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FIRE DETECTOR MADE OF TWO SPECIAL ELECTRIC WIRES

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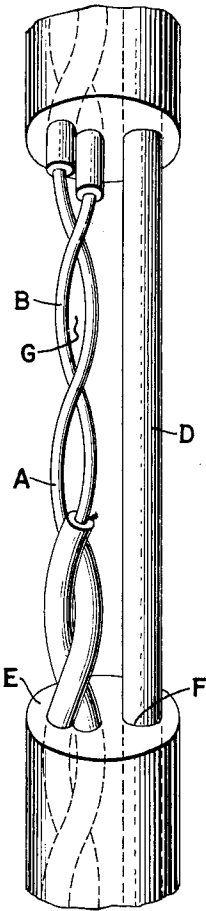


FIG. 1

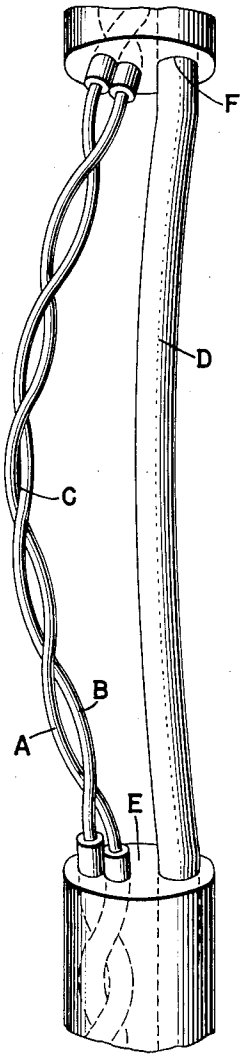


FIG. 2

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FIRE DETECTOR MADE OF TWO SPECIAL ELECTRIC WIRES

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The object of this invention is to provide a fire detector which may be established around each essential part of any airplane engine as a circular or spiral loop and which comprises a thin electric cable which is composed of two insulated wires preferably made of different metals. These wires are helically twisted together and insulated from each other as explained hereinafter with a determinate thickness of a combustible varnish so that they become instantaneously sensitive, at any portion of their length, to the initial contact of a flame. The purpose of this improved sensitivity is to arrest instantaneously the engine high-pressure fuel-flow, and to extinguish any accidental flame before its dangerous propagation, thus avoiding the fusion at 660° C. of engine parts made of aluminum alloys and the carbonization of the rubber pipes and sealing rings at 300° C.

Another object of this invention is to obtain a flexible fire detector-cable of light, continuous, and simple construction, which is suitable for mass production, and which detects fire wherever the atmosphere reaches an abnormal temperature above 287° C.

Still another object of this invention is to protect instantaneously the passengers of aircraft, against the known fact that at high speeds any large flame is activated by the oxygen of the airflow, up to a so great intensity, that behind the fire wall, the aluminum alloy wing structure which supports the engine, melts and also takes fire. Thus, if the original flame is not detected instantaneously, and extinguished automatically, the fire may become uncontrollable before the pilot can shut off the fuel supply.

Still a further object of this invention is to use only the usual aircraft electrical equipment, which provides 115-120 volts of direct or alternating current, and which is used by the detector only during the period of fire detection. There is thus no loss of electrical energy to the detector during normal flight, and no need to establish around the detector a radio shield which could diminish its sensitivity.

Another object of this invention is to detect instantaneously the original flame even in the narrow regions of the engine where the non-instantaneous tubular flexible thermistor detectors cannot be folded, and wherever the non-instantaneous bulky thermostatic detectors cannot be installed. The flexible thermistors that are contained in a long metallic tube, and the mechanical thermostatic detectors that are contained in a metallic or glass casing, may not be heated instantaneously across their metallic or glass cover which reflect respectively 88% and 99% of the heat applied, and consequently, they cannot give the instantaneous electrical conductivity which is necessary for the relays of the extinguishing system.

