

PATENT SPECIFICATION

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(54) IONIZATION-TYPE FIRE SENSOR

(71) We, CERBERUS AG., a corporation organised under the laws of the confederation of Switzerland, of Mannedorf, Switzerland, 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:—

The present invention relates to an ionization-type fire alarm sensor, and more particularly to a sensor including an ionization chamber in which a radioactive substance is located. The electrical resistance of the ionization chamber rises when fire is sensed and the sensor further includes an evaluation circuit including at least one threshold detector, as well as an alarm indicator.

Ionization type fire sensors, in which a radioactive substance generates ions are so arranged that, upon application of an electric voltage to the electrodes of the ionization chamber, there passes between the electrodes an ion current which decreases upon penetration of smoke or fire aerosols into the chamber. Decrease of ion current in the ionization chamber is detected by an electrical circuit which includes a threshold detector. Upon detection, an alarm circuit can be activated. In one form, the ionization chamber is connected in series with a resistance element, for example another ionization chamber which may be termed a reference ionization chamber since it is so constructed that it is substantially separated from ambient air, and thus not subject to smoke or fire aerosols. The relative voltage drops across the ionization chambers are sensed and applied to a threshold detector, for example to a field effect transistor (FET). If the voltage drop across the sensing ionization chamber rises, due to increase in its resistance, then the threshold level of the FET is exceeded, it begins to become conductive, and provides a fire alarm signal.

Known ionization-type fire sensors are connected to a central control position. The increased FET current may be conducted directly to the central position, or may con-

trol a switching element, such as a relay, a SCR, or other solid-state switching means controlling a further current. The central position provides an alarm signal. The sensor advantageously includes in its structure, or in its vicinity, an alarm indicator such as a lamp or other illuminating device which provides an indication that a specific sensor has responded. This indication is of particular advantage when a plurality of sensors are connected in parallel over a common line to a central control position. In such a case the central control position can determine that one of the sensors on the line has responded to give an alarm, but it is difficult to determine which one of the sensors has responded. By checking the alarm indicators of the various sensors, the location of the responding sensor can be determined.

Known ionization fire sensors utilize electrical components with very high resistances. For example, the inherent or internal resistance of the ionization chamber is of the order of 10^{10} ohms. The input resistance of the connected electrical circuit, particularly when this includes an FET, must be higher by an order of magnitude. To further increase sensitivity, and to decrease the required activity of the radioactive substances, it has recently been attempted still further to decrease the ion current, that is, to further increase the resistance of the ionization chamber. It has been found to be very difficult, in actual practice, to maintain the required high insulation resistances in an ionization fire sensor over long periods of time, for example over years. The resistance may change, particularly due to precipitation of dust within the fire sensor, slow changes in some materials, and the like. As a result, the voltage drop across the ionization chamber will change slowly. In many instances it has been found that the voltage drop, in time, slowly approaches the alarm threshold level. An erroneous fire alarm may thus result.

It is an object of the present invention to provide an alarm indicator for fires of the ionization-type, which provides an indication

when the voltage in the ionization chamber approaches the alarm threshold. This permits identification of alarm sensors which may have a tendency to give a false alarm, so that such sensors may be replaced, exchanged, or cleaned and maintained before a false alarm has been signalled. It is well known that false alarms may be as dangerous as undetected real fires.

According to the present invention there is provided an ionisation fire sensor comprising an ionisation chamber of which the resistance value changes in response to the presence of fire aerosols, smoke particles or the like in the ambient atmosphere, a first detector arranged to provide a warning signal when the resistance value of the ionisation chamber changes from a normal value so as to pass a first threshold level and a second detector arranged to provide an alarm signal when said resistance value changes further in the same sense so as to pass both said first and a second threshold level.

An ionization fire sensor in accordance with the present invention has the advantage that an incipient fire provides, even in a very early stage, a warning signal, before the actual fire alarm signal is generated. A certain warning time will thus be provided between the quiescent condition and the real fire alarm. This warning time permits an investigation as to whether a fire is really beginning, or whether other reasons are present which might cause the sensor to provide the warning signal, such as, for example, excessive cigarette smoke, welding gases, high dust or particle concentrations, or the like. The warning signal may be used, for example, to prepare an otherwise deactivated fire extinguishing system, that is, to bring the system into a "get-ready" state, the system itself being activated only when the final alarm signal, indicative of an actual fire, is received. Thus, it is possible to avoid costly steps, or possible damage by the fire extinguishing system itself, before it is sure that a fire really has started, while however, an indication is being made available that a possibly suspicious situation should be investigated.

