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W. H. T. HOLDEN
ELECTROOPTICAL SYSTEM

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FIG. 1

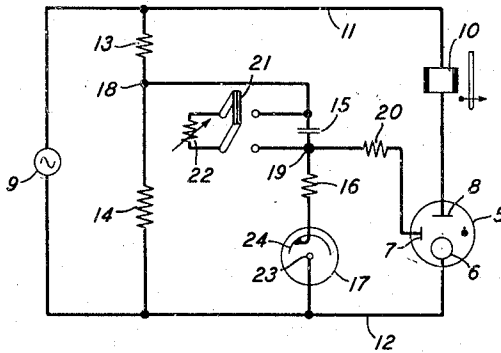
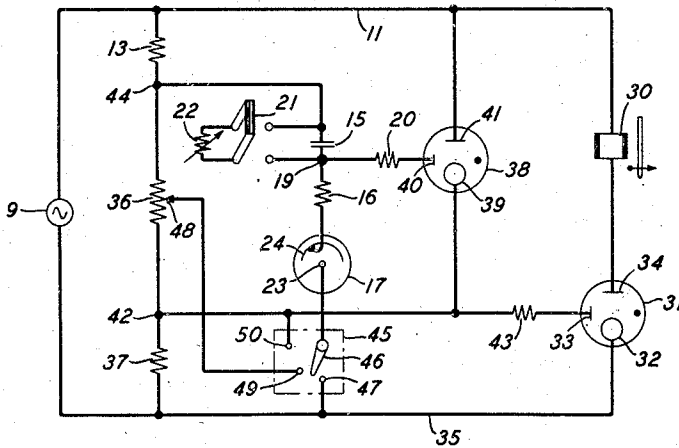


FIG. 2



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ELECTROOPTICAL SYSTEM

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This invention relates to electrical control systems and more particularly to electro-optical systems.

An object of the invention is to provide an improved electrical control system comprising a gaseous discharge device.

Another object is to provide an improved method of controlling the firing of gaseous discharge trigger tubes.

In an example of practice of the invention a gaseous discharge device having a cold cathode, an anode, and a control electrode is connected in circuit with a load device and a source of alternating current voltage so that the energization of the load device may be controlled by the illumination of a photoelectric tube. Increased sensitivity to light is obtained by so connecting the photoelectric cell in a circuit between the control electrode and the cathode of the gaseous discharge tube, that a condenser is charged by current flowing through the photoelectric cell during each half wave of the alternating current voltage which makes the anode negative with respect to the cathode and the voltage due to such charge is added to the alternating current voltage during each succeeding half wave which makes the anode positive with respect to the cathode to eventually produce a summation positive voltage on the control electrode with respect to the cathode to trigger off the main discharge, or, in other words, to fire the gaseous discharge tube.

In this example of practice of the invention the source of alternating current voltage is connected in series with the energizing winding of a relay which serves as load device and the main discharge path of the gaseous tube. A resistive voltage divider is connected across the source of alternating current voltage. Across a portion of this voltage divider there is connected a condenser, a resistor and a photoelectric tube in series in the order named with the anode of the photoelectric tube connected to the terminal of the voltage divider which is connected to the cathode of the gaseous discharge tube. The junction of the series resistor and condenser is connected through another resistor to the control electrode of the gaseous discharge tube. The peak voltage which is impressed on this series arrangement of condenser, resistor and photoelectric tube from the voltage divider is insufficient alone to fire the gaseous discharge tube even on a positive peak half wave. However, on each negative half wave when the photoelectric tube is illuminated, a charge is accumulated on the condenser which is of a polarity tending to make

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the control electrode positive with respect to the cathode. This charge is trapped on the condenser because it leaks off during the positive half wave period very much more slowly than it is accumulated on the negative half wave period. The voltage due to this accumulated charge is added to the positive half wave of the alternating current voltage to make the control electrode more positive with respect to the cathode than it would be otherwise. This summation voltage therefore fires the gaseous discharge trigger tube.

