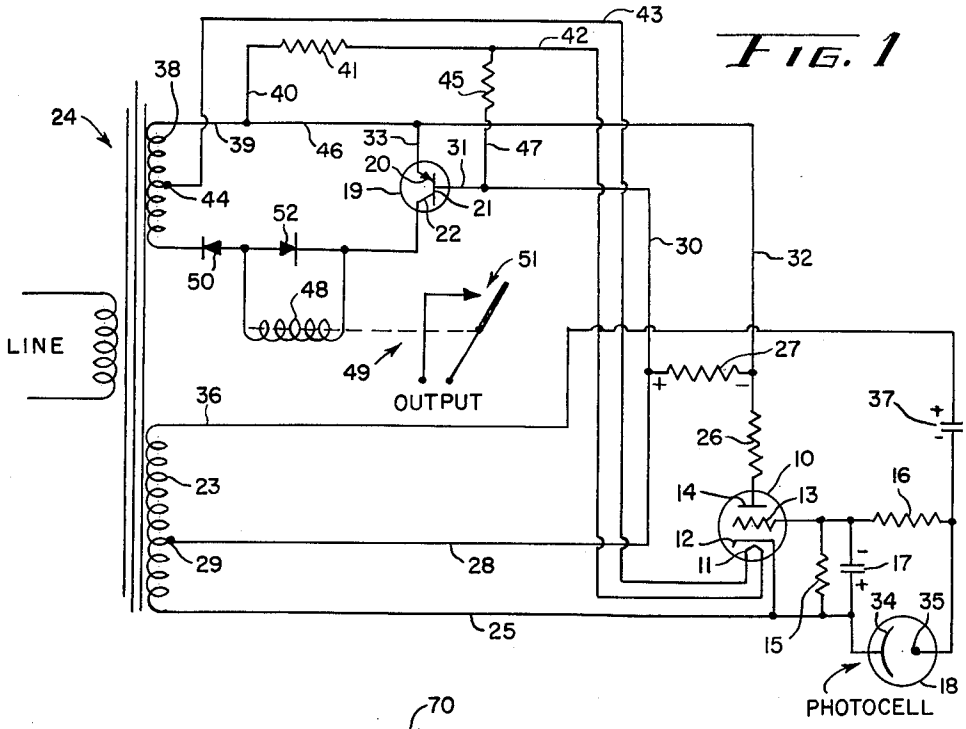
Feb. 6, 1962 W. B. HAMELINK 3,020,413

CONDITION RESPONSIVE MEANS

Filed Sept. 6, 1960

FIG. 1



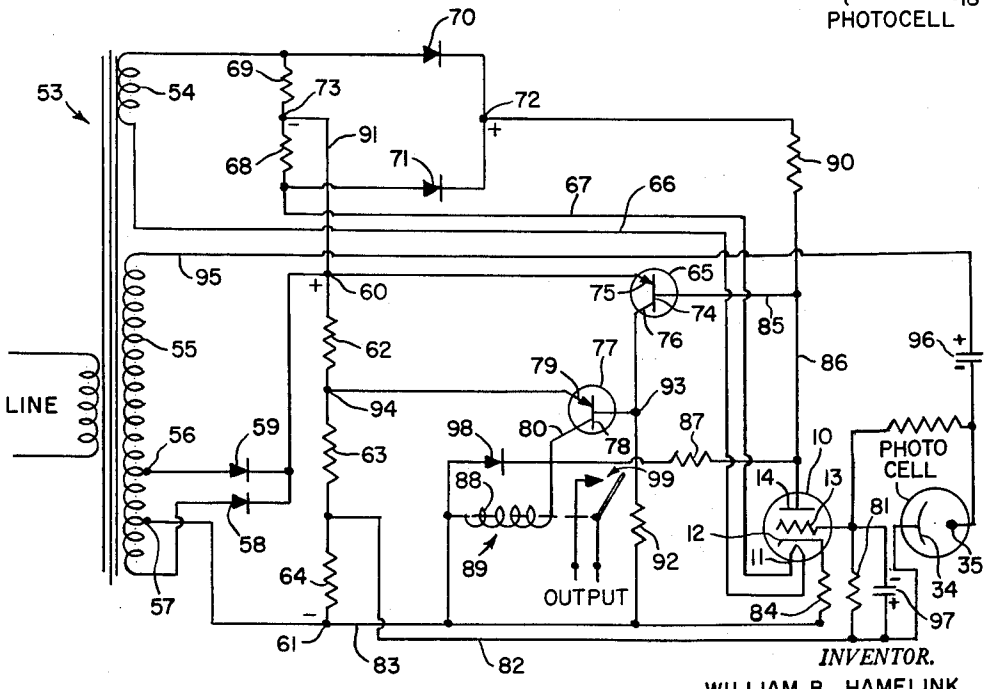


FIG. 2

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CONDITION RESPONSIVE MEANS

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This invention is concerned with condition responsive means and particularly with a condition responsive means which, in its preferred embodiment, is utilized as a flame detector, wherein an electronic circuitry has its input connected to flame sensing means in the form of a photocell and has an output which may comprise an electromagnetic flame relay.

In accordance with the teachings of the present invention, the electronic circuitry includes a hot cathode electron discharge device which is interconnected with transistor means. Electronic flame detectors utilizing both hot cathode discharge devices and transsistor means interconnected to form an electronic network are known to be old. While such an electronic network is reliable for many applications, when such a network is used as an electronic flame detector portion of combustion safeguard systems, it is desirable to achieve the optimum in reliability since an unsafe failure (a failure wherein the electronic network senses the presence of flame at the fuel burner unit being controlled when in fact the flame may not be present) may produce disasterous results.

The inventive concept of the present invention resides in the use of a biasing network for the transistor means, which biasing network is controlled or dependent upon the continued electrical continuity of the cathode heater of the hot cathode electron discharge device. In this manner, should the electron discharge device fail due to open circuiting of its cathode heater, then the biasing circuit for the transistor is also rendered ineffective. In this manner, the transistor is controlled to fail safe. In this condition, so far as the flame relay is concerned, the apparatus has failed in a safe manner to indicate the absence of flame at the fuel burner unit being controlled.