The invention will be described by way of example with reference to the accompanying drawings, wherein:

Figure 1 is a schematic circuit diagram of one embodiment of an ionization-type fire sensor in accordance with the present invention;

Figures 2a and 2b illustrate voltage and current characteristics useful in connection with the explanation of the operation of the device; and

Figures 3 to 6 are schematic circuit diagrams of various other embodiments of sensors in accordance with the invention.

The construction of a sensor in accordance with the present invention will be described

with reference to Figures 1, 2a and 2b. A fire sensor D is connected by means of lines 1, 2 to a central control position S. The lines may extend, as schematically shown by lines 1', 2', for the parallel connection of further sensors, for example of the same type.

The sensor shown has an ionization chamber 3 which is open to the ambient air. It includes two electrodes and a radioactive source. The chamber is connected in series with a resistance, advantageously a reference ionization chamber 4 which is essentially closed off against ambient air. A controllable resistor 5 is connected in series with the chamber 3, 4, across the supply lines 1, 2.

The voltage drop across ionization chamber 3, which varies with the presence of aerosols or smoke particles in the atmosphere, is applied to the control electrode 6 of a field-effect transistor (FET) 7, or an equivalent electronic element. As an equivalent element, a complete integrated-circuit network may, for example, be used. The source-drain path of the FET 7 is connected in series with the series combination of two resistors 9, 10, and a light-emitting diode (LED) 11, the whole series circuit being connected across lines 1, 2. LED 11 may be a gallium arsenide, or a gallium phosphide diode, or may include some other light-emitting material.

The input voltage, that is, the voltage on gate electrode 6 of FET 7 is so adjusted by means of resistor 5 that, under ordinary quiescent condition, the FET is cut off. Such conditions arise when no fire has been sensed, so that there are no smoke or fire aerosols in the air penetrating into chamber 3. For an input voltage at the gate electrode 6 of FET 7, less than a first threshold level indicated as S_1 (Figure 2a) no current will flow through LED 11. If, however, the input voltage at the control electrode 6 rises above this first threshold (warning) level S_1 , FET 7 becomes conductive and a current will flow through the FET 7 depending on input voltage across lines 1, 2. The LED 11 becomes luminescent. The brightness of LED 11 is a measure of the extent by which the voltage drop across ionization chamber 3 has exceeded the warning threshold level S_1 .

The junction point between resistors 9 and 10 is connected to the base of a bipolar transistor 12, the emitter of which is connected by way of LED 11 to the supply line 2. The collector of transistor 12 is connected to the junction of the adjustable resistor 5 with ionisation chamber 3. If the current through FET 7 and resistors 9, 10 exceeds a predetermined threshold level I_2 (Figure 2b), corresponding to a second threshold voltage S_2 at the input 6 of the control electrode of the FET 7 (Figure 2a) transistor 12 becomes conductive, which increases the voltage drop

across resistor 5. The voltage at the gate electrode 6 of FET 7 increases, which causes a still further increase in current through transistor 12.

Resistor 5 thus has a dual function: first, it sets the first, or warning threshold level and, secondly, it acts as a feedback resistor to ensure that when the alarm threshold level S_2 is reached, the current through the sensor D rises abruptly and extensively. The circuit will then, also, be self holding; in other words, the sensor changes state to an alarm condition which cannot be terminated by the reversion of the ionization chamber resistance to its normal lower value.

Lines 1, 2, will thus have a current flow there through of suddenly increased amplitude, which current is supplied by a source (not shown) at central control position S. Included in the central control position S is a current detector 13 which responds when such a current is detected, in order on the one hand to provide an external alarm (for example an alarm notification to a fire signalling station, an acoustical signal, optical indication or the like, or direct alarm to a fire department). The current detector 13 advantageously also causes periodic changes in the supply voltage supplied to lines 1, 2, so that the LED 11 is supplied with a pulsed supply voltage and will flash in the same rhythm. A suitable frequency is about 1 Hz.

The alarm central may have other circuits, for example voltage evaluation circuits and the like, as referred to in the co-pending Patent Application No. 34094/73 (Serial No. 1,401,146), of even date herewith.

