

[54] OPTICAL SMOKE DETECTOR

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[22] Filed: Dec. 14, 1971

[21] Appl. No.: 207,791

[30] Foreign Application Priority Data

Dec. 21, 1970 Switzerland..... 18902/70

[52] U.S. Cl. 340/237 S, 250/218, 356/207

[51] Int. Cl. G08b 21/00

[58] **Field of Search** 340/237 S; 250/218;
356/207

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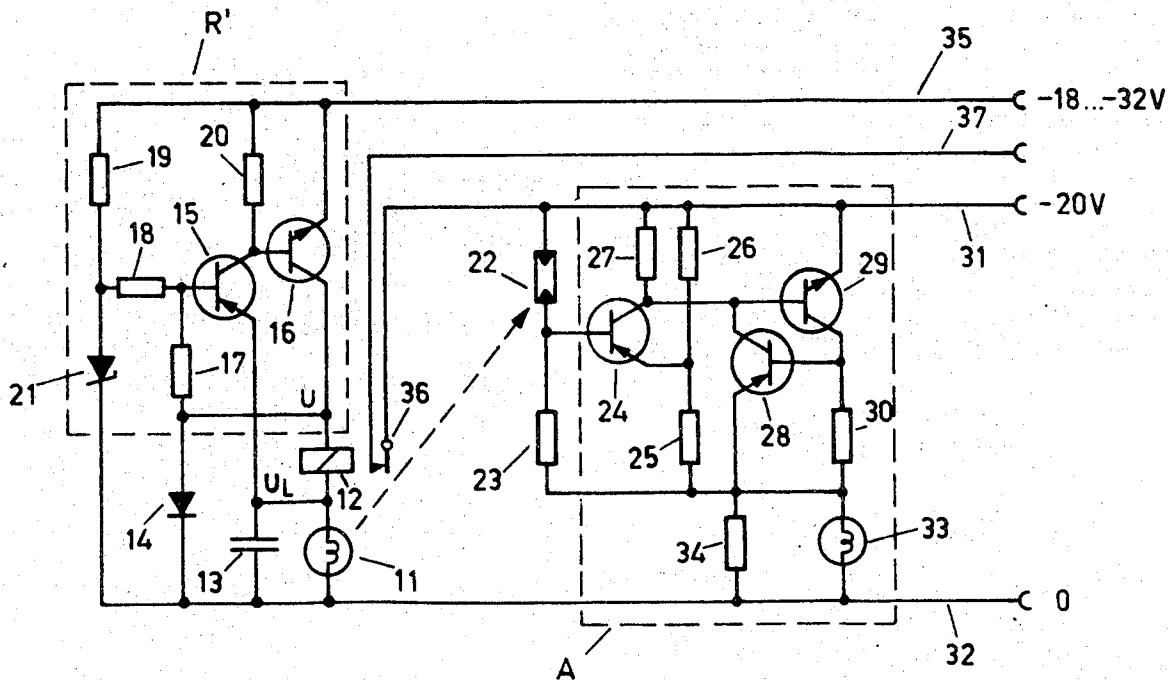
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[57]

ABSTRACT

A detection chamber has gases, such as air, applied thereto, in which the presence of smoke is to be detected. The detection chamber is illuminated, and a light detector, such as a photoelectric transducer is provided, located to be differentially affected by light from the gases, depending upon whether smoke is included therein or not. To provide for detection of even small levels of smoke in the gases, and prevent spurious response due to changes in the illumination, an electric supply is provided for the illumination source which includes an electric lamp, and a power control means which senses the power applied to the lamp and controls power to a constant level. Preferably, power is interrupted to the lamp, periodically, and at a rate which is so high that the thermal inertia of the lamp will provide for constant light output, the lamp itself being included in a circuit which has an energy storage device, such as an inductance therein to provide for practically continuous flow of current through the lamp.