This inventive concept will be apparent to those skilled in the art upon reference to the following specification, claims, and drawings, of which:

FIGURE 1 is a schematic representation of a first embodiment of the present invention, and

FIGURE 2 is a schematic representation of a second embodiment of the present invention.

Referring now to FIGURE 1, reference numeral 10 identifies a hot cathode discharge device having a cathode heater 11, a cathode 12, a control electrode 13, and an anode 14. The cathode and control electrode of discharge device 10 constitute input means which is connected through a network including resistors 15 and 16 and capacitor 17 to a condition sensing means in the form of a photoemissive cell 18 having an anode 35 and a cathode 34. The anode and cathode of discharge device 10 constitute output means which is connected in controlling relation to a transistor 19.

Transistor 19 is provided with an emitter 20, a base 21, and a collector 22. Electrodes 20 and 21 constitute input electrodes to the transistor while electrodes 20 and 22 constitute output electrodes for this transistor.

The apparatus of FIGURE 1, as well as that of FIGURE 2, may constitute the electronic flame detector portion of a complete combustion safeguard system, which safeguard system includes further means such as a main burner control relay and a safety cutout means. These further means have not been shown. When the apparatus of FIGURES 1 or 2 is utilized in this manner, photocell 18 is positioned to view the firebox of the fuel burner unit which is being controlled. In this manner photocell

18 is subjected to the presence or absence of the condition to be detected, namely the flame.