Advantageously and as shown a normally inactive Zener diode 14 is connected across lines 1, 2 to protect against over-voltages and inverse polarity upon connection of the sensor to the lines 1, 2. A resistor 15, which is connected between supply line 2 and the junction of adjustable resistor 5 with ionization chamber 3, forms, together with resistor 5, a voltage divider by which the bias on the gate electrode 6 of FET 7 may be adjusted.

The operation of the circuit of Figure 1 will now be described with reference to Figures 2a, 2b. Under normal, quiescent conditions, when no fire is being sensed, the total current drawn by the sensor is very small, being essentially the current which flows through the two ionization chambers 3, 4, and the practically negligible current through the parallel resistor 15. Upon penetration of smoke, or fire aerosols into ionization chamber 3, the resistance of the chamber 3 will increase. As soon as this resistance has increased to such an extent that the voltage at the input 6 of FET 7 exceeds the lower, or warning, threshold level S_1 (W), current starts to flow in the FET, and the LED 11 begins to light with a brightness which depends on the amount by which the input voltage exceeds

the threshold level. If the voltage increases further and reaches the second or alarm threshold level S_2 (A), the sensor changes suddenly into the alarm condition and a greatly increased alarm current I_a will flow to the central control position S. The central control position may thereupon command periodic reduction of the supply voltage, so that the LED 11 will blink or flash, thus unambiguously indicating an alarm condition, and differentiating an alarm condition from a warning condition.

In the further embodiments now to be described, parts having similar functions will not be described again, and have been given the same reference numerals.

In the embodiment shown in Figure 3 the drain electrode of FET 7 is connected over two series-connected LED's 16, 17 and over a voltage divider formed by two resistors 18, 19, to line 2. The tapping point of the voltage divider 18, 19, controls the base of transistor 12, the collector-emitter path of which is connected in parallel with the series combination of the two ionization chambers 3, 4. When the voltage on gate electrode 6 of FET 7 exceeds the warning threshold S_1 , then FET 7 becomes conductive, and both LED's 16, 17 become luminescent. Upon further increase of input voltage, to the gate 6 of FET 7, that is, when the alarm threshold S_2 is passed, transistor 12 will become conductive which switches the sensor into the alarm condition, as described with reference to Figure 1. LED 17 will indicate if the fire sensor is in normal condition, warning condition or alarm condition. Under alarm conditions, a highly increased alarm current will flow over line 2 to central control position S, where it may be identified, for example by current detector A, and utilised to provide an alarm. The sensor further includes a photoresistor 21 which is arranged to receive light emitted from LED 16. One terminal of the photoresistor 21 is connected to line 1, and the other terminal to a line 20, likewise supplied from central control position S. The photoresistor is so arranged that it can be controlled only by light from LED 16. Under normal, quiescent condition when the diode does not emit light, photoresistor 21 has a very high dark resistance. When the threshold level W being passed, diode 16 begins to luminesce, the resistance of resistor 21 changes suddenly and warning current flows over line 20 to central control position S, to be there evaluated by a further current detector W and provide a warning signal, as described. In this embodiment, the alarm indicator indicates by a discrete signal if the sensor is under normal warning or alarm conditions; additionally, the central control position can separately distinguish if one of the sensors connected thereto is in the warning conditions or the alarm condition, thus pro-

viding a remote indication. This circuit may also use a plurality of ionization fire sensors, connected in parallel over lines 1, 2, and 20 to signal central control position S.

Instead of two diodes 16, 17, a single diode can be used, so located that its light can be used simultaneously for visual indication, as well as for optical transmission to the photoresistor 21. The optical path to the photoresistor must, of course, be shielded against stray or extraneous illumination or light penetration.