This system is extremely sensitive to illumination of the photoelectric tube. High voltage gaseous discharge tubes may be employed because the system is not dependent upon a high current-carrying capacity of the photoelectric tube so that vacuum photoelectric tubes may be employed. For rapid action, the capacity of the condenser may be made small providing only that it is large enough to supply the transfer current for the gaseous discharge tube. The sensitivity to small illumination is dependent upon the leakage of charge from the condenser during the positive half wave periods. One significant leakage path is between the control electrode and the cathode within the gaseous discharge tube. This leakage path determines the minimum illumination on which the gaseous tube will fire. The sensitivity may be reduced by connecting a resistor in shunt of the condenser.

In a further modified arrangement illustrative of this invention two gaseous discharge tubes are employed. The first is a tube requiring low transfer current which is fired under control of a photoelectric tube as above described. A small condenser only is needed to supply such transfer current. The second is fired by the firing of the first in such a manner that a voltage developed across a resistor by the main discharge current of the first gaseous tube is added to a part of the positive half wave voltage of the alternating current voltage source to trigger off the second gaseous discharge tube.

The invention may be embodied in still other arrangements.

The invention will now be described more in detail having reference to the accompanying drawing.

Fig. 1 illustrates one embodiment of the invention comprising a single gaseous discharge tube.

Fig. 2 illustrates a second embodiment of the invention comprising two gaseous discharge tubes.

Like elements in the several figures of the drawing are indicated by identical reference characters,

Referring now to Fig. 1 of the drawing, a specific embodiment of the invention is illustrated in the form of an electro-optical control system. A gaseous discharge trigger tube 5 comprising a cold cathode 6, a control electrode 7 and an anode 8 is connected in circuit with a source of alternating current voltage 9 and a load device, such as a relay 10. One terminal of relay 10 is connected to one terminal of the source 9 by conductor 11. The other terminal of relay 10 is connected to the anode 8. The cathode 6 is connected to the other terminal of source 9 by conductor 12. A voltage divider consisting of resistors 13 and 14 is connected across the alternating current voltage source 9 between conductors 11 and 12. Across resistor 14 there is connected condenser 15, resistor 16 and photoelectric tube 17 in series, the anode 23 of tube 17 being connected to conductor 12 and the upper terminal of condenser 15 being connected to the junction 18 of the joined terminals of resistors 13 and 14. The junction 19 between the joined terminals of condenser 15 and resistor 16 is connected by a resistor 20 to the control electrode 7 of gaseous discharge tube 5. By means of a double pole switch 21 a variable leakage resistor 22 may, if desired, be connected in shunt of condenser 15.

The peak voltage of the source 9 is set below the breakdown voltage of the discharge path between the cathode 6 and anode 8 of the gaseous discharge tube 5, when the condenser 15 is in discharged or almost discharged condition, that is, when the peak voltage across resistor 14 on the positive half wave only is impressed on the control electrode 7 to make it positive with respect to the cathode 6. Under these conditions the gaseous tube 5 cannot fire. With the switch 21 open the junction 19 on the positive half wave assumes approximately the potential of the junction 18 which is positive with respect to the conductor 12 and cathode 6. There is some tendency for electrons to flow from the cathode 6 to the control electrode 7 but no disruptive discharge occurs and the condenser 15 is only slightly charged with the lower plate negative with respect to the upper plate, that is, with a polarity to oppose the positive half wave voltage across resistor 14. With the switch 21 closed even a smaller charge accumulates on condenser 15. During the period of the positive half wave the photoelectric cell 17 is substantially blocked so that no current flows therethrough. During the period of the negative half wave of voltage of the source 9 there is obviously no tendency for the gaseous tube 5 to fire because the anode 8 is negative with respect to the cathode 6. Under these circumstances the junction 19 is negative with respect to conductor 12 and cathode 6 and there results only a very small flow of electrons from the control electrode 7 to the cathode 6 through the gaseous path within the tube 5 and any inherent leakage path between the control electrode 7 and the cathode 6. Such flow of electrons tends to charge the condenser 15, making the lower plate positive with respect to the upper plate. Such charge, however, would not exceed an exceedingly small value because of the inherent leakage between the terminals of condenser 15 even with the switch 21 open and would be negligible if the switch 21 were closed to connect leakage resistor 22 in shunt of condenser 21. When junction 19 is negative with respect to conductor 12 there is a tendency for current flow through the photoelectric tube 17 because the anode 23 is positive with respect to the cathode 24. However, if the tube 17 is in the dark, that is, not il-

