the tube, or both. Such electrons and ions initiate a gas avalanche breakdown in the gas tube in a manner similar to the light-photoemitted electrons described above, except that the gas is subject to direct ionization by the X- or gamma rays, whereas neon, for example, is not ionized by radiation of wavelengths longer than about 50 millimicrons. Accordingly, the circuits already described may be used for detecting X-rays or gamma rays, and in a practical application for this purpose the apparatus would be used in complete darkness or the gas detector tube would be shielded from all but the desired radiation by a suitable filter. An opaque cloth enveloping the gas tube, for example, might be suitable. In such applications, load 7 could be constituted by an alarm device which would operate if the radiation level exceeded a selected value. If the radiation is of relatively low intensity, a circuit such as shown in FIGURE 5 could serve to operate a counter device for counting the photons impinging on the detecting gas tube.

FIGURE 7 is a circuit diagram of such an arrangement for providing a direct readout on an indicator which is proportional to the counting rate (i.e., firing rate) of SCR 26. In this modification, the circuit comprises rectifying diode 33, load resistor 34, and SCR 26 connected in series across A-C supply terminals 1a, 2a, and detecting gas tube 13 and resistor 27 are connected across SCR 26 and to control electrode 26a as in the FIGURE 5 circuit. In an X-ray detecting application, shield 35 permits only X-ray radiation 36 to impinge on gas tube 13. In this embodiment, the thermal switch arrangement of the FIGURE 5 circuit is replaced by an RC charging circuit to integrate the output across load resistor 34. This charging circuit comprises resistor 40 and charging capacitor 41 connected in series across load resistor 34, with diode 42 in series with resistor 40 serving to isolate the charging circuit from the described SCR circuit. Connected across charging capacitor 41 is microammeter 43 in series with current limiting resistor 44. Discharge resistor 45 is also connected across capacitor 41. An indicator lamp 46, such as a neon glow tube, in series with current limiting resistor 47 is connected across load resistor 34.

When SCR 26 is gated on in response to breakdown of radiation detecting gas tube 13, most of the applied voltage is dropped across resistor 34, thus charging capacitor 41 through resistor 40 and diode 42. When the applied voltage becomes less than the voltage across capacitor 41, the charge on the latter is prevented by diode 42 from passing back through load resistor 34. However, the charge is permitted to leak off at a controlled rate through discharge resistor 45, which typically has a resistance value several times that of resistor 40. Discharge resistor 45 thus serves to leak off a small percentage of the charge on capacitor 41 for the purpose of forcing the voltage across capacitor 41 to reflect the integrated voltage appearing across resistor 34 over a selected period of time, dependent on the selected values of resistor 40, resistor 45, and capacitor 41. Microammeter 43 thus provides an indication of this integrated voltage which is proportional to the firing rate of SCR 26.

In those cases where indicating meter 43 has a suitable level of internal resistance, discharge resistor 45 may be dispensed with.

Neon glow lamp 46 gives a visual indication of the firing rate of SCR 26 and, hence, the relative intensity of the impinging X-ray radiation.

Where the intensity of the incident radiation is above a certain level, e.g., 60 photons per second, the circuit shown in FIGURE 7 would become saturated and therefore would not reflect the actual radiation intensity. The range of the circuit could, if desired, be extended by the use of radiation absorbing filters which absorb a predetermined percentage of the incident photons.

Alternatively, high counting rates may be achieved by the multi-stage circuit in FIGURE 8. Shown therein is a four-stage counter in which each successive stage is set to have, say, one-tenth the sensitivity and therefore ten times the counting range of the previous stage. The portion of the circuit of FIGURE 8 designated as Stage 1 is essentially that shown in FIGURE 7, with like components designated by like numerals. In addition, a variable resistor 50 is placed in series with SCR 26, load resistor 34, and line diode 33. When SCR 26 is gated on, a major portion of the applied voltage appears across load resistor 34, while some voltage drop appears across SCR 26 and variable resistor 50. Since Stage 2, which is essentially the same as Stage 1, is connected across load resistor 34 of Stage 1 it would be responsive to the applied voltage minus that portion thereof which is dropped across the SCR and variable SCR cathode resistor 50 of Stage 1. Variable resistor 50 is adjusted so that the voltage applied to Stage 2 is reduced, thereby reducing the sensitivity of Stage 2. It will be evident that Stage 2 will not respond to radiation impinging on its detecting gas tube 13a unless Stage 1 has already been actuated.

