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(54) IMPROVEMENTS RELATING TO SMOKE DETECTORS

(71) We, CHUBB FIRE SECURITY LIMITED, formerly known as THE PYRENE COMPANY LIMITED, a British company of Pyrene House, Sunbury-on-Thames, Middlesex, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention is concerned with improving the stability of smoke detectors of the kind in which an electrically energised detector circuit is connected to an electrical supply circuit and generates at its output an electric signal which undergoes a significant variation in the presence of smoke, the output of the detector circuit being connected to a circuit for providing an alarm indication in response to the said signal.

According to the present invention, a feedback circuit incorporating a delay circuit is connected between the output of the detector circuit and the electrical supply circuit for the detector circuit, the feedback circuit acting to adjust the voltage provided by this supply circuit so that the output of the detector circuit is at least partly compensated for variations occurring over a period the minimum value of which is determined by the delay circuit.

The electrically energised detector circuit may be of the kind in which the amount of light from a light source which reaches a photosensitive cell is changed in the presence of smoke. Alternatively, it may be of the kind employing an ionisation chamber. If the detector circuit employs a light source and photosensitive element, we prefer to arrange them with a barrier between them so that in the presence of smoke the scattering of light from the light source results in an increase in the light falling on the photosensitive element. In constructions employing a housing containing the light source and light-sensitive element, a small amount of light reaches the photosensitive element even in the absence of smoke. A trigger circuit is connected to the light-sensitive element, which is preferably of the photoconductive kind, and operates an alarm indicator in response to variations in the output of the light-sensitive element which are sufficiently rapid, in relation to the period of the delay circuit, to avoid compensating action through the feedback circuit. The feedback circuit may affect the supply voltage of the photoconductive cell, or the supply voltage for the light source, or the supply voltages for both of these elements.

If the amount of illumination reaching the photosensitive element in the absence of smoke is insufficient to operate the feedback circuit, a small hole can be made in the barrier or baffle which normally prevents direct light reaching the photosensitive element.

Using such a feedback circuit, a smoke detector can be given much greater stability. This is of importance because in some cases a smoke detector may be required to operate at an intensity of smoke corresponding to 5% light obscuration per metre; with prior circuits this would have been difficult to achieve because the drift in the circuit would have been such that at such a sensitivity a false alarm could have resulted.

In order that the invention may be better understood, three examples will now be described with reference to the accompanying drawings, in which:—

Figure 1 is the circuit diagram of a first form of photosensitive smoke detector;

Figure 2 is a circuit diagram of a second form of photosensitive smoke detector; and

Figure 3 is the circuit diagram of a smoke detector employing an ionisation chamber.

In the circuit of Figure 1, the projector lamp LP1 constitutes the light source of the smoke detector and is connected across lines 18 and 19. The photoconductive element PC1

is shielded from direct light from the lamp LP1 by a baffle 16 and is connected in series with a fixed resistor R7, the base-emitter path of the npn transistor T7 and a variable resistor RV1 across the lines 18 and 19. The collector of transistor T7 is connected directly to the line 18. From its emitter there is a connection to the trigger electrode of a silicon-controlled rectifier SCR1, the cathode of which is connected to the line 19 through a biasing zener diode Z2. Between the anode of the silicon-controlled rectifier and a signal line 17 there is a parallel circuit comprising a resistor R6 and an indicator lamp LP2.

The zener diode Z2 defines a reference voltage for the silicon-controlled rectifier, which switches on when the triggering signal across resistor RV1 is sufficient to overcome this reference. A resistor R4 in series with a diode D3 biases the zener diode Z2.

The supply and compensating circuits for the lamp LP1 will now be described. A 28-volt supply is connected across the positive and negative supply lines 18*b* and 19. A transistor T2 has its emitter and collector in series with the positive supply line and forms a part of a voltage-stabiliser circuit, the remainder of which is constituted by a resistor R5 and a zener diode Z1 connected in series between the supply lines 18*b* and 19. The junction of these components is taken to the base of transistor T2.

The transistor T2 provides line voltage stabilising, as the detector feedback circuit is not intended to compensate for external changes but only for drift within the circuit. This compensating feedback circuit has its input at the wiper of the potentiometer RV1. The fraction of the signal voltage tapped from potentiometer RV1 by this wiper is applied to the base of transistor T3. Variations in this signal fraction cause variations in the current drawn by transistor T3 and consequently variations of the potential at the junction of the collector of transistor T3 and the resistor R3 through which this collector is connected to the supply line 18*a* to the left of transistor T2. The potential variations at this junction are applied through a diode D4 to the base of transistor T4. This is the first of three transistors T4, T5 and T6 which together form an emitter-follower train having a high input impedance and a low output impedance. The collector and emitter of the last transistor T6 of this chain are connected in series with the supply line. The voltage on line 18, to the left of transistor T6, is therefore varied by the feedback circuit in accordance with variations at the wiper of potentiometer RV1.