luminated, no electron flow takes place and condenser 15 remains practically discharged so that discharge tube 5 is not fired even on positive half waves of the alternating current voltage from source 9.

Conditions are quite different, however, when the photoelectric tube 17 is illuminated even to a small amount. On the negative half wave of the alternating current voltage the junction 19, as hereinbefore mentioned, is negative with respect to the conductor 12, that is, the anode 23 of photoelectric tube 17 is positive with respect to the cathode 24. Electrons flow from the cathode 24 to the anode 23 which makes the lower plate of condenser 15 positive with respect to the upper plate. During the following positive half wave the voltage on condenser 15 is added to the voltage across resistor 14 to make the potential of control electrode 7 more positive with respect to the cathode 6 than it otherwise would be. This charge on condenser 15 is substantially trapped during the positive half wave. However, if the illumination is large enough and the condenser small enough, the charge accumulated on condenser 15 may be great enough during a single negative half wave to produce a voltage on condenser 15 which, when added to the peak voltage across resistor 14 on the following positive half wave, will fire the gaseous discharge tube 5. On smaller illuminations the accumulation of increments of charge on condenser 15 during several negative half waves may be required to produce sufficient voltage to fire the tube 5 on a following positive half wave.

From the foregoing description of the arrangement of Fig. 1, it is seen that a very sensitive electro-optical control circuit results from this invention. It will operate on both small and large illuminations. The minimum illumination required to fire the gaseous tube 5 is a function of the leakage conductance across the terminals of condenser 15. The number of negative half waves required to cause firing of the gaseous tube 5 with minimum illumination of photoelectric tube 17 is a function of the capacitance of the condenser 15. The minimum capacitance of the condenser 17 is dependent upon the amount of transfer current required to fire the gaseous tube 5. The resistance of resistor 20 is a function of the time required to sustain the transfer current discharge to effect the main discharge. The leakage conductance of condenser 15 is a function of the conductance between control electrode 7 and cathode 6 of gaseous tube 5 and the value of resistor 22 when switch 21 is closed. As shown in Fig. 1, resistor 22 may be varied as desired.

It is to be noted that photoelectric tube 17 functions as a current controller in a unilateral or one-way circuit. Electrons flow only from the cathode 24 to the anode 23 except for a normally insignificant amount of leakage conductance between the terminals of the tube. Dependent upon the results desired, it is seen from the foregoing description that other kinds of unilateral current controllers may be used.

In order to operate some types of load devices, a type of gaseous discharge device is required which itself requires a relatively high value of transfer current. This necessitates the use of a relatively high capacity condenser 15 which, in turn, reduces the sensitivity of the system for rapid action.