11 Claims, 4 Drawing Figures



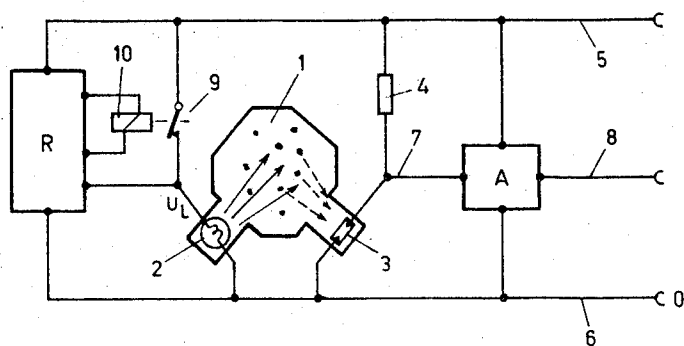


Fig. 1

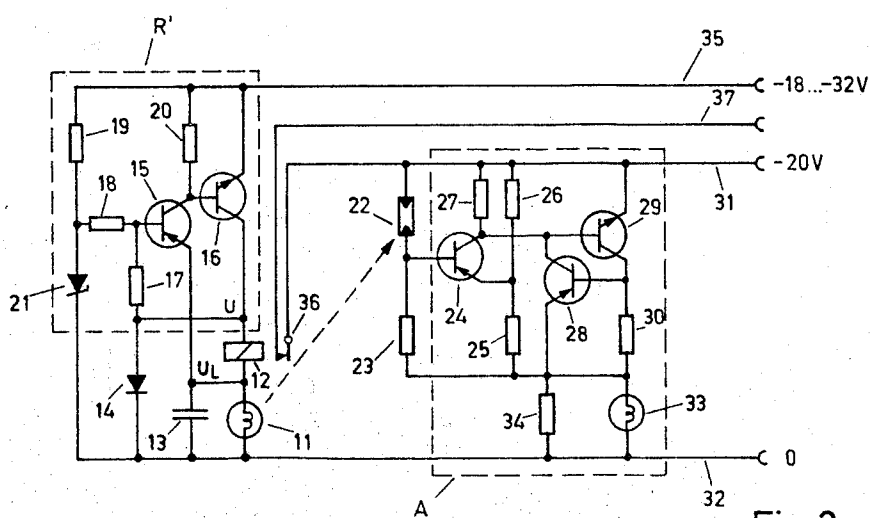


Fig. 2

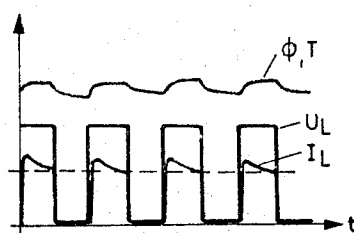


Fig. 3

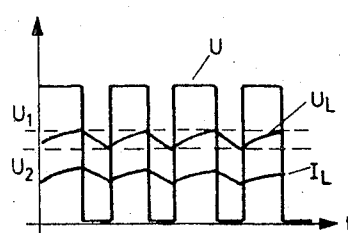


Fig. 4

OPTICAL SMOKE DETECTOR

The present invention relates to a smoke detector in which gases, such as air, are conducted to a chamber, and the presence of smoke in the gas is detected therein. The chamber is illuminated by an incandescent lamp, and light is sensed by a photoelectric transducer which is so arranged that the light from the photoelectric lamp, applied to the transducer, changes when smoke is included in the gases supplied to the measuring chamber. The change in output from the transducer is then utilized to provide an indication, or alarm signal.

Smoke detectors of the described type are used, for example, in fire alarm systems. Air from the space to be supervised is provided by natural, or forced circulation to the detection or measuring chamber, for example over ducts. Two basic types of sensing units are known. In one, a lamp and a photosensitive element are so arranged that, in the absence of smoke, direct light from the lamp does not impinge on the photosensitive element. If smoke should be present in the measuring chamber, the light is scattered, and the photo-sensitive element will be illuminated. This type is sometimes referred to as a scattered-light fire alarm unit. The second type utilizes a measuring chamber in which a photosensitive element is constantly subjected to light from the incandescent lamp. When smoke is present, the amount of light impinging on the photosensitive element is attenuated, causing a change in the output from the transducing element.