Another object of this invention is to obtain an accurate though flexible fire detector, which is simply based on the principle of electrical conductivity of the atmosphere (and of the flame) at high temperatures. This conductivity is caused by the dielectric breakdown of gases at high temperatures and high voltages that are proportional of the gap between the conductors and to the density of the gas which decreases with temperature. As soon as the insulation which separates the wires is carbonized or evaporated at a temperature of about 287° C., the required conductivity of the hot air gap

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between the two wires is attained, although the flame is not necessarily in contact with the wires. As shown hereinafter by calculation the detection may not happen accidentally at a lower temperature than required, contrarily to the fire detector cables that use a fusible wire of tin-lead alloy which fuses between 70° C. and 250° C., under the direct action of the flame, to connect the two electric wires that conduct the alarm current. The said fusible wire of tin-lead alloy has not a uniform sensitivity along its length to the chosen low temperature of fusion, and may fuse at some parts of its length at a much lower temperature than required, because its percentages of tin, lead, bismuth and cadmium are not necessarily constant along its length. The point of fusion being not uniform along the easily fusible wire, a false alarm is unavoidable with this type of fire detector, since aeroplane engines may sometimes produce, temporarily, high ambient temperatures at the engine section, between 50° C. and 250° C., near the engine surface, without being in danger. Among these easily fusible detectors, those that use the fusible wire itself as one of the wires that will conduct the alarm current, are in disadvantage because the said fusible wire has not a sufficient rigidity for resisting the vibrations of the engine during flight before any detection. Another disadvantage of these fusible detectors is, that, if they are designed to operate at a temperature of about 300° C., they take more than three seconds to absorb the heat necessary for fusion, through the asbestos paper which covers the whole.

An additional object of this invention is also to detect fire mechanically as a safety measure, by means of two insulated wires, helically twisted together, that have different coefficients of linear expansion. The heat of the flame establishes a useful elongation of one wire relatively to the other, and provides thus a rapid lateral deflection of one wire relatively to the other, when a good length of the two wires has had the time to be heated only up to 300° C.; therefore, the mechanical contact of the two electric wires is obtained in less than one second on account of the heat furnished by the highly combustible external coating which easily takes fire at about 287° C.

In the accompanying drawings:

FIG. 1 represents, on a greatly enlarged scale, the two electric wires after the carbonization or volatilization of their insulation.

FIG. 2 represents the mechanical contact which is obtained thereafter when the two electric wires are of dissimilar metals that have different coefficients of linear expansion.

The two flexible wires A and B (FIG. 1) are twisted helically together, but their instantaneous sensitivity to the flame is due to their individual phenolic varnish coating of $\frac{1}{20}$ millimeter thickness, which establishes between them a gap G of $\frac{1}{10}$ millimeter and which burns easily or carbonizes at 287° C. in the neighborhood of a flame. These two wires are connected at one end to the 120 volts supply and are free from any connection at their other end. This voltage causes dielectric breakdown of the hot air separating the wires after the insulation has been destroyed. The dielectric breakdown of the hot air occurs instantaneously before the heating of the wires A and B by the flame, because, whilst the phenolic varnish carbonizes between the two wires at 287° C., the flame is not yet in true contact with the wires, which reflect the greatest part of the heat applied.

As mentioned hereinbefore, an additional factor of security may be obtained by choosing two electric wires of different metals that have very different linear coefficients of expansion, and that are coated separately with a

$\frac{1}{20}$ millimeter thickness of insulating varnish; these wires A and B are helically twisted together with a medium pitch in order to obtain after the instantaneous dielectric breakdown of the hot air and gases therebetween, a useful extension of one wire relatively to the other (FIG. 2) and a consequent lateral deflection of its geometrical helical curve relatively to the helical curve of the other wire. This deflection produces a mechanical contact C between the two electric wires as soon as the relative lateral deflection reduces the gap G to zero. This provides in one second a useful mechanical fire detection even if the voltage supplied to the fire detector is by accident insufficient for the instantaneous dielectric breakdown of the hot air and gases across the $\frac{1}{40}$ millimeter gap.

The wires A and B (FIGS. 1 and 2) are much thinner than the wire gage No. 16, so they must be accompanied by a third wire D which is sufficiently thicker than gage No. 16 to resist efficiently against vibrations and rupture. Therefore, the regulations concerning the rigidity of the wires installed at the engine section are completely executed by fixing this fire detector cable at regular and short intervals around the engine parts; with this simple combination, the thin insulated wires for fire detection may remain undamaged even when they are bent around small curves, since they have a normal flexibility. These wires for fire detection should be placed at $\frac{1}{2}$ inch or 1 inch from the engine parts round which they are disposed, in order to be at the hottest regions of the flame where the air flow is richer in oxygen than closer to the metallic surfaces where oil or fuel may be leaking.

