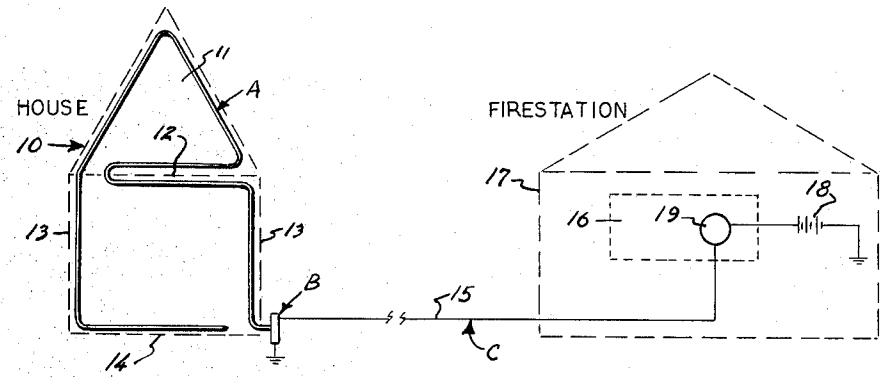
May 31, 1966 J. E. LINDBERG, JR 3,253,572

HEAT DETECTION SENSOR

Filed March 9, 1961

FIG. 1



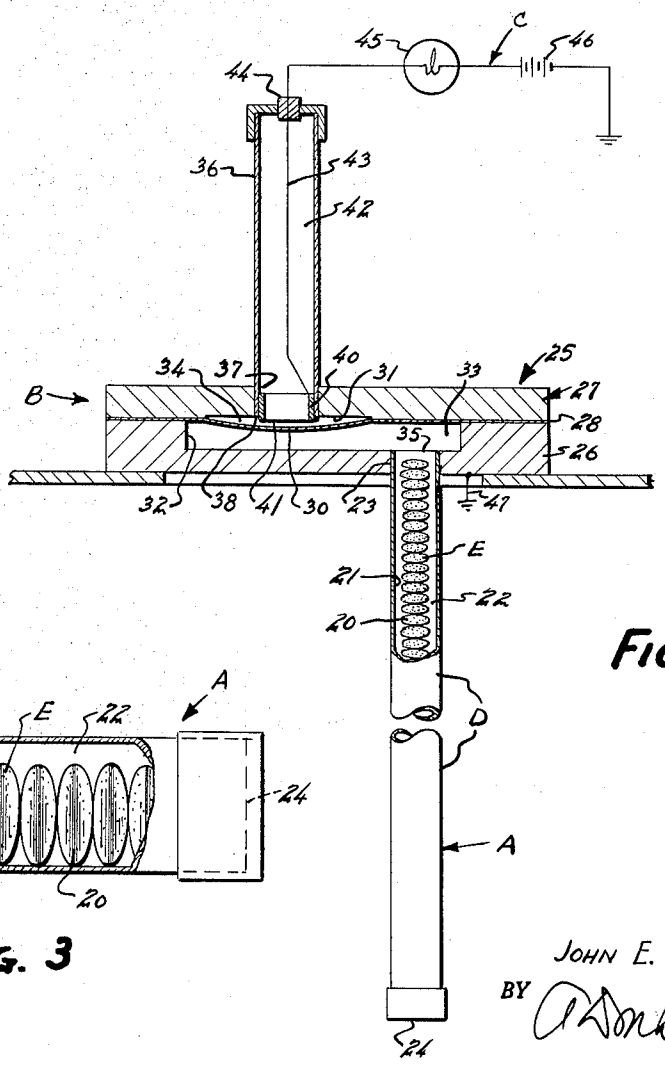


FIG. 2

FIG. 3

INVENTOR.
JOHN E. LINDBERG, JR.
BY
ATTY.

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HEAT DETECTION SENSOR

John E. Lindberg, Jr., 1170 Oleander Drive, Lafayette, Calif.