A modified form of circuit which overcomes the above-mentioned disadvantage of the arrangement of Fig. 1 is illustrated in Fig. 2. The relay 30 of Fig. 2 is of a type which requires a gaseous

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discharge tube 31 having a high value of transfer current to effect the main discharge to operate the relay 30. The tube 31 comprises a cold cathode 32, a control electrode 33 and an anode 34. One terminal of relay 30 is connected to one terminal of the source of alternating current voltage 9 by conductor 11. The other terminal of relay 30 is connected to anode 34. Cathode 32 is connected to the other terminal of the alternating current voltage source 9 by conductor 35. A voltage divider consisting of resistor 13, potentiometer 36 and resistor 37 is connected across the alternating current voltage source 9 between conductors 11 and 35. A second gaseous discharge tube 38 having a low value of transfer current is used to effect the firing of gaseous discharge tube 31. Tube 38 comprises a cold cathode 39, a control electrode 40, and an anode 41. The anode 41 is connected to one terminal of alternating current voltage source 9 by conductor 11. The cathode 39 is connected to the junction 42 between the joined terminals of potentiometer 36 and resistor 37. The cathode 39 is also connected to control electrode 33 of gaseous tube 31 through resistor 43. The condenser 15, resistor 16, photoelectric tube 17, switch 21 and resistors 20 and 22 are arranged to control the firing of gaseous tube 38 in much the same manner that the same elements in Fig. 1 are arranged to control the firing of gaseous tube 5. The upper plate of condenser 15 is connected to the junction 44 of the joined terminals of resistor 13 and potentiometer 36. The anode 23 of photoelectric tube 17 may be connected by a three-position switch 45 to conductor 35 when switch blade 46 is closed on contact 47, or to the movable contact 48 of potentiometer 36 when switch blade 46 is closed on contact 49, or to the junction 42 between the joined terminals of potentiometer 36 and resistor 37 when the switch blade 46 is closed on contact 50. The operation is much the same whether the switch blade 46 is closed on contacts 47, 49 or 50. In every case, when the photoelectric tube 17 is maintained dark the gaseous tube 38 is not fired because the condenser 15 remains in a practically discharged condition with little or no voltage being developed across its terminals. However, when the photoelectric tube 17 is illuminated, electrons flow from the cathode 24 to the anode 23 on the negative half waves of the voltage from the alternating current voltage source 9 and the junction 19 becomes positive with respect to the junction 44 due to the charge on condenser 15. During the positive half waves this voltage across condenser 15 is added to the voltage drop across potentiometer 36 making the control electrode 40 enough positive with respect to the cathode 39 of the gaseous tube 38 to fire the tube 38. The main discharge current of tube 38 is added to the normal current flow through resistor 37 to cause a voltage drop across resistor 37 of sufficient amount to fire gaseous tube 31. As soon as the gaseous path between the control electrode 33 and cathode 32 breaks down, the discharge is sustained by current flowing through the main discharge path of gaseous tube 38 and resistor 43. This sustained discharge provides the transfer current for the gaseous tube 31.

The connections through contacts 49 and 50 of switch 45 to movable contact 48 of potentiometer 36 and junction 42, respectively, are to insure operation of the circuit on high values of illumination of the photoelectric tube 17. With the anode 23 of photoelectric tube 17 connected to conductor 35 through switch blade 46 and

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switch contact 47 and the cathode 24 of photoelectric tube 17 highly illuminated, it might happen that the charge on condenser 15 would be sufficiently large to produce enough positive potential at junction 19 with respect to cathode 39 of gaseous tube 38 to cause a disruptive discharge between the control electrode 40 and cathode 39 before any or sufficient voltage from the positive half wave could be impressed on the main discharge path of the gaseous tube 38 to cause it to fire. Under these circumstances the gaseous tube 38 would fail to fire, and the system as a whole would fail to function. This condition is prevented by closing switch blade 46 on contact 50. An even further reduction of charge of condenser 15 may be obtained and of an adjustable amount by closing switch blade 46 on switch contact 49.

In the arrangement of Fig. 2 the gaseous tube 38 may be prevented from firing even with the photoelectric tube 17 illuminated by leaving switch 45 open as shown. The tube 38 may be fired merely by closing the switch blade 46 to an appropriate one of contacts 47, 49 or 50. According to this method of operation, the photoelectric tube 17 acts merely as a unilateral or one-way current conducting device.