In either one of the above two cases, the light applied to the photosensitive element, and thus the current therethrough changes upon presence of smoke in the measuring chamber, thus, the presence of smoke differentially affects the light on the photosensitive element, depending upon whether smoke is present or not. Change in the electrical current through the photoelectric transducer element causes an alarm or other signal, indicating the presence of smoke in the space to be supervised.

Smoke detectors of the aforementioned type are frequently connected to a central signalling station, to which they are connected by means of lines subject to ordinary line voltage, that is, between 100 and 250 V. Usually, direct current is utilized, although alternating current can also be used. The usual type of current supply for the lamp itself is an incandescent lamp; discharge lamps may also be used. The source of current supply may be by pulses. The electrical circuit itself usually contains a current sensitive device or circuit in order to provide an alarm signal including, usually, a switching element such as a switching tube, for example of the cold cathode type.

It has been proposed to provide transistorized smoke detectors, operating in accordance with the foregoing principle, that is, to provide a completely solid state electrical circuit, operating with semi conductors, so that the only low voltage need be used, requiring only low voltage lines. The best light source operating at low voltage is an incandescent lamp. Light emitting semi conductors have a low light output, and a poor efficiency. Smoke detectors utilizing incandescent lamps, particularly when operating at low voltage have, however, the disadvantage that the amount of light output from incandescent lamps changes substantially with even small changes of applied voltage. Change in supplied light of course also changes the amount of light

on the photoelectric transducer, thus detracting from best sensitivity of the entire system. In actual operation, variations in supply voltage are practically unavoidable. Even smoke detectors which are supplied from batteries are subject to such variations; fire control systems utilizing a central power supply over lines from a central source are likewise subject to voltage variations. Low voltage installations require comparatively high current levels and thus, occasionally, cause substantial losses and voltage drops, particularly if the lines are long. Stabilization of voltage is thus a requirement if smoke detectors are to be effectively operated at low voltage levels.

It has been suggested to provide for stabilization of lamp voltage, and hence of light output by interconnecting a Zener diode in parallel to an incandescent lamp, or to provide series stabilization in accordance with known transistor circuits. Both solutions, however, result in comparatively large losses, which decrease the efficiency of the entire system since the excess of voltage, as well as the necessary current to stabilize the lamp, and connected in parallel thereto not only results in a generation of heat which is useless, but which may also provide a cooling problem.

It is an object of the present invention to provide a smoke detector which can operate with low power, requires but little supply capacity, and enables the use of stabilized incandescent lamps in low voltage circuits, and which is simple, reliable and of sufficient low cost to be readily applied at the point of use, that is, at a smoke detection chamber.

As a further object of the invention, and to additionally improve the reliability of the smoke detector, in that heat being generated in the controller is a minimum.

SUBJECT MATTER OF THE PRESENT INVENTION

Briefly, the smoke detector includes a light source formed as an incandescent lamp, light from the light source differentially affecting a photoelectric transducer which provides an output signal when the light falling thereon changes. To stabilize the source of illumination, the incandescent lamp is connected into a circuit which senses the electrical power supply to the lamp and periodically interrupts voltage supply to the lamp, so that the power supplied to the lamp will be controlled to have a constant value. Preferably, the interruption frequency of the voltage is so selected that the temperature of the incandescent filament of the lamp remains practically constant, in spite of periodical interruption, so that the light output from the lamp varies only 5 percent or less.

