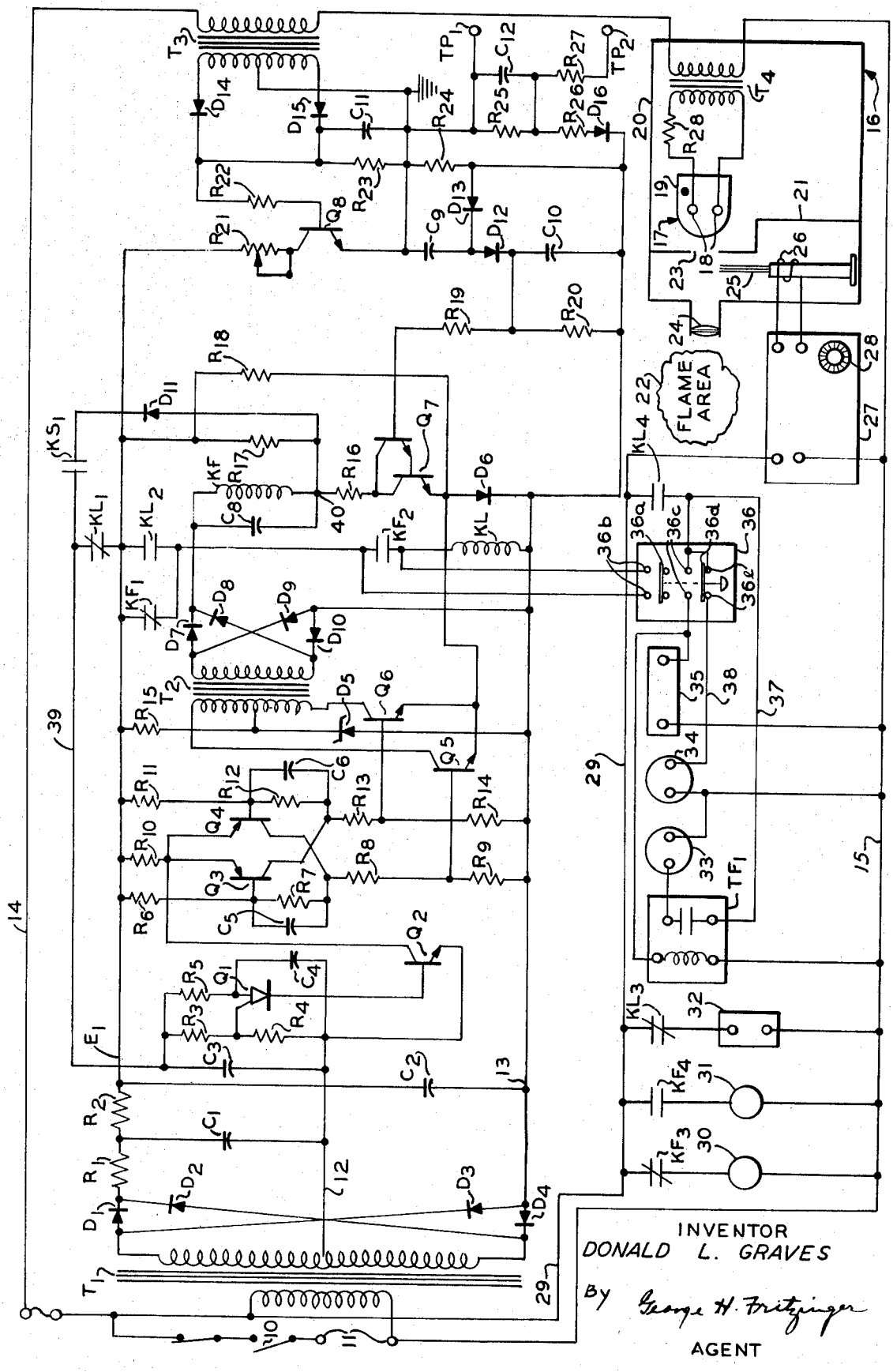
Nov. 17, 1970 D. L. GRAVES 3,541,549

SELF-CHECKING FLAME DETECTION APPARATUS

Filed Aug. 19, 1968



United States Patent Office

3,541,549
Patented Nov. 17, 1970

3,541,549

SELF-CHECKING FLAME DETECTION APPARATUS

Donald L. Graves, Montville, N.J., assignor to McGraw-Edison Company, Elgin, Ill., a corporation of Delaware