In the absence of flame, photocell 18 is nonconductive and the discharge device 10 is conductive. The current flow circuit for this discharge device can be traced from the tap 29 of secondary winding 23 of a power transformer 24, through resistor 27, resistor 26, the anode-to-cathode circuit of discharge device 10, and conductor 25 to the lower terminal of secondary winding 23. This current flow circuit causes a voltage to be developed across resistor 27 such that the left-hand terminal is positive with respect to the right-hand terminal, this polarity of this voltage being shown on FIGURE 1. The positive terminal of resistor 27 is connected by means of conductors 30 and 31 to the base of transistor 19 whereas the negative terminal of this resistor is connected by means of conductors 32 and 33 to the emitter of this transistor. This voltage constitutes a reverse bias for transistor 19. As a result, so long as discharge device 10 is in a conducting state, transistor 19 is biased to be nonconductive.

If it is now assumed that photocell 18 is subjected to the presence of the condition to which it is sensitive, for example the presence of flame, then its cathode 34 becomes electron emissive and unidirectional current flows from anode 35 to the cathode. This current flow circuit can be traced from the upper terminal of secondary winding 23 through conductor 36, capacitor 37, the anode-to-cathode circuit of photocell 18, and conductor 25 to the lower terminal of secondary winding 23. As a result of this unidirectional current flow capacitor 37 is charged to the polarity of voltage indicated on FIGURE 1. This voltage charge is then distributed through resistor 16 to charge capacitor 17 to the polarity indicated. As can be seen, the positive plate of capacitor 17 is connected to cathode 12 whereas the negative plate of this capacitor is connected to control electrode 13, thus providing a cutoff bias for discharge device 10 to render this discharge device nonconductive in the presence of flame.

The nonconductive state of discharge device 10 results in the absence of the above mentioned voltage developed across resistor 27. As a result, the reverse biasing of transistor 19 is removed.

Transistor 19 is then rendered conductive by virtue of a forward biasing current. This forward biasing circuit is supplied from a circuit network which can be traced from the upper terminal of secondary winding 38 through conductors 39 and 40, resistor 41, conductor 42, cathode heater 11, and conductor 43 to the tap 44 on secondary winding 38. This current flow circuit provides operative energization of heater 11 through resistor 41 to thereby heat cathode 12 to an operating temperature. Furthermore, a branch current flows through a circuit which includes the emitter and base of transistor 19 connected in series with a resistor 45, the series circuit being connected in parallel with resistor 41. This can be seen by tracing a circuit from the left-hand terminal of resistor 41, through conductors 40 and 46, the emitter-to-base circuit of transistor 19, conductor 47, and resistor 45 to the right-hand terminal of resistor 41. The current flowing through this last named series circuit, which is in parallel with resistor 41, provides a forward biasing current for transistor 19. When discharge device 10 is in a conducting condition or state, the voltage developed across resistor 27 is of a sufficient magnitude to overcome this forward biasing current. However, upon discharge device being rendered nonconductive, this forward biasing current is effective to render transistor 19 conductive.

Upon transistor 19 becoming conductive, a current flow circuit can be traced from the upper terminal of secondary winding 38 through conductors 39, 46 and 33, the emitter-to-collector circuit of transistor 19, winding 48

of relay 49, and diode 50 to the lower terminal of secondary winding 38. Current flow in this output circuit causes switch means 51 of relay 50 to move to a closed condition to provide an output. Since this output may take a number of different forms, it has been merely labeled "output" on FIGURE 1 to simplify the disclosure of the present invention. Relay 49 may be characterized as a flame relay, when used as part of a combustion safeguard system.

Thus far, the explanation has been concerned with the normal states of operation of the apparatus. The first state of operation is the no-flame state in which discharge device 10 is conductive and, as a result of the voltage developed across resistor 27, transistor 19 is biased to be nonconductive to thereby maintain relay 49 deenergized. The second state of operation is the flame state in which photocell 18 causes a cutoff bias to be developed at capacitor 17 to render discharge device nonconductive. The voltage present across capacitor 27 therefore no longer exists and the above mentioned forward biasing current is effective to render transistor 19 conductive to energize relay 49.