In accordance with a feature of the invention, the illumination source for the smoke detector is not completely interrupted upon interruption of the current to the lamp; rather, even when the voltage to the lamp is disconnected, a series connection of the lamp with a current supply element will remain in circuit. The current supply element, in a preferred form, is the coil of a relay which, in itself, can be used in the supply circuit to indicate that the lamp is functioning properly. By utilizing a current storage element, the lamp current continues to flow even when power supply is interrupted, so that the current through the lamp varies only little, thus providing for low light value variations. Such an arrangement does not require a controller which is re-

sponsive to lamp power, that is, to the average square value of the current through the lamp; rather, control of the linear average value is sufficient. If a relay coil is selected as the current supply element, complete interruption of lamp current, for example due to failure of the lamp itself, causes drop-out of the relay and a resulting indicator signal. The periodic interruption of the lamp can readily be controlled by an electronic switch, built as a chopper, for example utilizing a pair of transistors.

The invention will be described by way of example with reference to the accompanying drawings, wherein: FIG. 1 illustrates a smoke detector and a circuit therefor;

FIG. 2 is a detail view of a smoke detector utilizing scattered light;

FIG. 3 is a series of graphs illustrating operation of the circuit in accordance with FIG. 1; and

FIG. 4 is a series of graphic illustrating operation of the circuit of FIG. 2.

FIG. 1 illustrates the invention in schematic block diagram form, in which atmosphere to be supervised is introduced into a measuring chamber 1. The interior of chamber 1 is illustrated from an illumination source 2, indicated as an incandescent lamp. If smoke particles are present in the chamber 1, as schematically indicated by the dots, a portion of the light emitted from the bulb 2 will be scattered, and thus a photoelectric transducer, such as a photo resistor 3 will be partly illuminated. The transducer 3 may be of any type, such as a photo cell, a photosensitive semiconductor, or the like. The housing defining the chamber 1 is impervious to light and the interior is so treated that it will not reflect light from source 2 towards the transducer 3, without the presence of scattering particles in the atmosphere within chamber 1. The photosensitive resistance 3 is in series with a resistor 4, connected between a pair of supply lines 5, 6 which are connected to a low voltage signalling center, for example supplying a voltage of less than 60 V. If the change of potential junction point 7 exceeds a predetermined value, that is, if there is a change in resistance values between the resistance of transducer 3 and fixed resistor 4 which exceeds a predetermined amount, the alarm circuit A will provide an alarm signal over line 8. This signal can also be detected by sensing the change in current flowing through lines 5 and 6, the change in current causing a relay in the signal center to be pulled in and to provide an alarm, or indicating signal on line 8. Additional visual, and acoustic indications may be given.

Incandescent lamp 2 is connected in series with an interrupter formed of a relay contact 9, connected across supply lines 5, 6. The voltage drop across lamp 2 governs the action of a controller R which causes relay contact 9 to be periodically opened, by periodically changing, or interrupting current through a relay coil 10. The time duration of opening is controlled by the controller R. The controller is so arranged that the power consumed by lamp 2, in view of the periodic interruption of lamp current, is controlled to have a constant value, independent of supply line voltage across lines 5, 6.

It is particularly suitable to select the frequency of the periodic interruption to be so high that the temperature of the incandescent filament of the lamp drops only negligibly, due to the thermal inertia of the filament itself. The illumination supplied by the lamp, that

is, the beam of irradiation depending directly from temperature of the incandescent filament will then vary only slightly, in spite of the constant interruptions of supply current. The effectively approximately constant temperature of the otherwise temperature depending resistance of the incandescent lamp will be approximately constant. Thus, the control of lamp power can be effected by forming the average square of lamp voltage, U_L , of lamp current I_L . It has been found that an interruption frequency in which the variation in light output is roughly 5 percent, or less, is in the order of the accuracy of control required for the overall system or any of the components thereof. Lamps having relatively high thermal inertia, such as thick-filament, gas-filled lamps may have a lower frequency limit in which such light variations are still perceptible in the order of about 20 Hz; specific, very thin filament, high-vacuum type lamps have perceptible flicker in the order of about 5 percent at frequencies of about 100 Hz. It is thus preferred to select an interruption frequency of at least 100 Hz.