Filed Aug. 19, 1968, Ser. No. 753,387
Int. Cl. G08b 29/00; F23q 23/08
U.S. Cl. 340—410 12 Claims

ABSTRACT OF THE DISCLOSURE

A system responsive to flame characteristics is provided for detecting the flame of a fuel burner and for initiating the closing of the fuel valve if a flame failure occurs for any reason. The system includes means for checking intermittently the operability of the detector and for initiating automatic closing of the fuel valve to stop the burner if either the detector or the checking apparatus is not functioning properly.

If the flame fails in a fuel burner and th fuel valve is not closed shortly thereafter, and explosion hazard may occur. It is therefore essential from a safety standpoint that each fuel burner installation be provided with a safeguarding apparatus which will close the fuel valve with little delay when a flame failure occurs. However, such safeguarding apparatus may itself become defective and no longer perform its safeguarding function. The present system includes a comprehensive safety means which checks the detector by intermittently shielding the detector from the sensed flame characteristic to simulate a condiion of flame failure and then reacts to initiate closing of the fuel valve if either the detector or the checking apparatus does not function properly.

Prior fail-safe systems such as are taught by Rowell Pats. Nos. 2,798,213, 2,807,009 and 2,807,011 are characterized typically by feedback-operated shutter systems which may intercept the sensed flame characteristic by as much as fifty percent of the time leaving them as much as fifty percent dead time when the flame detector is inoperative to perform its intended function, and by energy storage devices (condensers) which are switched intermittently with the operation of the shutter between a D.C. voltage source and the protective relay to operate such relay directly by the stored energy. These systems are characterized by frequent operation of the switching means, causing heavy wear and tear on the apparatus, particularly since the checking operation is carried on continuously day and night. In the present improved system, a burner control relay is not operated directly by stored energy but is operated by a generated power supply controlled by stored energy in a high impedance circuit allowing periods of continuous operation of up to two minutes between recharging of a comparatively small condenser. Also, the shutter operation is not controlled by a feedback circuit but by timing means which can be set to reoperate the shutter at inervals approaching the discharge period of the condenser, with the duration of each shutter operation being set as low as one second or less. Thus, the dead time is reduced and the rate of shutter and switch operation is less frequent, causing the wear and tear on the apparatus to be reduced and enabling accordingly a higher checking and performance reliability.

An object of the invention is therefore to provide a novel safety apparatus for a fuel burner which checks intermittently the operability of the flame detector system and of the checking apparatus itself while imposing a dead time on the detector system of generally less than ten percent, and without incurring excessive wear and tear

on the apparatus whereby to enable a higher reliability in detection and in checking performance to be attained.

Another object is to provide such improved safety apparatus which can be preset to check the detector at intervals ranging from a few seconds to two minutes or more.

These and other objects and features of the invention will be apparent from the following description and the appended claims.

In the description of the invention, reference is had to the accompanying schematic circuit diagram showing a preferred embodiment of the invention.

The primary power supply for the system comprises an input power transformer T_1 having a primary winding connected through an on-off power switch **10** to a pair of power leads **11** to be connected to a 120 volt A.C. source not shown. The secondary winding of the transformer T_1 is center tapped and connected through a full-wave rectifier D_1–D_4 to provide a primary 24 volt D.C. supply. The positive side of this 24 volt D.C. supply is filtered with respect to a center tap line **12** by a series resistor R_1 and a shunt capacitor C_1 and the full 24 volts are filtered with respect to the negative side **13** by series resistors R_1 and R_2 and a shunt capacitor C_2. The 24 volt supply provides the operating power for the electronic components of the system except for an oscillator Q_1 and a trigger amplifier Q_2 connected to the center tap line **12.** The oscillator is operated from the charge stored in a condenser C_3. The condenser is initially charged by connecting it between the center tap line **12** and the plus side E_1, and is recharged intermittently to keep the oscillator running as necessary by connecting it to a voltage supply variably intermediate that of the center tap line **12** and the plus side E_1. As will appear, the oscillator must be kept running in order to permit sustained energization of a burner control relay KF.