It is obvious from the foregoing description that other kinds of load devices may be substituted for the relays 10 and 30. The relays 10 and 30 are of the slow release type and will hold up on pulsating current such as flows through the main discharge paths of gaseous tubes 5 and 31.

It has been found that with a gaseous tube requiring a relatively high transfer current, a system like that of Fig. 1 will function properly if the source 9 supplies a voltage of 120 volts and 60 cycles per second, if the root-mean-square voltage drop across resistor 14 is 50 volts or the peak voltage is 72 volts, and if the condenser 15 has a capacity of 0.001 microfarad. With this arrangement if the gaseous tube 5 is to fire on the positive half wave immediately following the first negative half wave during which the photoelectric tube 17 becomes illuminated and a voltage of 25 volts across the condenser 15 is required, the photoelectric tube 17 must produce an average current of 3.125 milliamperes during the full negative half wave. The sensitivity of such an arrangement is relatively low. By using a gaseous tube requiring a relatively low transfer current, a much smaller condenser 15 may be used. It has been found that in an arrangement like that of Fig. 2 with a condenser having a capacitance of 30×10^{-12} farad the photoelectric tube 17 need supply a current of only 0.09375×10^{-6} ampere or slightly less than 0.1 microampere. The examples of practice described hereinbefore are merely illustrative since many different embodiments of the invention are possible.

The invention may be embodied in a variety of forms all of which come within the purview of the appended claims.

What is claimed is:

1. A photoelectric control system comprising a gaseous discharge trigger tube having a cathode, an anode, and a control electrode, a source of alternating current voltage, a voltage divider connected across said source of voltage, a series circuit including a condenser and a photoelectric tube having a cathode and an anode connected across a portion of said voltage divider with the anode remote from said condenser in said series

circuit, a conductive connection from a point in said series circuit intermediate said condenser and said photoelectric tube to said control electrode, a conductive connection from the cathode of said trigger tube to the portion of the voltage divider to which said photoelectric tube is connected, and a conductive connection from the anode of said trigger tube to the portion of said voltage divider to which said photoelectric tube is not connected.

2. A photoelectric control system comprising a gaseous discharge trigger tube having a cathode, an anode, and a control electrode, a source of alternating current voltage, a voltage divider connected across said source of voltage, a series circuit including a condenser and a photoelectric tube having a cathode and an anode connected across a portion of said voltage divider with the anode remote from said condenser in said series circuit, a conductive connection from a point in said series circuit intermediate said condenser and said photoelectric tube to said control electrode, a conductive connection from the cathode of said trigger tube to the portion of the voltage divider to which said photoelectric tube is connected, a conductive connection from the anode of said trigger tube to the portion of said voltage divider to which said photoelectric tube is not connected, and means to connect a resistor in shunt of said condenser.

3. An electrical control system comprising a gaseous discharge tube having a cathode, an anode and a control electrode, a source of alternating current voltage, a series circuit including said source and the discharge path between said cathode and anode, and means including a condenser and an asymmetrically conductive device in a circuit connected between said control electrode and said cathode for charging said condenser through said asymmetrically conductive device during each half wave of the voltage from said source which makes said anode negative with respect to said cathode and during each following half wave from said source adding a voltage to the voltage of said condenser to make the control electrode positive with respect to said cathode in a manner adapted to cause a gaseous discharge between said control electrode and cathode to trigger off the main discharge when the charge on said condenser is sufficiently large.

4. An electrical control system comprising a gaseous discharge tube having a cathode, an anode and a control electrode, means to impress impulses of voltage on the discharge path between said cathode and anode with a polarity to make said anode positive with respect to said cathode, means including a condenser to impress impulses of voltage on the discharge path between said cathode and control electrode with a polarity to make said control electrode positive with respect to said cathode in phase effectively with said voltage impressed on said anode and cathode path, and means external to said discharge tube to produce a trapped charge on said condenser during the period between the impressing of impulses of voltage on said control electrode and cathode path with a polarity to increase the total voltage impressed on said control electrode and cathode path during the following period when an impulse of voltage is impressed on said control electrode and cathode path.