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6 Claims. (Cl. 116—114.5)

This invention relates to improvements in heat detection and especially fire detection. This application is a continuation-in-part of application Serial No. 815,406, filed May 25, 1959, now U.S. Patent 3,122,728.

The invention is characterized by its provision of a novel non-electric heat-detecting element or sensor. Only this detecting sensor need be located in a fire zone (or other heat-detection zone), and it is connected, preferably outside the zone, to an electrical warning or corrective system, preferably by a pressure-sensitive instrument that I term a responder. The responder may most conveniently be located outside the zone in which detection is desired, though usually close to it. The actual alarm or heat-condition indicator can be connected to the responder by a wire of practically any desired length. For example, the non-electric heat-detecting sensor may be inside a house, the responder just outside the house, and the indicator at the fire station.

Furthermore, the novel heat-detecting sensor may be wire-like,—a long, very-narrow-diameter, hollow tube. It may extend along a line, around a circle, or along any desired path and for quite a considerable length. The invention is useful for detecting fire or overheat conditions at any point in any vehicle or building, and has numerous commercial and industrial applications.

False alarms have plagued heat and fire-detecting systems relying on electrical circuits extending into the fire zone. For example, moisture condensation has often caused electrical fire detectors to develop low-resistance shorts that resulted in false alarms. The present invention solves the problem of preventing moisture and other atmospheric conditions from causing false alarms, and it does this by using a sensor that is never actuated by moisture or by atmospheric conditions, and by using a low-impedance circuit.

This invention also eliminates other factors that led to false alarms or failures in prior-art devices. Such problems as moisture condensation in voids at the joints between successive elements of continuous-type detectors and the accumulation of foreign material in the connections, both leading to low resistance shunt paths between the inner conductor and the outer shell and hence to false warning, cannot occur in this invention. My invention uses only the simplest electrical connection and normally locates that connection at or behind the fire wall where it is well protected.

An outstanding feature of the invention is that the warning circuit can be operated at an impedance of less than one ohm. This feature greatly increases the reliability of the system, for this impedance is so low that complete immersion of the circuit in water does not seriously affect its operation.

Some prior-art types of fire detectors have given false alarms because they responded to the *rate of change* of temperature rather than, or in addition to, a predetermined high *temperature level*. The device of this invention can be made independent of the rate of change of temperature or can be made to have any desired degree of dependence on it; so another source of false alarms is obviated.

Prior-art continuous-type fire detectors also gave false alarms whenever the detector element was seriously damaged, because short circuits were then caused within the element. The sensor of the present invention can be completely severed, cut open, dented, or bent in any fashion without causing a false alarm.

A further object is to provide a simple one-shot fire detector.

Another object is to provide a fire-detection system which avoids the complexities characteristic of the circuits and mechanical elements of other fire detectors. For example, no amplifiers or relays need be used in this system.

Another object is to provide a completely hermetically sealed heat-detection transducer, entirely free from environmental errors caused by such things as pressure changes, moisture condensation, and so on.

Other objects and advantages of the invention will appear from the following description of several preferred embodiments thereof.

In the drawings:

FIG. 1 is a diagrammatic view in elevation of a fire-detection system embodying the principles of this invention, so installed as to detect fire in a house and give an alarm in a fire station, when and if fire does occur in the house. The broken line in the conductor indicates that the distance between the house and the fire station is not shown and can be any such distance as is commonly encountered.

FIG. 2 is an enlarged view in elevation and in section of a simplified form of fire-detection system, as may be used in the FIG. 1 system. It shows the responder and a heat-detection sensor that is broken in the middle to conserve space. The electrical circuit is shown diagrammatically.

FIG. 3 is a greatly enlarged view in elevation and in section of a portion of a preferred form of a heat-detection sensor of this invention.