Capacitor 51 shown connected in shunt with Stage 2 and in series with its variable resistor 50a prevents the high-frequency voltage wave front generated by SCR 26 in Stage 1 from causing the corresponding Stage 2 SCR to inadvertently fire due to the high rate of voltage change.

Each successive Stage shown in FIGURE 8 is arranged and operates as described in connection with Stage 2. The reading on the microammeter in the Stage having the appropriate sensitivity for the existing radiation conditions will accurately reflect the radiation intensity.

Capacitor 52 shown connected between the SCR control electrode and cathode in Stage 2 is preferably provided in the case where the detecting gas tube 13a is packaged in a probe-type configuration where its leads may run parallel for some distance, and serves to prevent inadvertent firing of the SCR due to inductive coupling effects attendant on such probe-type configurations. Such capacitors may be dispensed with where the detecting tube leads are individually shielded from each other.

As used herein, the terms "photoelectric" "photo-sensitive" refer to sensitivity to the action of radiant energy, as is evident from the foregoing description.

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 scope of the invention. Therefore, the appended claims are intended to cover all such equivalent variations as come within the true spirit and scope of the invention.

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

1. Control device for controlling the operation of a load comprising, in combination, a photo-sensitive gaseous discharge tube having a predetermined breakdown voltage and constituting a voltage sensitive switch, said gaseous discharge tube being normally non-conductive but rendered conductive by the application of said predetermined voltage thereto and the simultaneous incidence thereon of radiant energy, means for connecting said gaseous discharge tube to a power supply for applying said breakdown voltage thereto, means operatively associated with said gaseous discharge tube for repeatedly interrupting conduction of current therethrough for making the operation of said tube substantially continuously dependent on the presence of said radiant energy, and switch means responsive to the operation of said gaseous discharge tube for controlling operation of the load.

2. A device as defined in claim 1, said switch means comprising means for integrating the output of said gaseous discharge tube.

3. A device as defined in claim 2, said switch means comprising a heating resistance means and a thermostat switch exposed to the heat produced by said heating resistance means for turning the load off and on in response to predetermined temperature levels.

4. A device as defined in claim 3, said current interrupting means comprising intermittently operating circuit interrupting means connected in series with said gaseous discharge tube.

5. A device as defined in claim 3, said current interrupting means comprising electrode metals in said gaseous discharge tube having different work function values.

6. A device as defined in claim 3, said current interrupting means comprising rectifier means for blocking current flow from an alternating current supply on alternate half cycles.

7. A device as defined in claim 2, and means responsive to the signals produced by breakdown of said gaseous discharge tube for amplifying the power of said signals and transmitting the same to said integrating switch means.

8. A device as defined in claim 7, said power amplifying means comprising a second gaseous discharge tube connected across said first-mentioned gaseous discharge tube and having a pair of main electrodes and a triggering electrode, said triggering electrode being connected to said first-mentioned gaseous discharge tube.

9. A device as defined in claim 7, said power amplifying means comprising controlled rectifier means connected across said gaseous discharge tube and having a control electrode connected to said gaseous discharge tube.

10. A device as defined in claim 9, said controlled rectifier means comprising symmetrical bi-directional conducting means.

11. A device as defined in claim 1, wherein said load comprises indicating means connected to said switch means for indicating the operation of said gaseous discharge tube.

12. A device as defined in claim 1, and integrating means connected to said switch means for integrating the output of said gaseous discharge tube.

13. A device as defined in claim 1, said switch means comprising controlled rectifier means connected across said gaseous discharge tube and having a control electrode connected to said gaseous discharge tube.

14. A device as defined in claim 13, and integrating

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circuit means connected to said controlled rectifier means for integrating the output of said gaseous discharge tube.

15. A device as defined in claim 14, said integrating circuit means comprising impedance means connected in series with said controlled rectifier means, and an RC network including a resistor and a capacitor connected in series across said impedance means.

16. A device as defined in claim 15, said integrating circuit means including indicator means connected across said capacitor for indicating the thus integrated output of said gaseous discharge tube.

17. A device as defined in claim 16, wherein a plurality of such devices are connected successively in stages across the impedance means of the preceding stage, and variable impedance means connected in series with the controlled rectifier means of the respective stages for adjusting the sensitivity of the respective stages to the radiation incident on the gaseous discharge tubes thereof.

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U.S. Cl. X.R.

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