5. An electrical control system comprising a gaseous discharge tube having a cathode, an anode and a control electrode, means to impress

impulses of voltage on the discharge path between said cathode and anode with a polarity to make said anode positive with respect to said cathode, means including a condenser to impress impulses of voltage on the discharge path between said cathode and control electrode with a polarity to make said control electrode positive with respect to said cathode in phase effectively with said voltage impressed on said anode and cathode path, and means including a light sensitive electric device to produce a trapped charge on said condenser during the period between the impressing of impulses of voltage on said control electrode and cathode path with a polarity to increase the total voltage impressed on said control electrode and cathode path during the following period when an impulse of voltage is impressed on said control electrode and cathode path.

6. An electrical control system comprising a gaseous discharge tube having a cathode, an anode and a control electrode, means to impress impulses of voltage on the discharge path between said cathode and anode with a polarity to make said anode positive with respect to said cathode, means including a condenser to impress impulses of voltage on the discharge path between said cathode and control electrode with a polarity to make said control electrode positive with respect to said cathode in phase effectively with said voltage impressed on said anode and cathode path, and means including a vacuum type photoelectric tube having a photo-emissive cathode and an anode to produce a trapped charge on said condenser during the period between the impressing of impulses of voltage on said control electrode and cathode path with a polarity to increase the total voltage impressed on said control electrode and cathode path during the following period when an impulse of voltage is impressed on said control electrode and cathode path.

7. An electro-optical control system comprising a source of alternating current voltage, a gaseous discharge trigger tube including a cold cathode, an anode, and a control electrode, a load device, a series circuit including said load device and the main discharge path between said cathode and anode connected across said source of voltage, a voltage divider connected across said source of voltage, a condenser connected from an intermediate point of said voltage divider to said control electrode, and a light sensitive electric device connected between said control electrode and the cathode of said trigger tube in such a manner as to constitute a high impedance when the voltage from said source makes the cathode of said trigger tube negative with respect to the anode of said trigger tube.

8. An electro-optical control system comprising a source of alternating current voltage, a gaseous discharge trigger tube including a cold cathode, an anode, and a control electrode, a load device, a series circuit including said load device and the main discharge path between said cathode and anode connected across said source of voltage, a voltage divider connected across said source of voltage, a condenser connected from an intermediate point of said voltage divider to said control electrode, and a photoelectric tube having a cathode and an anode connected between said control electrode and the cathode of said trigger tube with said cathode of said photoelectric tube nearer to said control electrode.

9. An electro-optical control system comprising a source of alternating current voltage, a gaseous

discharge trigger tube including a cold cathode, an anode, and a control electrode, a load device, a series circuit including said load device and the main discharge path between said cathode and anode connected across said source of voltage, a voltage divider connected across said source of voltage, a condenser connected from an intermediate point of said voltage divider to said control electrode, a photoelectric tube having a cathode and an anode connected between said control electrode and said cathode of said trigger tube with said cathode of said photoelectric tube nearer to said control electrode, and a resistor adapted to be connected in shunt of said condenser.

10. An electro-optical control system comprising a source of alternating current voltage, a gaseous discharge trigger tube including a cold cathode, an anode, and a control electrode, a load device, a series circuit including said load device and the main discharge path between said cathode and anode connected across said source of voltage, a voltage divider connected across said source of voltage, a condenser connected from an intermediate point of said voltage divider to said control electrode, a photoelectric tube having a cathode and an anode, said anode being connected to the cathode of said trigger tube, and a resistor connected between the cathode of said photoelectric tube and said control electrode.