The insulation between the two wires is preferably composed of a phenol furfural plastic containing a mineral filler; since this synthetic plastic has a low volume resistivity of approximately 10^9 or 10^{11} ohm/cm.³, according to the dilution of varnish used, it may procure a more rapid conductivity between the wires at the very beginning of the touch of the flame than if other natural or synthetic resins were used. Also, this phenolic plastic has a good tensile strength of about 8,000 to 20,000 lb./sq. in., the best resistance to heat between 176° C. and 260° C., a carbonization temperature of 287° C., and a normal inflammability.

The $\frac{1}{40}$ millimeter gap is structurally obtained during the adjunction of the two wires (covered individually with a varnish thickness of $\frac{1}{20}$ millimeter) into a thin longitudinal silicone-rubber flexible and combustible coating E (FIGS. 1 and 2), that has an external duct F which contains the thick supporting wire D. The sensitivity of the detector may be increased by using, instead of a silicone-rubber external coating E of slow burning rate, a common coating made of pyroxylin cellulose nitrate which has a very high burning rate, or a common coating of butyrate cellulose acetate which has a medium burning rate.

In order to improve the detection of fire the varnish coat may contain small quantities of bromine, metal powder, or phosphorous. An additional but not necessary way for increasing the fire sensitivity is to introduce also into the varnish composition a percentage of sulfate of radium that establishes a greater density of ionization which facilitates the passage of the current when the varnish takes fire.

The gap of $\frac{1}{40}$ millimeter which separates the wires A and B (FIG. 1), and the 115-120 volts that are used only at the very moment of the detection, are however the essential and sufficient characteristics that establish an instantaneous fire detection, on account of the following reasons.

After 500 successive tests Hayden and Eddy have determined that the breakdown voltage of air at normal temperature and pressure, amounts to at least 22.5 kilovolts for a gap of 1 centimeter (see paragraph Normal Deviations in the Dielectric Strength of Air, of subsection Gases of Section 4 of McGraw-Hill Standard Handbook for Electrical Engineers), or proportionately less for a smaller gap.

The breakdown voltage of air varies with its density, which may be calculated from the equation

$$\delta = \frac{3.92b}{273+t}$$

where b is the barometric pressure in centimeters of mercury, t the temperature in degrees centigrade, and δ the density factor with respect to the density of air at normal temperature and pressure (see paragraph Effect of Air Density on Dielectric Strength, of sub-section Gases of Section 4 of the same handbook); thus at 76 centimeters of pressure and 287° C., δ becomes equal to

$$\delta = \frac{3.92 \times 76}{273+287} = 0.532 = \frac{53.2}{100}$$

and therefore, the density of air is reduced to 53.2% of the density of air at normal temperature and pressure.

Consequently, when we consider that the lowest breakdown voltage of air at normal temperature and pressure is equal to 22.5 kv. for a gap of 1 centimeter, we find that the breakdown voltage of air at 287° C. and 76 centimeters of mercury (when $\delta=0.532$) becomes for a gap of 1 centimeter, equal to $22.5 \times 1,000 \text{ volts} \times 0.532 = 11.97 \times 1,000 \text{ volts}$, or

$$\frac{11.97 \times 1,000}{100} = 119.7 \text{ volts}$$

for a gap of $\frac{1}{40}$ millimeter, since $\frac{1}{40}$ millimeter is 100 times smaller than 1 centimeter. As these 120 volts are supplied to the detector-cable, the detection is attained as soon as the phenolic varnish chars at 287° C.; the same calculations show that for a temperature of 1,300° C. between the detector-wires, the 120 volts supplied are advantageously three times greater than the breakdown voltage required.

Since

$$\delta = \frac{3.92 \times 76}{273+t}$$

and since, according to the above-mentioned deductions, the breakdown voltage of an air gap of $\frac{1}{40}$ millimeter at a temperature t becomes equal to

$$\frac{22.5 \times 1,000 \times \frac{3.92 \times 76}{273+t}}{100} = \frac{22.5 \times 1,000 \times 3.92 \times 76}{100(273+t)} = X \text{ volts}$$

it results that by choosing the minimum temperature t at which fire detection is required, this equation may give the minimum voltage X that is necessary to operate the detector.

In case by defective construction some part of the gap used between the detector-wires is equal to only $\frac{1}{20}$ millimeter, instead of the $\frac{1}{40}$ millimeter recommended, the detector will not operate at a temperature lower than 287° C. since the phenolic varnish must first carbonize at 287° C. before any detection; in case the gap used is by defective construction equal, at some part along the cable, to $\frac{1}{40}$ millimeter, the corresponding calculations show that the 120 volts supplied will be however sufficient for obtaining the detection of fire at a temperature of about 844° C., that is to say that the upper limit for the dimension of the spacing used between the detector-wires may be practically equal to even $\frac{1}{40}$ millimeter.