The A.C. power supply **11** is connected also through the on-off power switch **10** by leads **14** and **15** to the series connected primaries of a coupling transformer T_3 and a voltage step-up transformer T_4 which is associated with an ultraviolet flame detector **16.** The secondary of the transformer T_4 is connected through a resistor R_{28} to a U-V detector tube **17** preferably of the type disclosed in the Howling Pat. No. 3,047,761, dated July 31, 1962. This detector tube comprises two symmetrical electrodes **18** enclosed in a glass envelope **19** containing an ionizing gas such as hydrogen. The tube is capable of passing alternating current when a firing potential of 700 volts is applied across the electrodes and the electrodes are subjected to ultraviolet radiation. Once the tube is fired it continues to pass current until the applied potential falls below a sustaining value of around 330 volts. Thus, when the tube is operated from alternating current supply it is quenched automatically after each half cycle. The tube is housed in one compartment of a box **20** subdivided by a partition wall **21.** Exposure of the detector tube to a flame area **22** of the burner is via an aperture **23** in the partition wall **21** and a lens **24** in an outside wall of the box **20.** In the second compartment of the box **20** is a shutter **25** operable across the aperture **23** by a coil **26** to intercept the U-V radiation from the flame area to the detector tube whereby to simulate a flame failure. The coil **26** is connected to an electronic timing circuit **27** diagrammatically indicated which can be manually set as by a knob **28** to cause the shutter to be operated intermittently at adjustable intervals and to be held operated for a given period of relatively short duration.

The A.C. power supply **11** is also connected through the on-off power switch **10** to a lead **29** to provide A.C. power with reference to the lead **15** for a flame-out indicator **30,** a flame-on indicator **31** and an alarm device

32. A trial for ignition timer TFI, an igniter fuel valve 33, a main fuel valve 34 and an ignition transformer 35 are connected also between the power leads 15 and 29 under control of a manual start switch 36 as is hereinafter described.

The burner control relay KF must be held operated in order to keep the main fuel valve 34 open and the burner running. A generated D.C. current supply is made available to the relay KF so long as the condenser C_3 has a charge thereon above a predetermined level to keep the oscillator Q_1 running. The oscillator Q_1 feeds through an amplifier stage Q_2 to trigger a flip-flop circuit Q_3–Q_4, and the flip-flop circuit feeds through amplifier transistors Q_5 and Q_6 to the primary winding of a transformer T_2. The secondary winding of this transformer feeds through a full-wave rectifier D_7–D_{10} into a circuit including the relay KF, a small resistor R_{16}, a switching transistor Q_7 and a diode D_6. One terminal of the diode D_6 is connected to the negative side 13 of the primary voltage supply.

The switching transistor Q_7 is coupled to the U-V detector tube 17 through the coupling transformer T_3, a pair of rectifiers D_{14} and D_{15}, and an amplifier transistor Q_8. When the detector tube is rendered intermittently conductive by incident U-V radiation, a sufficient current flows through the coupling transformer T_3 and the amplifier transistor Q_8 to charge a biasing condenser C_{10} in the input circuit of the transistor Q_7 whereby to render the transistor Q_7 conductive within about .4 second after the detector tube is triggered. Thus, to keep the burner control relay KF operated, not only must the condenser C_3 bear a sufficient charge but the U-V detector tube 17 must also be repetitively triggered to hold the transistor Q_7 conductive except for the short check periods.

The oscillator Q_1 has a high impedance input so that a condenser C_3 of the order of 400–500 microfarads is capable of keeping the oscillator Q_1 running for a period exceeding two minutes after each recharging of the condenser before the energy stored in the condenser falls below the level necessary for operation. It is to be noted that the discharge time of condenser C_3 establishes the maximum time between the successive periods for checking the detector system since the power to the condenser is shut off during the normal operating periods of the detector system and the condenser is recharged only when the shutter 25 is operated to simulate a flame failure and the transistor Q_7 is nonconductive. A condenser C_8 is connected across the burner control relay KF to hold this relay operated at least for a normal checking period.