11. An electro-optical control system comprising a source of alternating current voltage, a gaseous discharge trigger tube including a cold cathode, an anode, and a control electrode, a load device, a series circuit including said load device and the main discharge path between said cathode and anode connected across said source of voltage, a voltage divider connected across said source of voltage, a condenser connected from an intermediate point of said voltage divider through a resistor to said control electrode, and a light sensitive electric device connected between said control electrode and said cathode of said trigger tube in such a manner as to constitute a high impedance when the voltage from said source makes the cathode of said trigger tube negative with respect to the anode of said trigger tube.

12. An electro-optical control system comprising a source of alternating current voltage, a gaseous discharge trigger tube including a cold cathode, an anode, and a control electrode, a load device, a series circuit including said load device and the main discharge path between said cathode and anode connected across said source of voltage, a voltage divider connected across said source of voltage, a condenser connected from an intermediate point of said voltage divider through a resistor to said control electrode, and a photoelectric tube having a cathode and an anode, the cathode of said photoelectric tube being connected to the terminal of said condenser nearer said control electrode and the anode of said photoelectric tube being connected to the cathode of said trigger tube.

13. An electro-optical control system comprising a source of alternating current voltage, a first gaseous discharge trigger tube having a cold cathode, an anode, and a control electrode, a voltage divider having a first and second terminal connected across said source of voltage, a conductive connection between the anode of said first trigger tube and a first terminal of said voltage divider, a condenser connected between a first intermediate point of said voltage divider and said control electrode of said first

trigger tube, a conductive connection between the cathode of said first trigger tube and a second intermediate point on said voltage divider more remote from said first terminal than said first intermediate point, a second gaseous discharge trigger tube having a cold cathode, an anode and a control electrode, a load device, a series circuit including said load device and the main discharge path between said cathode and anode of said second trigger tube connected across said voltage divider with the cathode of said second trigger tube conductively connected to said second terminal of said voltage divider, a conductive connection from the control electrode of said second trigger tube to the cathode of said first trigger tube, and a light sensitive electric device connected between said control electrode of said first trigger tube and a point of said voltage divider more remote from said first terminal than said first intermediate point in such a manner as to constitute a high impedance when the voltage from said source makes the cathode of said first trigger tube negative with respect to the anode of said first trigger tube.

14. An electro-optical control system comprising a source of alternating current voltage, a first gaseous discharge trigger tube having a cold cathode, an anode, and a control electrode, a voltage divider having a first and second terminal connected across said source of voltage, a conductive connection between the anode of said first trigger tube and a first terminal of said voltage divider, a condenser connected between a first intermediate point of said voltage divider and said control electrode of said first trigger tube, a conductive connection between the cathode of said first trigger tube and a second intermediate point on said voltage divider more remote from said first terminal than said first intermediate point, a second gaseous discharge trigger tube having a cold cathode, an anode and a control electrode, a load device, a series circuit including said load device and the main discharge path between said cathode and anode of said second trigger tube connected across said voltage divider with the cathode of said second trigger tube conductively connected to said second terminal of said voltage divider, a conductive connection from the control electrode of said second trigger tube to the cathode of said first trigger tube, and a photoelectric tube having a cathode and an anode connected between said control electrode of said first trigger tube and a point of said voltage divider more remote from said first terminal than said first intermediate point with said cathode of said photoelectric tube nearer said control electrode of said first trigger tube.