FIG. 3 illustrates a time diagram of the various characteristic parameters in the circuit, at a sufficiently high interruption frequency. The lamp voltage U_L is interrupted for predetermined periods. Light output Φ and temperature T drop only slightly during the switch-off period of voltage. The current I_L , due to the only slightly changing lamp resistance, does not show the high initial switch-on peaks, otherwise found in incandescent lamps, but follows, roughly, voltage U_L .

FIG. 2 illustrates a further embodiment of the present invention, in which, in spite of periodic interruption of the voltage, the current flowing through the lamp varies only slightly. The light output of the incandescent lamp thus remains approximately constant. Low voltage lamp 11 is connected in series with an inductance 12, acting as an energy storage element. A condenser 13 is in parallel to the lamp 11 and a diode 14 in parallel to the series connection of lamp 11 and inductance 12. The inductance, which is a current storing device, permits current to flow from the inductance 12 through diode 14 and lamp 11, forming a closed circuit, during the time when voltage from the supply lines is interrupted. Although, as seen in FIG. 4, the voltage U at the output of controller R' has an essentially square wave characteristic, lamp voltage U_L and lamp current I_L decrease only slightly during the turnoff period of the circuit due to the current storing effect of the inductance. When the voltage U is again connected by controller R' , lamp voltage and current U_L and I_L increase again, although only slightly. Since lamp current and lamp voltage, both, vary only slightly, the average square value of either (representing energy) is practically equal to the average linear value of either current or voltage. Thus, the controller can be made to react not to the average square voltage but can be formed to be much simpler, and constructed with much less equipment by utilizing the average linear variation of lamp voltage, without loss of accuracy.

Controller R' , in the embodiment of FIG. 2, includes a pair of complementary transistors 15, 16, forming together an astable switch to effect interruption of supply voltage. If lamp voltage U_L rises above a predetermined value U_1 , transistor 15 switches from conductive to blocked condition. The base of transistor 15 has a voltage applied thereto which is determined, essentially, by the Zener diode 21 and resistances 17, 18 and 19. The

second transistor 16 is controlled from transistor 15 and the voltage across collector resistance 20. Both transistors will block. If, during the turn-off period (due to blocking of transistor 16) lamp voltage U_L drops to a second predetermined value U_2 , both transistors are switched back to conductive condition; thereafter, upon rise of lamp voltage, the cycle repeats. Positive feedback of the voltage being switched is obtained from resistances 17, 18, forming a voltage divider.

The frequency of the periodic interruption is determined by the capacity of condenser 13 and the value of inductance of coil 12. If a capacity of $5 \mu F$, and an inductance of $10 \mu H$ is used, an interrupting frequency of about 20 kHz is obtained.

The physical size of a fire alarm unit should be as small as possible, and thus electronic elements of substantial size should be avoided. An interrupting frequency of about 1 kHz can be obtained with still acceptable values of inductance and capacitance. It is not suitable, however, to make these elements too small, since at frequencies of over about 100 kHz, the losses in the switching transistors become appreciable, since the switch-over times in the transistors cannot be decreased below a certain value, consistent with appropriate economics in this field.

The change in light is sensed by a photoelectric resistance element 22, connected in series with a resistance 23. The alarm circuit A has an input transistor 24, the base of which is controlled by voltage drop across the photo sensitive resistor element 22. The emitter of transistor 24 is connected to a voltage divider formed of resistances 25, 26. The voltage drop on collector resistance 27 of transistor 24 controls a bistable switch formed of transistors 28, 29 and the associated collector resistance 30.