In the embodiment shown in Figure 4 the warning signal is directly electrically indicated; the second LED 16 and photoresistor 21, and the optical path being eliminated. Instead, resistor 19 is connected to third line 20 (instead of to line 2). When current flows through FET 7 upon the warning level S_1 being passed, a warning relay W in the central control position will have current flowing therethrough, so that not only will LED 17 in detector D provide a warning signal but, additionally, a warning signal will appear at the central control position S. If the alarm threshold of the second transistor 12 is exceeded, transistor 12 becomes conductive and line 2 will have an alarm current flowing through central control position S which, as before, provides a pulsed voltage supply to effect flashing of LED 17, and additionally provides an alarm signal. The embodiments of Figures 3 and 4 require a three-wire circuit to provide separate alarm and warning indications. The embodiment of Figure 5 provides discrete signals representative of warning condition and alarm conditions over two lines only. A third, switching transistor 22 is provided, having a threshold below the alarm threshold level of the second transistor 12. Its base is controlled over the voltage divider formed by resistors 18, 19, 21, by the current of the FET 7. When the threshold level of the third transistor 22 is exceeded, a multivibrator oscillator, including transistors 23, 24, capacitors 25, 26 and resistors 27, 28, 29, 30 is brought into oscillation. The multivibrator is of conventional construction, and is coupled to transistor 22 over coupling resistor 31. Lines 1, 2, therefore will have a-c signals applied thereover when the warning threshold is exceeded. These signals can be coded, that is, made uniquely denotive of a particular sensor, by suitable construction of the multivibrator. When the alarm threshold is exceeded, however, transistor 12 will pass direct current over the lines 1, 2, to the central control position. The signal central control position includes circuits which can distinguish between a-c components and d-c warning currents, by well known isolating and filtering networks. Two lines can thus carry, separately, a warning signal and alarm signal from a sensor to a signal central control position. In many

cases, the lines may already be subject to a-c in the kiloHertz range, particularly in cases in which a plurality of sensors are connected, in parallel, over a long line to the signal central control position, and continuity of the lines up to the last sensor is sensed by a terminating member 37 (Figure 6), connected at the end of the line and providing a pulsed output, or changing its internal resistance, in pulsed steps. Figure 6 illustrates a circuit which still permits transmission of a warning signal, separate from an alarm signal, over only two lines. In this case third transistor 22 controls a switching element 34, which may be a transistor, an SCR, or the like, over a collector resistor 32, connected between supply lines 1 and 2, and a resistance 33. Switching element 34, which may be a transistor or an SCR, is connected in series with a capacitor 35 between lines 1 and 2. A resistor 36 is connected in parallel with switching element 34. When the warning threshold is exceeded, transistor 22 controls the switching element 34 to close, thus inserting capacitor 35 between lines 1, 2, and short circuiting pulses provided by the oscillator 37. The transistor 12 is triggered into conduction as previously explained.

Various changes and modifications may be made in the circuits of the present invention; for simplicity, a central control position has been indicated, connected to the sensors by wire communication links, but radio communication may also be used.

WHAT WE CLAIM IS:—

1. An ionisation fire sensor comprising an ionisation chamber of which the resistance value changes in response to the presence of fire aerosols, smoke particles or the like in the ambient atmosphere, a first detector arranged to provide a warning signal when the resistance value of the ionisation chamber changes from a normal value so as to pass a first threshold level and a second detector arranged to provide an alarm signal when said resistance value changes further in the same sense so as to pass both said first and a second threshold level.

2. A sensor in accordance with claim 1 wherein the warning signal is a continuous signal, and the alarm signal is a signal of changing intensity.

3. A sensor in accordance with claim 1 or claim 2 wherein the warning signal is arranged to be suppressed upon response of the second detector to provide said alarm signal.

4. A sensor in accordance with claim 1, 2 or 3 wherein the first detector comprises a field-effect transistor, the gate electrode potential of which is controlled by the voltage drop across said ionization chamber.

5. A sensor in accordance with claim 4 wherein said field-effect transistor is con-



viding a remote indication. This circuit may also use a plurality of ionization fire sensors, connected in parallel over lines 1, 2, and 20 to signal central control position S.

5. Instead of two diodes 16, 17, a single diode can be used, so located that its light can be used simultaneously for visual indication, as well as for optical transmission to the photo-resistor 21. The optical path to the photo-resistor must, of course, be shielded against stray or extraneous illumination or light penetration.