To prevent the feedback circuit compensating for signal variations due to smoke, a delay element is incorporated. This is provided in the circuit shown by the capacitor C3 which is such that short-term variations in the signal output, such as are caused by the ingress of smoke, do not affect the emitter-follower transistor chain. Such variations are effectively absorbed by the capacitor C3 and consequently the silicon-controlled rectifier is able to respond to the resultant light changes. On the other hand long changes which occur over a period of, for example, more than 20 minutes, will affect the compensating feedback circuit.

Transistor T8 is inserted to prevent "overshoot" when the detector is first switched on. Such overshoot can occur due to the abnormal sensitivity of the photoconductive cell after it has been in total darkness. The switch SW1B is used to short circuit the transistor T8 for calibration purposes to ensure that the lamp quickly reaches its steady state.

By taking the feedback circuit back to the light source, compensation is provided for drift whether the drift is attributable to contacts in the wiring, component value drift or ageing of the lamp or even accumulation of dirt in the optical system. If for any reason the output increases the feedback causes the light from the lamp to be dimmed by a corresponding amount. As a consequence, the resistance of the photoconductive cell increases and this reduces the output to its normal value and maintains the voltage applied to the base of the silicon-controlled rectifier at the predetermined value. A decrease in light output produces the reverse effect.

Diode D5 and switch SW1A short out the time delay on the feedback circuit while SW1A is closed. This allows the output voltage to be set by RV1 without lengthy stabilising periods. Capacitor C1 draws charging current as the voltage on line 18 increases from zero after switch-on. The charging current flows into the base of transistor T8 causing a voltage drop across R3 which inhibits the rapid build-up of voltage at line 18. Hence a time constant of about 20 minutes is put on the lamp light-up time and overshoot problems are eliminated.

Resistor R2 protects transistor T8 from excessive base current.

When SW1B is closed the charging current for capacitor C1 is shorted to earth and the above time constant is eliminated. This is done to allow for quick and easy calibration.

In the circuit shown, the change of voltage on line 18 due to feedback, when there is a change of light output, is also experienced by the photoconductive cell. The effects of the feedback on the lamp and on the photoconductive cell act in unison and produce a more closely controlled feedback characteristic than would be possible if the feedback acted on the lamp alone. However, if desired the feedback may act only on the light source

supply voltage or even only on the supply voltage for the photoconductive cell.

In the circuit of Figure 2 corresponding elements have been given the references used in Figure 1. The output switching circuit is basically the same as that of Figure 1 but the gate circuit of the silicon-controlled rectifier includes a fixed temperature cut-out device, in this example a fusible element TF1, which becomes open-circuit at a predetermined temperature. When this happens the silicon-controlled rectifier SCR1 fires due to the anode-to-gate leakage current. This ensures that the detector will operate at a fixed temperature, if it has not already operated in response to the signal from the photoconductive element PC1.

In the feedback circuit the voltage from the slider of potentiometer RV1 is now applied to two transistors T3*a* and T3*b* in series and the voltage changes at the collectors of these transistors are applied through the diode D4 to the emitter-follower transistors T5 and T6. The voltage variations on the supply line 18 are applied to the photoconductive element PC1 but not to the lamp LP1. As before, capacitor C3 provides a delay to ensure that quick changes do not actuate the feedback circuit. The resistors R10 and R11 and the thermistor TH1 provide a bias network to compensate for the effects of temperature changes on the components within the feedback loop.

The circuit for supplying the projector lamp voltage is somewhat different from that shown in Figure 1. As a positive voltage begins to build up on zener diode Z1, transistors T2*b* and T2*a* begin to conduct and the voltage across the supply rails 18*a* and 19 starts to increase. To enable a corresponding increase to appear across capacitor C1, this capacitor draws a small charging current which flows through the capacitor into the base of transistor T10. Transistors T11 and T12 provide current amplification and the total collector current of these three transistors flows through the load resistors R5 of the zener diode Z1. Consequently, the voltage across the supply rails 18*a* and 19 can only build up very slowly as capacitor C1 becomes charged. A time of approximately 30 minutes is required for this supply voltage to reach the maximum permitted by the zener action of zener diode Z1.

Transistor T2*b* enables a higher value of resistor R5 to be used than would be possible if the voltage drop across resistor R5 caused by the base current of transistor T2*a* were not to override the zener action of diode Z1. Diode D2 allows capacitor C1 to discharge rapidly through resistor R12 and the projector lamp filament when the supply voltage is interrupted.

In Figures 1 and 2, the components LP1, PC1, T7 and RV1 represent the detector circuit and the alarm indicator circuits responsive to the signals for the detector circuit include components SCR1 and LP2. The compensating delayed feedback circuit of Figure 1 includes transistors T3 to T6, diode D4 and capacitor C3. In Figure 2, the delayed feedback circuit includes transistors T3*a*, T3*b*, T5 and T6, diode D4, and capacitor C3.