It will be seen that when the power switch 10 is closed, the flame-out indicator 30 and the alarm device 32 are energized, a striking voltage is made available through transformer T_4 to the detector tube 17 so that the tube will trigger as soon as it is excited by U-V radiation from a flame of the burner, and power is supplied to the shutter timer control 27. Also, the condenser C_3 is charged from the line E_1 through contacts KL_1 of a load relay KL and center line 12 to start the oscillator Q_1 running. However, the burner control relay KF is not operated yet because the switching transistor Q_7 is still nonconducting.

If the operator presses the button of the start switch 36 while the relay KF is not operated, the switch pole 36*a* closes contacts 36*b* to activate the relay KL via switch contacts KF_1 of the relay KF. Operation of the relay KL opens its contacts KL_1 to cut off the initial charge circuit for the condenser C_3, closes contacts KL_2 paralleling initially closed contacts KF_1 of the relay KF to provide one element of a hold circuit for the KL relay, opens KL_3 to deenergize the alarm device 32 and closes contacts KL_4 to activate the ignition transformer 35 and an ignition timer TFI from the line 29 through contacts 36*c* and pole 36*d* of the start switch 36. Also, the closing of the contacts KL_4 provides power from the line 37 through a contact of the ignition timer TFI to open the igniter fuel valve 33. Since fuel is now supplied to the igniter burner and the ignition transformer 35 is activated, a flame is ignited. If the flame ignition does not occur the detector tube 17 is not triggered and the burner control relay KF is not operated, with the result that the circuit for the relay KL is opened at the contacts 36*b* to drop out the relay KL and shut down the burner when the start switch 36 is released. On the other hand, if flame ignition occurs the detector tube 17 is triggered, and if the coupling of the detector tube to the switching transistor Q_7 is functioning properly the transistor Q_7 is rendered conductive to operate the relay KF. Operation of the relay KF opens contacts KF_1 to make continued operation of relay KL dependent on its hold contacts KL_2, closes contacts KF_2 to keep the relay KL operated when the start switch 36 is released and makes continued operation of the relay KL dependent on relay KF, opens contacts KF_3 to shut off the flame-out indicator 30 and closes contacts KF_4 to activate the flame-on indicator 31. Upon now releasing the start button of switch 36, the ignition transformer 35 and the coil of ignition timer TFI are cut off by the opening of contacts 36*c*, and switch pole 36*d* makes with contacts 36*e* to activate the main fuel valve 34 from the line 38 via the contacts KL_4 of the relay KL and the contacts 36*e* of the start switch. With ignition flame and main fuel present, the main flame is ignited. A predetermined time after the coil of the TFI timer is deenergized (typically 10 seconds), the switch contact of TFI opens to cause the igniter fuel valve to close. Although the igniter flame is shut off, the detector 17 continues to be triggered by the main flame. The burner is now in normal running condition.

Within a preselected interval after the power switch 10 is closed, the shutter timer control 27 operates the shutter 25 and holds the shutter operated for typically one second. This operation of the shutter intercepts the U-V radiation from the burner flame to the detector tube 17 to start a checking operation. Firstly, if the detection tube is functioning properly so that it ceases to trigger when the radiation is intercepted, it will be quenched the instant the applied A.C. voltage falls below a sustaining value of about 330 volts, and if the coupling circuitry from the detector and switching transistor Q_7 is returned to off condition about ¼ second thereafter by the discharge of bias condenser C_{10} through resistor R_{20} to cut off flow from the generated current supply to the relay KF. However, the charge on the condenser C_8 will hold the KF relay operated at least for a normal checking period. Should some malfunction occur causing the checking period to be extended beyond a normal time, the relay KF will drop out which in turn will drop out the relay KL by the opening of the contacts, KF_2, and the drop out of the relay KL will shut off the main valve 34 to stop the burner. On the other hand, if the shutter 25 is returned to off position after a normal checking period, the switching transistor Q_7 is returned to on position at the end of the checking period to close again the primary energizing circuit for the KF relay before the charge on condenser C_8 drops below the hold-in requirement of relay KF.