A. GENERAL STATEMENT OF THE INVENTION

As shown in FIG. 1, the fire-detection system of this invention comprises (1) a non-electric detection means, preferably in the form of a generally wire-like sensor A of indeterminate length, (2) a responder B, and (3) an electrical circuit C. The function of the sensor A is to actuate the responder B, and the function of the responder B is to actuate the electrical circuit C in response to predetermined conditions of temperature obtaining in the environment within which the sensor A is located. Thus, the sensor A and the responder B, considered together, comprise a transducer.

The sensor A may be further defined in general terms (see FIG. 3) as a generally wire-like enclosure D of extended length connected to the responder B and containing means E responsive to heat in the environment of the sensor A, for raising the pressure in the responder B. The responder B may be thought of as typically a pressure-actuated electrical switch that opens or closes the electrical circuit C in response to pressure changes induced by the sensor A as a result of the effect of temperature on the sensor A. The electrical circuit C may be a warning circuit or a remedial circuit. Several responders B may be used in one circuit, if desired, to control it in some manner that depends on the temperature of the environments to which the sensors A are exposed.

B. A HOME INSTALLATION (FIG. 1)

The fire-detector system of this invention may be used to give instant alarm in a first station when there is a fire in a home. For example, as shown in FIG. 1, the detector element or sensor A may be disposed along critical locations in John Doe's house **10**; such as in an attic **11**, immediately beneath and above a ceiling **12**, down one or more walls **13**, and along one or more floors **14**. As will be shown presently, the sensor A may

comprise a thin, generally wire-like tube and may be quite inconspicuous when installed.

The responder B may be located just outside the house **10** and is an actuator that closes an electrical circuit C, none of which extends inside the house **10**. The circuit C includes a conductor **15**, such as copper wire that leads to an alarm panel **16** in a fire station **17**. The circuit C may have its power supply **18** located in the fire station **17**. The panel **16** may include a bell or buzzer or other audible warning (not shown) as well as a signal light **19** identifying the house **10** as John Doe's house. There may be as many lights **19** on the panel **16** as there are homes having the warning system installed; so each house can be instantly identified.

When a fire occurs in John Doe's house **10**, the sensor A is heated. In a manner explained later, the rise in temperature increases the pressure inside the sensor A, and this pressure acts on the responder B almost instantaneously, closing the circuit C (in a manner also explained later). Upon closure of the circuit C, current flows through the conductor **15** and lights the light **19**, also giving audible warning if desired. The men in the fire station can take immediate remedial action to save John Doe's house.

C. DETAILED DESCRIPTION OF SOME PREFERRED FORMS OF THE SYSTEM AND ITS COMPONENTS

(*1*) *The sensor A*

The fire detector of this invention includes a novel detecting means or sensor A. The sensor A has a gas-tight enclosure D, preferably comprising a narrow-diameter metal tube of constant cross-sectional area and of any desired length. Within this enclosure D is means E responsive to the temperature of the enclosure D for varying the pressure inside the enclosure D. The only opening in the enclosure D is connected to the responder B, which itself defines a closed chamber connected to the enclosure D. An alteration of the internal pressure within the enclosure D therefore affects the responder B.

(*a*) THE TRANSDUCING AGENT E

This invention depends, in most aspects, upon the ability of certain classes of substances known as "blowing agents," to release or liberate large volumes of gas or vapor when elevated to a temperature sought to be detected. In this specification, the term "blowing agent" means those solids that non-explosively decompose irreversibly, when heated, into a large amount of gas. When these blowing agents are employed as the means E and are enclosed in a constant-volume container D and subjected to an increase in temperature, the resultant change in the internal pressure of the container D is employed to actuate the responder B to close or open a warning system C.

Heretofore, the blowing agents have been almost solely used in the manufacture of sponge rubber and foam plastic. Typical blowing agents are:

(a) Celogen, a white crystalline powder with a specific gravity of 1.56 that decomposes at about 151° C. to 156° C., liberating about 105 to 110 cc. of non-condensible gas per gram of powder, 98.45% of the gas being nitrogen. Chemically, Celogen is p, p′ oxy bis (benzene sulfonyl hydrazide).