In Figure 3 a closed ionisation chamber 31 and an open ionisation chamber 32 are connected in series across positive and negative voltage supply lines 18 and 19. Each of these chambers contains a source of radiation. The chamber 32 is open to air to be sampled and in the presence of products of combustion there is a reduction in the conductivity of the air in this chamber which results in an increase in the voltage drop across the chamber 32. Thus the voltage at the junction of the chambers 31 and 32 becomes more positive. The chamber 31 is a reference element, enabling a comparison to be made between the conductivity of the air in the closed chamber 31 and the conductivity of the air entering the open chamber 32. If desired, the chamber 31 can be replaced by a resistor.

The voltage at the junction of the chambers 31 and 32 is applied to the gate of a high-input impedance transistor T20, the main current path of which is connected in series with a zener diode Z10 and a resistive circuit, consisting of parallel potentiometers RV1 and RV2, across the supply conductors 18 and 19. Potentiometer RV2 supplies a signal for the gate of a silicon-controlled rectifier SCR2 which has an alarm indicator lamp LP2 in its anode circuit and a biasing zener diode Z2 in its cathode circuit. The wiper of potentiometer RV1 supplies a signal for the feedback circuit. This feedback signal is applied to the base of a transistor T3, the collector of which supplies a signal through a diode D4 to the base of a transistor T6. The main current carrying path of the transistor T6 is connected in series between the supply conductor 18, for the ionisation chambers and transistor T20, and the positive terminal 33. A capacitor C3 provides the delay necessary to prevent the feedback circuit from providing compensation for alarm signals. In the circuit shown, long term variations cause a change in the potential derived from the potentiometer RV1 and this acts to vary, through transistor T6 the voltage applied across the ionisation chambers. It will be appreciated that the long term variation may arise from a number of causes, such as change of sensitivity of one or both of the ionisation chambers, or change in response of transistor T20. The effect of the feedback on the supply circuit is to restore the voltage output of the detector circuit substantially to

the value which it had in the absence of the said long term variation.

In Figure 3, the detector circuit includes the two ionisation chambers, transistor T20 and potentiometer RV2. The alarm indicator circuit includes the silicon-controlled rectifier SCR2 and the alarm indicator lamp LP2. The feedback circuit includes potentiometer RV1, transistor T3 and transistor T6, diode D4 and capacitor C3.

WHAT WE CLAIM IS:—

1. A smoke detector of the kind in which an electrically energised detector circuit is connected to an electrical supply circuit and generates at its output an electrical signal which undergoes a significant variation in the presence of smoke, the output of the detector circuit being connected to a circuit for providing an alarm indication in response to the said signal, the detector including a feedback circuit incorporating delaying means connected between the output of the detector circuit and the supply circuit for the detector circuit, the feedback circuit operating to adjust the voltage provided by the supply circuit in such a sense that the output of the detector circuit is at least partially compensated for variations occurring over a period the minimum value of which is determined by the said delaying means.

2. A smoke detector in accordance with Claim 1, in which the detector circuit includes a light source and a photosensitive element.

3. A smoke detector in accordance with Claim 1, in which the detector circuit includes an open ionisation chamber.

4. A smoke detector of the kind including a detector circuit having a light source and a light sensitive element with a barrier interposed between them so that in the presence of smoke, the resultant scattering of light from the light source results in an increase in the light falling on the light sensitive element, and in which an output signal derived from the detector circuit is applied to a circuit for providing an alarm indication, the detector including a feedback circuit incorporating delaying means connected between the output of the light sensitive element and a supply circuit for the light source or the light sensitive element or for both the light source and the light sensitive element, the feedback circuit operating to adjust the voltage provided by the said supply circuit so that the output of the light sensitive element is compensated for variations occurring over a period the minimum value of which is determined by the delaying means.

5. A smoke detector in accordance with claim 4, in which the barrier is perforated to permit some light to reach the light sensitive element directly.

6. A smoke detector in accordance with claim 2, 4 or 5, in which the light sensitive element is a photoconductive cell.

7. A smoke detector in accordance with any one of the preceding claims, in which the feedback circuit includes a transistor having its main current carrying path connected in series with the said voltage supply circuit and having its base biased by a feedback signal.

8. A smoke detector in accordance with any one of the preceding claims, including a fixed-temperature cut-out device so connected to the alarm signal circuit that when the ambient temperature is sufficient to cause the said device to cut out the alarm circuit is operated.

9. A smoke detector in accordance with Claim 1, substantially as herein described with reference to Figure 1 or Figure 2 or Figure 3 of the accompanying drawings.

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In Figure 3, the detector circuit includes the two ionisation chambers, transistor T20 and potentiometer RV2. The alarm indicator circuit includes the silicon-controlled rectifier SCR2 and the alarm indicator lamp LP2. The feedback circuit includes potentiometer RV1, transistor T3 and transistor T6, diode D4 and capacitor C3.

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