As may readily be appreciated, in prior art devices of this general type an unsafe failure occurs in the event that cathode heater of the hot cathode discharge device open circuits to thereby render the discharge device nonconductive regardless of the presence or absence of flame. When the discharge device of such a prior art device is rendered nonconductive due to the malfunctioning of the cathode heater, then the remaining portion of the electronic network and particularly the transistor which it is controlling views such a nonconducting state of the discharge device as an indication of the presence of flame. However, the apparatus of the present invention, as above described, utilizes a particular construction for the forward biasing circuit means for transistor 19 which insures that such a malfunction is not viewed by transistor 19 as an indication of the presence of flame. Specifically, open circuiting of cathode heater 11 also opens the circuit which includes resistor 41. This resistor is connected in parallel with the emitter-to-base circuit of transistor 19, and as a result, when cathode heater 11 opens the forward biasing current is not applied to transistor 19. Therefore, even though discharge device 10 is rendered nonconductive transistor 19 is maintained in a nonconducting condition due to the absence of a forward bias and relay 49 therefore fails in a safe condition, that is a deenergized condition.

The apparatus of FIGURE 1 in a specific instance has been construed with the following components.

Secondary winding 38	24 volts center tapped.
The upper portion of secondary winding 23	190 volts.
The lower portion of secondary winding 23	65 volts.
Discharge device 10	7586.
Transistor 19	2 and 1172.
Diodes 50 and 52	*SD*91.
Resistor 41	39 ohms.
Resistor 45	2.2K.
Resistor 27	10K.
Resistor 26	5.6K.
Resistor 16	37M.
Resistor 15	6.8M.
Capacitor 37	.002 microfarad.
Capacitor 17	.032 microfarad.

FIGURE 2 incorporates this inventive concept wherein the open circuiting of the cathode heater of the hot cathode discharge device insures that the failure will be a safe failure. In the apparatus of FIGURE 2, a first and a second transistor are utilized and the transistor portion is maintained in the condition indicative of no-flame by means of a positive forward biasing current, as will be apparent.

Referring specifically to FIGURE 2, electron discharge device 10, and the components thereof, is again identified by the reference numeral utilized in FIGURE 1. Photocell 18 and its components are likewise identified by similar reference numerals.

In the apparatus of FIGURE 2 energizing voltage is received from a transformer identified by reference numeral 53. This transformer is provided with a first secondary winding 54 and a second secondary winding 55, secondary 55 being tapped at 56 and 57. The lower portion of secondary winding 55 is connected to diodes 58 and 59 to thereby provide a source of D.C. voltage between a positive terminal 60 and a negative terminal 61. Voltage divider means consisting of resistors 62, 63 and 64 are connected across terminals 60 and 61.

Secondary winding 54 is connected to provide operating voltage to energize the cathode heater 11 of discharge device 10, and as will be apparent, to also supply a biasing current for a first transistor 65. The energizing circuit for cathode heater 11 can be traced from the lower terminal of secondary winding 54 through conductor 66, heater 11, conductor 67, and resistors 68 and 69 to the upper terminal of secondary winding 54. The current which flows in this circuit not only energizes heater 11 but also provides a voltage drop across resistors 68 and 69. This voltage drop is applied to diodes 70 and 71, which diodes rectify this voltage and produce a source of D.C. biasing voltage, the positive terminal of which exists at terminal 72 and the negative terminal of which exists at terminal 73.

Referring now to the transistor portion of FIGURE 2, transistor 65 is provided with a base 74, an emitter 75, and a collector 76. A second transistor 77 includes a base 78, an emitter 79 and a collector 80.