(b) Unicel ND, a white powder that decomposes at 180° C. to 190° C., liberating about 116 cc. of gas per gram of powder, 90 to 95% of the gas being nitrogen. Chemically, Unicel ND is dinitrosopentamethylenetetramine.

(c) Porofor DB (diazoaminobenzene).

(d) Wingcel S (p-tert-butylbenzoylazide).

(e) Porofor N (azocyano methane).

(f) Porofor BSH (benzene sulfonyl hydrazide).

These blowing agents are useful for "one shot" or non-cyclical processes. Their process of gas liberation is classified as irreversible, for once the gas has been released, it cannot be recombined with the remaining solids except under the most extreme treatment. A blowing agent may be enclosed within a rigid container D, then when heat is applied to elevate the substance E to its triggering temperature, the subsequent release of gas raises the internal pressure of the container D quite sharply.

These materials, when located within a closed chamber, provide an effective means of altering the internal pressure of the chamber as a function of the temperature applied to the material. Thus, the enclosed blowing agents function to effectively convert temperature variations into pressure variations, and that is why they are referred to herein as transducing agents.

(*b*) TYPICAL SENSOR STRUCTURES

FIG. 3 illustrates one of the ways in which the sensor A may be constructed. The blowing agent E may be used in a pellet form or some other suitable form, always being placed inside the sensor tube D which may be a non-porous tube of constant cross-sectional area. In all cases there has to be passage means for transmitting the pressure changes along the tube. In applications where the tubes D are to be bent or curved around corners, metal is the preferred material. Suitable metals are pure iron, which is impermeable to many gases, stainless steel, and molybdenum, for example. In applications where bending is not required and minimum diffusion is desired, the tube D is preferably made from non-porous quartz, ceramic, or special glass. In any event, the inner surface of the tube D should not react with the materials it contacts, including the gas involved. A typical sensor tube D is preferably about .030" to 0.060" outside diameter with a wall thickness of preferably about 0.005" to 0.015". Such tubes D are preferably about one to forty feet long, although they may be longer or shorter.

FIG. 3 shows a preferred form of blowing agent E enclosed in the sensor tube D. Here the blowing agent E is in the form of a series of pellets **20** such as Celogen. The pellets **20** are smaller than the bore **21** of the tube E, the space **22** between the wall **21** and the pellets **20** providing passage means for the gas along the tube.

As a simplified example of installation of the sensor A of FIG. 3 to the responder B, one end **23** (FIG. 2) of the tube D may be connected by a gas-tight seal to the responder B, while the other end **24** of the tube D is still open. This free end **24** may be connected to a vacuum pump and the tube D pumped free of undesired gas. Then it may, if desired, be filled with any desired gas or left evacuated. The free end **24** is then sealed off, and the device is ready for operation.

(*2*) *A simple form of responder B (FIG. 2)*

Any pressure switch that is properly sensitive and has the needed connections may be used as a responder B. However, I have invented a new pressure switch that is especially suitable for use herein. This switch is fully disclosed and claimed in a co-pending patent application, Serial No. 86,252, filed April 10, 1961, now U.S. Patent No. 3,180,956.

FIG. 2 shows a simple form of responder B, suitable for simple installations such as are shown in FIGS. 1–3. This responder B comprises a unit **25** and has two circular plates **26** and **27**, preferably of non-porous metal, between which is bonded (as by brazing) a thin metal flexible disc or diaphragm **28**. The plates **26** and **27** are hermetically sealed together and are in electrical contact for their full peripheries and over a substantial margin, but in the center the diaphragm **28** has a generally spherical depression **30** called a "blister," which is free to move relative to the plates **26** and **27** and constitutes the active or movable part of the diaphragm **28**. Use of a diaphragm with a blister **30** makes possible the use of an upper plate **27** with a planar lower surface **31** and gives a more pred-