Also, the instant the shutter 25 is shifted to operated position, a switch KS_1 is closed in a recharge circuit 39 for the condenser C_3. This recharge circuit runs from a junction point 40 between the relay KF and the switching transistor Q_6 and includes a diode D_{11} poled positively in the direction from the junction point to the condenser. This junction point 40 is connected through a resistor R_{17} to the plus side E_1 of the 24 volt primary voltage supply. When the transistor Q_7 is conducting, the potential of the junction point 40 is below that of the center tap line 12 with the result that no charging current flows into condenser C_3. Discharge current from condenser C_3 is prevented from dissipating through transistor Q_7 because the polarization of diode D_{11} prevents current flow in that

direction. However, when the transistor Q_7 is non-conducting, the potential of the junction point **40** rises above that of the center line **12** to permit charging current to flow to the condenser C_3 provided the switch KS_1 is then closed. Thus, if the detector apparatus is functioning properly to shift the transistor Q_7 to off position shortly after the shutter is operated, the condenser C_3 will be recharged to enable it to keep the oscillator Q_1 running for a period exceeding the interval between checking operations. However, if the detector apparatus is not functioning properly and the transistor Q_7 is not shut off responsive to the operation of the shutter, the condenser C_3 will not be recharged with the result that shortly after the shutter is returned to its non-intercepting position the oscillator Q_1 will stop to cut off the supply of generated current to the relay KF. Under these conditions the relay KF will soon drop out and shut down the burner even though the shutter is properly returned to its non-intercepting position.

If the timing control **27** should malfunction and fail to reoperate the shutter within the predetermined discharge period of the condenser C_3, the charge on the condenser will fall below the necessary predetermined level and will stop the oscillator to drop out the KF relay and shut down the burner. Any malfunctioning of the timer control causing it to reoperate the shutter at a faster rate will not shut down the burner but will have the detrimental effect only of increasing the dead time when the detector is ineffective to perform its flame detecting operation.

The embodiment of my invention herein particularly shown and described is intended to be illustrative and not necessarily limitative of my invention since the same is subject to changes and modifications without departure from the scope of my invention, which I endeavor to express according to the following claims.

I claim:

1. A fuel burner control system comprising a burner control relay, an oscillator and rectifying means for providing a D.C. current supply for operating said relay, sensing means for detecting a flame of said burner, means for intermittently intercepting said sensing means from said flame, and means responsive to said intercepting means for maintaining said oscillator running only if said intercepting means is reoperated within a predetermined interval.

2. The fuel burner control system set forth in claim **1** including means responsive to said sensing means for disconnecting said current supply from said relay when said sensing means is not activated, and means for delaying the drop out of said relay for a predetermined period after said current supply is disconnected from said relay.

3. A fuel burner control system comprising a burner control relay, flame sensing means, means for intercepting the sensing means from the flame of said burner, means for intermittently operating said intercepting means, current supplying means for said relay including a condenser for maintaining the supplying means in operative condition for a predetermined interval after each charging of the condenser, and a charge circuit for said condenser controlled independently by said interceptor operating means and said sensing means to cause the charge circuit to be rendered operative only when said intercepting means is operated and said sensing means is not activated.

4. The fuel burner control system set forth in claim **3** including timing control means settable to recycle said intercepting means within said predetermined interval and to hold the intercepting means operated for a predetermined period of relatively short duration, means for disconnecting said voltage supplying means from said relay when said sensing means is not activated, and a shunt condenser across said relay adapted to hold the relay operated at least for a time period of said predetermined duration after the relay is disconnected from said supplying means.

5. A fuel burner control system comprising an ultraviolet detector tube for detecting the flame of the burner, a burner control relay required to be operated to keep the burner running, current generating means for operating said relay including a condenser adapted to keep the generating means operative as long as the condenser bears at least a given charge, a shutter for intermittently intercepting transmission of U-V radiation from said flame to said detector tube, an electronic switch device required to receive an amplified signal from said detector tube in order to place the device in conductive condition, and means rendered operable to charge said condenser only when said shutter is operated and said switch device is non-conducting.