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cases, the lines may already be subject to a-c in the kiloHertz range, particularly in cases in which a plurality of sensors are connected, in parallel, over a long line to the signal central control position, and continuity of the lines up to the last sensor is sensed by a terminating member 37 (Figure 6), connected at the end of the line and providing a pulsed output, or changing its internal resistance, in pulsed steps. Figure 6 illustrates a circuit which still permits transmission of a warn-
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Various changes and modifications may be made in the circuits of the present invention; for simplicity, a central control position has been indicated, connected to the sensors by wire communication links, but radio com-
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WHAT WE CLAIM IS:—

1. An ionisation fire sensor comprising an ionisation chamber of which the resistance value changes in response to the presence of fire aerosols, smoke particles or the like in the ambient atmosphere, a first detector arranged to provide a warning signal when the resistance value of the ionisation chamber changes from a normal value so as to pass a first threshold level and a second detector arranged to provide an alarm signal when said resistance value changes further in the same sense so as to pass both said first and a second threshold level.
2. A sensor in accordance with claim 1 wherein the warning signal is a continuous signal, and the alarm signal is a signal of changing intensity.
3. A sensor in accordance with claim 1 or claim 2 wherein the warning signal is arranged to be suppressed upon response of the second detector to provide said alarm signal.
4. A sensor in accordance with claim 1, 2 or 3 wherein the first detector comprises a field-effect transistor, the gate electrode potential of which is controlled by the voltage drop across said ionization chamber.
5. A sensor in accordance with claim 4 wherein said field-effect transistor is con-



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- 10 6. A sensor in accordance with claim 4 or claim 5 wherein the second detector comprises a bipolar transistor, the base of which is controlled by the current in the source-drain path of the field-effect transistor, the bipolar transistor being connected to become conductive when the voltage drop across the ionization chamber, and thus the current through the field-effect transistor, passes said second threshold level.
- 15 7. A sensor in accordance with claim 6 and further comprising a second ionization chamber forming a reference ionization chamber and connected in series combination with said ionization chamber accessible to the atmosphere, the collector-emitter path of said bipolar transistor being connected in parallel with the series combination of said ionization chamber, a resistor being connected in series with said series combination of said ionization chambers and with the parallel-connected bipolar transistor, and voltage supply lines being connected respectively to the free terminals of said parallel circuits and of said resistor.
- 20 8. A sensor in accordance with claim 7 wherein the resistor is a variable resistor enabling said first threshold level to be adjusted.
- 25 9. A sensor in accordance with any one of the preceding claims and further comprising an alarm indicator providing a visual alarm indication.
- 30 10. A sensor in accordance with claim 9 wherein said alarm indicator is a light-emitting diode.
- 35 11. A sensor in accordance with any one of the preceding claims and further comprising a light source controlled to be illuminated when said first threshold level is passed, a photosensitive sensor arranged to receive light from said light emitting element and a warning control line connected to said photosensitive sensor, said warning control line having a signal thereon when the resistance of said photosensitive sensor changes as a result of illumination by said light emitting element.
- 40 12. A sensor in accordance with any one of claims 1-10 and further comprising a self holding or self locking circuit connected to the second detector to maintain the alarm output signal even if said second detector no longer senses conditions beyond said second threshold level.
- 45 13. A sensor in accordance with claim 4 and including a switching transistor, the base of which is controlled by current through the field-effect transistor, so that the switching transistor becomes conductive after the first threshold level is passed.
- 50 14. A sensor in accordance with claim 13 and further comprising an oscillator controlled by conduction of said switching transistor to provide a-c warning signals indicative that said first threshold level has been passed.
- 55 15. A sensor in accordance with claim 14 wherein said oscillator comprises a multi-vibrator-type oscillator.
- 60 16. A sensor in accordance with claim 13 and further comprising switch element controlled by said switching transistor so as to connect a low a-c impedance in circuit across the supply lines to the sensor in response to the passage of said first threshold.
- 65 17. A sensor in accordance with claim 13 and comprising an additional transistor connected to have its base controlled by the current through the field-effect transistor, and voltage divider means setting the threshold response levels of said switching transistor and of said additional transistor to be at different levels to provide said first and second threshold levels, conduction of said transistors, respectively, controlling said warning and said alarm signals.
- 70 18. A fire alarm installation including a sensor in accordance with any one of the preceding claims and further comprising a current detector connected in a warning signal line in which current controlled by said first detector flows when said first threshold is passed, thereby providing a signal to said current detector, independently of the alarm signal, and in advance thereof.
- 75 19. A fire alarm installation including a plurality of sensors in accordance with any one of claims 1-10 and further comprising a central control position and discrete signalling transmission links connecting the warning signal and the alarm signals of the individual sensors with said central control position.
- 80 20. An ionisation fire sensor substantially as described with reference to Figure 1, 3, 4, 5 or 6 of the drawings.
- 85 21. A fire-alarm installation substantially as described with reference to Figure 1, 3, 4, 5 or 6 of the drawings.
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