icatable response, but other diaphragm structures may be used where feasible. The lower plate **26** is formed with a recess **32** in its upper surfaces and the diaphragm **28** divides the resultant cavity between the plates into two regions or chambers **33** and **34**. Since the lower region **33** communicates with the sensor A, it may be called the "sensor chamber." The other region **34** is located on the opposite side of the diaphragm **28** from the sensor A; so it may be called the "anti-sensor chamber." Of course, either plate **26** or **27** may actually be made by brazing together several thin plates of the desired configuration, and the recess **30** may be provided by using a stack of preformed thin washers over a disc. The end **23** of the sensor tube D is joined to and sealed to the lower plate **26**, fitting within a hole **35**. The region **33** is closed and sealed except for its communication with the lumen of the sensor tube D.

A tube **36** of non-porous ceramic material or other non-porous electrically-insulating material extends through an opening **37** in the upper plate **27** and is hermetically sealed in place there with its lower end **38** flush with the bottom surface **31** of the plate **27**. The hole **37** and tube **36** are preferably centered with respect to the blister **30**, on the anti-sensor side thereof. A metal electrode **40** is located inside and joined securely to the tube **36** at the end **38** nearest the blister **30**, with a portion **41** of the electrode **40** extending below the lower surface **31** of the plate **27**. The amount by which the portion **41** extends below the surface **31** is carefully controlled so as to be uniform in each responder of any particular design. This geometry means that the blister **30** can make electrical contact with the electrode portion **41** when the blister **30** is forced up by pressure in the sensor chamber **33**. As shown, the electrode **40** may be annular to give good uniform contact with the blister **30** at that time and also to afford communication between the chamber **34** and the inside **42** of the tube **36**. A conducting wire **43** extends from the electrode **36**, preferably along the axis of the tube **40**, and is brought out of the tube **36** through a hermetic seal at a sealing cap **44**. The tube interior **42** and the anti-sensor chamber **34** thus are part of the same enclosure.

If sufficient pressure is applied to the sensor side of the blister **30**, it will deflect and make contact with the electrode portion **41**; and if the deflecting force is removed, the restoring force of the blister **30** will return it to its relaxed position and thus break contact with the electrode portion **41**. The force necessary to do this may be chosen by proper design of the blister to accommodate a wide range of values.

(*3*) *A simple circuit C and its operation* (*FIG. 2*)

As explained before, the responder B may be connected to an alarm circuit which, as shown in FIG. 2, may be a simple visual indicator consisting of a lamp **45** in series with the conducting wire **43** and a source **46** of electrical current, which may be a battery, as shown, or may be a source of alternating current. A return path for the electrical circuit C may be provided by grounding either one of the plates **26** or **27** and is shown as a ground wire **47** in FIG. 2.

In operation, when the sensor A is exposed to heat at a level high enough to cause the blowing agent E to rise above its threshold temperature, gas is liberated. This gas cannot escape from the sensor tube D except into the sensor chamber **33**, where it exerts pressure upon the blister **30**. This pressure tends to move the blister **30** away from the plate **26** and toward the plate **27**. The pressure in the sensor chamber **33** is a function of the temperature of the sensor A. This pressure, if great enough, will cause the blister **30** to make contact with the electrode **40**, but no contact will be made unless the temperature of the sensor A is at or above a definite level.

When the sensor A is exposed to heat at a level high enough to cause the blister **30** to make contact with the electrode **40**, current flows from the battery **46** through the lamp **45**, the conductor **43**, the electrode **40**, and the blister **30** to the plates **26** and **27** and returns to the battery **46** through the ground line **47**. This current flow causes the lamp **45** to light and provides a visual indication that the temperature of the sensor A is at or above a certain level. In this sense, the device shown in FIG. 2 functions as a threshold temperature indicator. When heat is removed from the sensor A, the blowing agent E will not reabsorb its previously liberated gas; it is a one-shot device. The alarm stays on until remedial action is taken.