Considering the operation of the apparatus of FIGURE 2 in detail, discharge device 10 is normally biased to be conductive by means of a circuit which can be traced from control electrode 13 through resistor 81, conductor 82, resistor 64, conductor 83, and resistor 84 to the cathode of discharge device 10. In this above traced circuit the voltage which is present across resistor 64 places a positive potential on the control electrode and thereby establishes a normal conducting state for discharge device 10. Conduction of discharge device 10 can be traced from positive terminal 60 through the emitter-to-base circuit of transistor 65, conductors 85 and 86, the anode-to-cathode circuit of discharge device 10, resistor 84, and conductor 83 to negative terminal 61.

This above traced current flow circuit provides a forward biasing current for transistor 65 to render this transistor conductive when discharge device 10 is conductive. This forward biasing current may be called a first forward biasing current.

A second forward biasing current for transistor 65 is provided and this circuit can be traced from terminal 60 through the emitter-to-base circuit of transistor 65, conductors 85 and 86, resistor 87, winding 88 of relay 89, and conductor 83 to the negative terminal 61. The magnitude of the current flowing in this circuit is relatively low, that is, is not of a sufficient magnitude to operatively energize winding 88. It is however of a sufficient magnitude to provide a forward biasing current for transistor 65.

A reverse biasing current is also provided for transistor 65 and this circuit can be traced from positive terminal 72 through resistor 90, conductor 85, the base-to-emitter circuit of transistor 65, terminal 60, and conductor 91 to negative terminal 73. As has been mentioned, this last named reverse biasing circuit for transistor 65 is dependent upon the electrical continuity of cathode heater 11. As has been above described in connection with FIGURE 1, should this cathode heater become inoperative due to an open circuit, then no voltage is developed across resistors 68 and 69 and likewise a voltage no longer exists

across terminals 72 and 73. Therefore, a reverse biasing current does not flow and transistor 65 is maintained conductive by means of the above described second forward biasing current. It will be remembered that the first above described biasing current depends upon conduction of discharge device 10 and in the case where the cathode heater open circuits, this first forward biasing current does not flow. The second forward biasing current is provided to provide a positive forward biasing current to insure that transistor 65 remains conductive, this being the desired state for an indication of the absence of flame. Thus a safe failure occurs.

Transistor 65 is connected in controlling relation to second transistor 77. When transistor 65 is conductive a current flow circuit can be traced from positive terminal 60 through the emitter-to-collector circuit of transistor 65, terminal 93, resistor 92, and conductor 83 to the negative terminal 61. Transistor 65, in a conductive state, has a very low emitter-to-collector impedance and therefore the potential level of terminal 93 is substantially at the potential level of terminal 60. However, terminal 94 to which emitter 79 of transistor 77 is connected is negative with respect to terminal 60 and therefore a reverse biasing voltage is applied to transistor 77. In other words, emitter 79 of this transistor is connected to negative terminal 94 whereas the base of this transistor is connected to positive terminal 93.

Thus far, the description of the apparatus of FIGURE 2 has dealt with the condition of operation wherein photocell 18 is not subjected to a flame. If it is now assumed that photocell 18 senses the presence of flame, a current flow circuit can be traced from the upper terminal of secondary winding 55 through conductor 95, capacitor 96, photocell 18, conductor 82, and resistor 64 to tap 57 on secondary winding 55. As has been described in connection with FIGURE 1, this current flow is effective to charge capacitor 96 to the polarity indicated and this voltage is then distributed to a capacitor 97 to apply a cutoff bias to the control electrode of discharge device 10. When discharge device 10 becomes nonconductive, the first above traced forward biasing current for transistor 65 no longer flows and the above traced reverse biasing current is now effective to render transistor 65 nonconductive.