If both transistors 28 and 29 are connected to be conductive, current will flow from ground, or chassis bus 32 over an alarm indicator lamp, or other device 33, schematically illustrated by a lamp. A resistance 34 is connected in parallel to indicator lamp 33 to ensure operativeness of the circuit if the lamp should burn out. An alarm is further indicated in a signalling center by the presence of an alarm current over line 31. In the illustrated example, the alarm line 31 is independent of supply line 35, provided to supply current to the incandescent lamp 33. This lamp, at all times, has a certain current flowing therethrough. If a substantial number of fire indicators are connected in parallel, it is preferred, and indeed in some installations required to separate the alarm and the supply conductors, since otherwise an alarm could no longer be indicated in a central signalling station due to the generally high base, or continuous operating current. If the voltage on the alarm line 31, in which normally no current flows, remains relatively constant, then the voltage in supply line 35 can vary within relatively wide limits. The voltage variations for the illumination source are compensated by controller R' , so that the overall sensitivity of the smoke detector is practically independent of supply line voltage variations.

In a particularly suitable embodiment, the inductivity 12 forms one coil of a relay which simultaneously is used to control the current flowing through incandescent lamp 11. So long as current flows through lamp 11, contact 36 associated with the inductance 12, that is, with the relay coil remains closed. If, however, for example lamp 11 burns out, current through relay coil

12 is interrupted, contact 36 will drop out and line 37 will have a malfunction alarm signal indicated thereon.

The smoke detector, utilizing an electronic switch, is only one embodiment of many within the inventive concept. Various equivalent circuits may be used, having essentially the same function, namely to so control the lamp current in the smoke detector that the overall power supplied to the lamp, and thus the lamp light output is approximately constant, the switching frequency being preferably so selected that the light output is subject only to small variations, and preferably within 5 percent of normal, rated light output, or less.

I claim:

1. Optical smoke detector comprising

a detection chamber (1) adapted to have gases which are to be analyzed for presence of smoke conducted therein;

illumination means (2, 11) including an electric incandescent lamp;

a photoelectric transducer (3, 22) located to be differentially affected by light from the illumination means depending on whether the gases are free from smoke, or contain smoke therein;

alarm means (A) connected to the transducer to provide a signal upon detection of smoke;

and an electrical supply supplying electrical energy to the lamp adapted to be connected to a voltage source, and wherein regulator means are provided having means (R ; R' , 17, 18, 19, 21) sensing lamp voltage, and repetitive cyclical interrupter means (9, 10; 15, 16) controlled by the lamp voltage sensing means to control the power consumption of the lamp to a constant, predetermined level by periodically interrupting the supply of electrical power from the voltage source to the lamp, to ensure that variations of the output from the photoelectric transducer will be representative of the presence of smoke in the gases only, and independent of variations in voltage of the electrical supply.

2. Smoke detector according to claim 1, wherein the frequency of interruption of the interrupter means is selected to be so high that the light output from the lamp varies by less than 5 percent of average light output.

3. Smoke detector according to claim 2, wherein the frequency of interruption is above 100 Hz.

4. Smoke detector according to claim 1, wherein the duration of interruption of the interrupter means is selected to provide for a constant mean square value of lamp current.

5. Smoke detector according to claim 1, wherein the regulator means comprises a current storage device connected in series with the lamp, the regulator periodically interrupting voltage supplied to the series connection of the lamp and the storage device.

6. Smoke detector according to claim 5, wherein the current storage device comprises an inductance.

7. Smoke detector according to claim 6, wherein the inductance comprises the coil of a relay, and a supervisory circuit is provided connected to the contacts of the relay.

8. Smoke detector according to claim 6, including a condenser (13) connected in parallel to the lamp (11) and a diode (14) connected in parallel to the series-connections of the inductance (12) and the lamp (11).

9. Smoke detector according to claim 1, wherein the interrupter means comprises an astable solid state

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switch including at least a pair of transistors, one of the transistors being controlled by lamp voltage.

10. Smoke detector according to claim 9, wherein the astable solid state switch comprises a pair of complementary transistors, and a feedback circuit interconnecting said transistors and holding said transistors ei-

ther conductive, or blocked.

11. Smoke detector according to claim 9, wherein the switching frequency of the astable switch is between 1 kHz and 5 kHz.

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