In practice, the sensor A is placed in the area (see FIG. 1) whose temperature is to be monitored, while the responder B may be located upon or behind a shielded wall or at some easily accessible area. Thus only the sensor A itself need be exposed to possible heat sources, and it contains no element of the electrical warning circuit. In this manner, protection for the responder B and its associated alarm circuit C may be provided.

(*4*) *Some ways of setting the threshold temperature* (*FIG. 2*)

The force necessary to deflect the blister **30** against the electrode **40** can be chosen to accommodate a range of values by a suitable choice of mechanical parameters. Once this force is determined, the dimensions of the sensor tube D and the amount of blowing agent E may be chosen by design to provide the force necessary to obtain contact between the blister **30** and electrode **40** under desired conditions.

In addition to mechanical design considerations, the necessary deflecting force may also be altered by precharging the anti-sensor chamber **34** with a gas under pressure or by partially evacuating it. To accomplish this, gas is forced into (or withdrawn from) the tube **36** after its attachment to the plate **27** and before it is closed by its cap **44**. The required deflecting pressure against the blister **30** becomes greater as more gas is present in the chamber **34**.

Alternatively, the deflecting pressure may be effectively lowered by precharging the inside of the sensor tube D and the sensor chamber **33** with gas. In this case, if the ambient pressure in the sensor chamber **33** is greater than normal, less than normal gaseous liberation from the transducing agent E is required to deflect the blister **30** against the electrode **40**. Most gases may be employed for this purpose; however, ideally the gas should not react chemically with its surrounding materials. Particularly suitable are the inert gases, such as helium, argon, neon, and xenon, (the helium family, known as the "noble gases") especially since they do not readily diffuse through most materials. As a consequence, a precharged pressure of argon, for example, may be maintained for an indefinite length of time to retain a desired biasing of the diaphragm **28**, as described.

Celogen will serve as an example of the blowing agent E. When a sensor A containing Celogen as the transducing agent E is exposed to a heat level of 156° C. (313° F.), the Celogen decomposes and deflects the blister **30** against the electrode **40**, thereby actuating the alarm circuit C. The reaction is irreversible; when the sensor A cools, the released gas is not reabsorbed, so the lamp **45** remains illuminated until the circuit C is externally opened. However, this "one shot" operation is desirable in some cases; for example, in a house fire alarm, as in FIG. 1. To monitor temperature again, the used sensor may be replaced with a new one or refilled with new Celogen.

With blowing agents, locally applied heat at or above the triggering temperature causes the liberation of gas. The material not exposed to heat will not liberate gas, but also it will not absorb the gas liberated from the

hotter portion; as a result, any liberated gas increases the pressure in the sensor chamber of the responder B.

To those skilled in the art to which this invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. The disclosures and the descriptions herein are purely illustrative and are not intended to be in any sense limiting.

I claim:

1. A continuous-type heat sensor comprising an imperforate narrow diameter wire-like generally tubular enclosure, a blowing agent, comprising a solid that irreversibly and non-explosively decomposes when heated into large volumes of gas, disposed substantially uniformly in and along substantially the full length of said enclosure, means providing continuous passage for gas through said enclosure and pressure responsive means positioned at a predetermined portion of said enclosure.

2. The sensor of claim 1 wherein said passage is filled with noble gas.

3. The sensor of claim 1 wherein said blowing agent comprises chunks placed in said enclosure loosely enough to afford said passage means.

4. The sensor of claim 1 wherein said blowing agent is disposed continuously along substantially the full length of said tube.

5. The sensor of claim 1 wherein a plurality of portions of said tube are filled with said blowing agent and these portions are separated by gaps.

6. The sensor of claim 5 wherein the said blowing agents used in some portions are of different type from the said blowing agents used in other portions.

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LOUIS J. CAPOZI, *Primary Examiner.*

NEIL C. READ, *Examiner.*