15. An electro-optical control system comprising a source of alternating current voltage, a first gaseous discharge trigger tube having a cold cathode, an anode, and a control electrode, a voltage divider having a first and a second terminal connected across said source of voltage, a conductive connection between the anode of said first trigger tube and a first terminal of said voltage divider, a condenser connected from a first intermediate point of said voltage divider through a resistor to said control electrode of said first trigger tube, a conductive connection between the cathode of said first trigger tube and a second intermediate point on said voltage divider more remote from said first terminal than said first intermediate point, a second gaseous discharge trigger tube having a cold cathode, an anode and a control electrode, a series circuit

including a resistor and a photoelectric tube having a cathode and an anode, the cathode of said photoelectric tube being connected to one terminal of said resistor and the other terminal of said resistor being connected to the terminal of said condenser remote from said voltage divider, a load device, a series circuit including said load device and the main discharge path between said cathode and anode of said second trigger tube connected across said voltage divider with the cathode of said second trigger tube conductively connected to said second terminal of said voltage divider, a conductive connection from the control electrode of said second trigger tube to the cathode of said first trigger tube, and switching means adapted to connect the anode of said photoelectric tube to either the cathode of said second trigger tube, or to said second intermediate point of said voltage divider, or to an adjustable contact on said voltage divider movable between said first and second intermediate points of said voltage divider.

16. The method of firing a gaseous discharge trigger tube which comprises applying impulses of voltage to the terminals of the main gaseous discharge path of a trigger tube of an amplitude less than the voltage required to produce a disruptive discharge of the gaseous trigger path, applying impulses of voltage to the terminals of the gaseous trigger path while said impulses of voltage are being applied to said main discharge path in a direction tending to produce a disruptive discharge of said gaseous trigger path but of an amplitude less than necessary to fire said trigger tube, charging a condenser through a circuit exclusive of said trigger tube, and adding the voltage across the terminals of said condenser due to said charge to the impulses of voltage applied to said trigger path to produce a disruptive discharge of said gaseous trigger path to fire said trigger tube.

17. The method of firing a gaseous discharge trigger tube which comprises applying impulses of voltage to the terminals of the main gaseous discharge path of a trigger tube of an amplitude less than the voltage required to produce a disruptive discharge of said path in the absence of a disruptive discharge of the gaseous trigger path, applying impulses of voltage to the terminals of the gaseous trigger path while said impulses of voltage are being applied to said main discharge path in a direction tending to produce a disruptive discharge of said gaseous trigger path but of an amplitude less than necessary to fire said trigger tube, charging a condenser through a predominantly one-way conductive circuit exclusive of said trigger tube during periods when said impulses are not being applied to said gaseous trigger path, and adding the voltage across the terminals of said condenser due to said charge to the

impulses of voltage applied to said trigger path to produce a disruptive discharge of said gaseous trigger path to fire said trigger tube.

18. The method of firing a gaseous discharge trigger tube which comprises applying impulses of voltage to the terminals of the main gaseous discharge path of a trigger tube of an amplitude less than the voltage required to produce a disruptive discharge of said path in the absence of a disruptive discharge of the gaseous trigger path, applying impulses of voltage to the terminals of the gaseous trigger path while said impulses of voltage are being applied to said main discharge path in a direction tending to produce a disruptive discharge of said gaseous trigger path but of an amplitude less than necessary to fire said trigger tube, charging a condenser through a predominantly one-way conductive circuit entirely controlled by radiant energy, and adding the voltage across the terminals of said condenser due to said charge to the impulses of voltage applied to said trigger path to produce a disruptive discharge of said gaseous trigger path to fire said trigger tube.

19. The method of firing a gaseous discharge trigger tube which comprises applying impulses of voltage to the terminals of the main gaseous discharge path of a trigger tube of an amplitude less than the voltage required to produce a disruptive discharge of said path in the absence of a disruptive discharge of the gaseous trigger path, applying impulses of voltage to the terminals of the gaseous trigger path while said impulses of voltage are being applied to said main discharge path in a direction tending to produce a disruptive discharge of said gaseous trigger path but of an amplitude less than necessary to fire said trigger tube, charging a condenser through a predominantly one-way conductive circuit entirely controlled by light, and adding the voltage across the terminals of said condenser due to said charge to the impulses of voltage applied to said trigger path to produce a disruptive discharge of said gaseous trigger path to fire said trigger tube.

WILLIAM H. T. HOLDEN.

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