Upon transistor 65 being rendered nonconductive, its emitter-to-collector impedance increases and the potential level of terminal 93 moves in a negative direction to thereby provide a forward biasing current for transistor 77. At this time, terminal 94 is positive and terminal 93 is negative. The current flow circuit for the output electrodes of transistor 77 can be traced from terminal 94 through the emitter-to-collector circuit of transistor 77, winding 88 of relay 89, and conductor 83 to the negative terminal 61. Once transistor 77 is rendered conductive, relay 89 is operatively energized and its switch 99 is moved to a closed condition. Here again, the output of the apparatus of FIGURE 2 has been merely labeled "output" to simplify the showing of the present invention.

As has been mentioned above, should the cathode heater 11 open circuit, then in that event the reverse biasing current no longer flows and the second named forward biasing current which flows through resistor 87 is effective to return transistor 65 to its conductiing condition and to thereby render transistor 77 nonconductive, thus deenergizing relay 89 to provide a safe failure.

From the description it can be seen that I have provided an improved condition responsive means wherein a hot cathode discharge device and a transistor are so interrelated and interconnected that an unsafe failure is prevented should the cathode heater of the hot cathode discharge device open circuit. Other modifications of the present invention will be apparent to those skilled in the art and it is therefore intended that the scope of the present invention be limited solely by the scope of the appended claims.

I claim as my invention:

1. Condition detecting means comprising; condition sensing means adapted to be subjected to a condition to be detected, a hot cathode electron discharge device having an electrically energizable cathode heater, a pair of main current conducting electrodes, and a control electrodes, means connecting said condition sensing means in controlling relation to the control electrode of said discharge device, a transistor having a pair of output electrodes and an input electrode, means connecting the output electrodes of said discharge device in controlling relation to the input electrode of said transistor, control means connected in circuit with the output electrodes of said transistor to thereby control said control means in accordance with the condition to which said sensing means is subjected, and biasing circuit means connected to the input electrode of said transistor, said biasing circuit means including said cathode heater whereby a malfunction of said discharge device due to an open circuited cathode heater also renders said transistor inoperative to control said control means.

2. In combination, a hot cathode electron discharge device having an electrically energizable cathode heater, a control electrode and a pair of output electrodes, a controllable current conducting device having a pair of output electrodes and an input electrode, means connecting the output electrodes of said discharge device in controlling relation to the input electrode of said current conducting device, and biasing means including said cathode heater connected to the input electrode of said current conducting device to establish a given state of operation for said current conducting device when said discharge device is nonconductive, whereupon open circuiting of said cathode heater renders said biasing means ineffective to establish said given state of operation for said current conducting device.

3. In combination; a hot cathode electron discharge device having an electrically energizable cathode heater, a control electrode adapted to receive an input signal, and having a pair of output electrodes; a transistor having a pair of input electrodes and a pair of output electrodes, said output electrodes being adapted for connection to output means to be controlled in accordance with the presence or absence of the input signal; circuit means connecting the output electrodes of said discharge device in controlling relation to the input electrodes of said transistor, biasing circuit means including in series therewith said cathode heater, and means connecting said biasing circuit means to the input electrodes of said transistor to establish a given state of operation for said transistor upon the absence of the input signal, said biasing circuit means being rendered inoperative upon an open circuiting of said cathode heater.

4. A flame detector comprising; a photocell adapted to be subjected to the presence or absence of flame, a hot cathode electron discharge device having a cathode heater, a control electrode, an anode and a cathode, circuit means connecting said photocell in controlling relation to said control electrode and cathode to render said discharge device nonconductive in the presence of flame, a transistor having a pair of input electrodes and a pair of output electrodes, means connecting said anode and cathode in circuit with said input electrodes to render said transistor nonconductive when said discharge device is conductive, biasing means, means connecting said biasing means in circuit with said input electrodes to render sad transistor conductive when said discharge device is nonconductive, and means connecting said cathode heater in circuit with said biasing means to render said biasing means ineffective to thereby insure that said transistor remains nonconductive in the event that said discharge device becomes nonconductive due to malfunction of said cathode heater.