6. The burner control system set forth in claim **5** wherein said electronic switch device is connected in the current supply circuit of said burner control relay to require the electronic switch device to be in conductive condition to enable current to be supplied to said relay, including a condenser connected across said relay for holding the relay operated at least for a predetermined period while said shutter is operated and said switch device is non-conducting.

7. A fuel burner control system including a burner control relay required to be operated to keep the burner running, a U-V detector tube for detecting the flame of the burner, a shutter for intermittently shielding the detector tube from said flame, an energy storage condenser, an oscillator rendered operative by said condenser so long as the condenser bears a charge above a predetermined level, means connected to the output of said oscillator for making D.C. operating power available to said burner control relay, means for recurrently operating said shutter within the time interval said condenser is capable of operating said oscillator after each recharging thereof, and means rendered operable with each operation of said shutter for recharging said condenser.

8. The fuel burner control system set forth in claim **7** including circuit means for providing an alternating firing potential capable of producing a pulsating glow discharge in said detector tube when the tube is excited by incident ultraviolet radiation, a switching transistor connected in the power circuit of said burner control relay, means supplying a potential to the junction between said transistor and burner control relay capable of charging said storage condenser only when the transistor is non-conductive, and means connecting the control electrode of said transistor to said detector tube to render the transistor conductive only when said detector tube is triggered into a conductive state.

9. The fuel burner control system set forth in claim **8** including a primary D.C. voltage supply having a center tap to which the negative side of said condenser and oscillator are connected, means connecting said transistor between said burner control relay and said negative side of said primary D.C. voltage supply, resistance means connecting the plus side of said primary D.C. voltage supply to the junction between said transistor and said burner control relay to provide a potential at said junction above that of said center tap when said transistor is in a non-conducting state and below that of said center tap when the transistor is in a conducting state, and a charge circuit for said storage condenser connected to said junction.

10. The fuel burner control system set forth in claim **9** including a diode in said charge circuit poled to prevent current from flowing from said storage condenser when said transistor is conducting, and a switch in said charge circuit operated in timed relation with said shutter to permit charge current to flow to said condenser only when said shutter is operated.

11. A fuel burner control system comprising a burner control relay, current supplying means for said relay in-

cluding a condenser required to be charged above a predetermined level to keep said supplying means operative, flame sensing means, a shutter for intercepting the flame from said sensing means, electronic switch means in said current supplying circuit responsive to said sensing means for supplying current to said relay only when said condenser is charged and said sensing means is activated, a charge circuit for said condenser rendered operable by said electronic switch means as the switch means is rendered non-conducting, a switch in said charge circuit timed with said shutter to close as the shutter is operated, and a diode in said charge circuit poled to prevent current flow from said condenser when said electronic switch means is conducting.

12. A condition-responsive apparatus comprising means for sensing the presence of a selected condition, an electronic switching device controlled by said sensing means to cause the switching device to be conductive when said sensing means is activated and relatively nonconductive when said sensing means is not activated, a first power supply, an energy storage device, means for charging said storage device from said first power supply, an oscillator operable by said storage device for a first time period after each recharging of said storage device, means connected to said oscillator for providing a second power supply only so long as said oscillator is operating, an electrically operable switching device connected to said second power supply via said electronic switching device to assume an unenergized state when said condition is not being sensed and an energized state

when said electronic switching device is conductive and said oscillator is operating, means to delay for a second time period less than said first time period a return of said electrically operable switching device to an unenergized state after said electronic switching device becomes nonconductive or said oscillator stops operating, means for intercepting said sensing means from said selected condition for a third time period shorter than said second time period, means for repetitively recycling said intercepting means at intervals shorter than said first time period and longer than said second time period, and means for preventing simultaneous energization of said electrically operable switching device from said second power supply and charging of said storage device from said first power supply.

References Cited

UNITED STATES PATENTS

3,143,161	8/1964	Graves et al.	340—410 X
3,143,162	8/1964	Graves et al.	340—410 X
3,190,341	6/1965	Giuffrida et al.	340—410 X
3,263,730	8/1966	Giuffrida	431—26
2,798,214	7/1957	Rowell	340—410
2,798,213	7/1957	Rowell	340—410

STANLEY M. URYNOWICZ, JR., Primary Examiner

U.S. Cl. X.R.

431—24