5. An electronic flame detector comprising; a hot cathode electron discharge device having a cathode heater, an

anode, a cathode, and a control electrode, load means, circuit means including load means connecting the anode and cathode circuit of said electronic discharge device to a source of operating voltage, said discharge device when conductive causing a voltage to be developed across said load means, a transistor having a pair of input electrodes and a pair of output electrodes, output means, circuit means connecting said output electrodes in circuit with said output means to a source of operating voltage for said transistor, further circuit means connecting the input electrodes of said transistor to said load means to thereby place said discharge device in controlling relation to said transistor, biasing circuit means including in series therewith the cathode heater of said discharge device and a source of voltage, said biasing circuit means being operative to apply a forward bias to said transistor and to energize said cathode heater to heat the cathode of said discharge device, said discharge device normally being conductive to develop a reverse bias voltage across said load means to maintain said transistor nonconductive, flame sensing means adapted to be subjected to the presence or absence of a flame to be detected and to provide a control signal upon the presence of such flame, means applying said control signal to the cathode and control grid of said discharge device to render said discharge device nonconductive in the presence of flame, whereupon said transistor is rendered conductive by virtue of said forward bias to thereby energize said output means, the apparatus functioning upon a malfunction of said discharge device due to open circuit of said cathode heater to thereupon remove the forward bias from said transistor and prevent conduction of said transistor as a result of such malfunction.

6. In combination, a hot cathode electron discharge device having a cathode heater, a cathode, an anode, and a control electrode, biasing circuit means for said discharge device and including input terminal means connecting said control electrode to said cathode to render said discharge device normally conductive, a transistor having a pair of input electrodes and a pair of output electrodes, circuit means connecting the input electrodes of said transistor in series circuit with the anode to cathode circuit of said discharge device to provide a forward bias current for said transistor to thereby maintain said transistor conductive so long as said discharge device is conductive, output means connected in circuit with the output electrodes of said transistor, and biasing circuit means for said transistor and including in series therewith said cathode heater connected to the input electrodes of said transistor to provide a reverse biasing current to said transistor to render said transistor nonconductive in the absence of conduction of said discharge device, said biasing circuit being dependent upon electrical continuity of said cathode heater such that malfunctioning of said discharge device to become nonconductive as a result of failure of said cathode heater likewise causes said reverse biasing current to be interrupted and thereby said transistor is maintained conductive and said output means is not actuated in the case of such a malfunction, said input terminals being adapted to receive an input signal to render said discharge device nonconductive in the presence of said signal and to thereby render said transistor nonconductive to actuate said output means in accordance with the presence of the input signal.

7. Condition detecting apparatus comprising; a hot cathode electron discharge device having a cathode heater, a cathode, an anode, and a control electrode; a first transistor having a pair of input electrodes and a pair of output electrodes connected to output load means, biasing circuit means for said discharge device connected to the cathode and control electrode of said electron discharge device to provide a normal conducting state for said discharge device, circuit means connecting the anode to cathode circuit of said discharge device in series with the input electrodes of said first transistor to thereby provide a first forward biasing current, biasing circuit means for said first transistor connected to the input electrodes of said first transistor to provide a second forward biasing current, biasing circuit means for said first transistor including the cathode heater of said discharge device connected to the input electrodes of said first transistor to provide a reverse biasing current; a second transistor having a pair of input electrodes and a pair of output electrodes, circuit means connecting the input electrodes of said second transistor to said output load means of said first transistor to render said second transistor nonconductive when said first transistor is conductive; and condition responsive means connected to the cathode and control electrode of said discharge device to render said discharge device nonconductive in the presence of a condition to be detected, the nonconduction of said discharge device being effective to cause said first transistor to become nonconductive as a result of said reverse biasing current, the apparatus functioning upon open circuiting of said cathode heater to render said reverse biasing current ineffective, whereupon said first transistor is maintained in a conducting state as a result of said second forward biasing current.

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