The thin silicone rubber coating E (FIGS. 1 and 2) chars under the action of the flame, and the phenolic varnish cannot be the cause of an internal rise of pressure at the contact of the fire, because the varnish softens first, while the silicone rubber shrinks, and chars; then the phenolic liquid boils and expands in the atmospheric pressure without any rise of pressure between the two electric wires. With an appropriate thickness of the silicone rubber coating, it may be made to shrink sufficiently, while the thin

varnish layer softens, and by such a coordinated action the insulated spacing may be reduced at the contact of the flame, thus improving the fire detection.

If the fire detection is practically attained at a temperature slightly greater than 287° C., this temperature will be however much lower than the melting point of the engine parts made of aluminum alloys, and insufficient to carbonize or fuse the internal synthetic-rubber sealing-rings inside the metallic connections of pipes. Moreover, if one of the two electric wires A and B (FIGS. 1 and 2) is made of copper, and the other wire is made of iron, the elongation of one wire with respect to the other will be at 287° C. sufficient to give an important lateral deflection of one wire with respect to the other which may provide in about one second the above-mentioned mechanical contact between the two wires.

The phenolic varnish has, according to its composition, a breakdown voltage of between 200 and 500 volts per mil; thus, since 1 mil=0.025 millimeter, it results that the breakdown voltage of a layer of 0.1 millimeter thickness must be at least equal to

$$\frac{0.1}{0.025} \times 200 \text{ volts} = 4 \times 200 = 800 \text{ volts, i.e. } \frac{800}{120} = 6.6$$

times greater than the 120 volts supplied to the detector. This means also that the insulated gap should be 6.6 times thinner than 0.1 millimeter for having an erroneous fire detection, which may thus be simply avoided by employing a wire that is carefully insulated with a phenolic coating of 0.1 millimeter thickness, and by twisting with this insulated wire another wire of different metal which has no individual insulation, in view of obtaining with accuracy the required gap of 0.1 millimeter.

Around the engine the ambient temperature must not stay for a long period of time in the neighborhood of 150° C. on account of the absorption of heat and of the loss of strength of the stressed light alloys at this temperature; therefore, the chosen fire detecting temperature of 287° C.=550° F. is usefully two times greater than the highest permissible temperature of 150° C., and also well above the normal ambient temperature of the engine section; as the ambient temperature of the engine section is indicated to the crew by means of an electric thermometer, the unusual temperatures that are smaller than 287° C.=550° F. may be controlled by the pilot, without the danger of obtaining during flight a false alarm from the fire detector for a temperature which may be normally reduced. Yet on account of the new formula

$$\frac{22.5 \times 1,000 \times 3.92 \times 76}{100(273 + t)} = X \text{ volts}$$

the smallest temperature for fire detection may be increased or decreased (some highly combustible coatings may take fire at less than 287° C.=550° F.), and the corresponding voltage which is required for the detec-

tion of fire may be calculated accordingly for the considered gap of $\frac{1}{10}$ millimeter=0.00399 inch. As the control of the temperature of fire detection is herein established around 287° C.=550° F. the practical result is a good protection of the powerplant, because, at this abnormal temperature, the gasket joints give rise to dangerous leaks before the birth of the flame; this useful detection of the danger of fire facilitates after the engine stopping and cooling, the safe and controlled re-utilization of said engine at a very reduced power when the other engines or the gliding flight may not afford a safe return travel. The re-utilization of the engine power is obviously continually dependent of the favorable indication of a thermistor or of the electric thermometer which is installed at the engine section, since, at a very reduced engine power, any high ambient temperature represents the repeated presence of a flame.

Having shown how the known phenomenon of dielectric breakdown of air at high temperatures may be utilized advantageously in order to obtain an instantaneous fire detector cable, and having shown how a malleable bimetallic cable may provide infallibly the mechanical contact which switches-on the electric circuit for fire detection and extinction, I claim as my invention only the following specific details:

1. An instantaneous fire detector made of two flexible electric wires helically twisted together and insulated the one from the other by an easily combustible varnish which establishes between the said wires a gap of between $\frac{1}{20}$ millimeter and $\frac{1}{10}$ millimeter, the voltage supplied between the wires being such as to cause instantaneous dielectric breakdown of the hot air and gas therebetween at any predetermined temperature, said voltage being calculated as shown hereinbefore.

2. A fire detector as claimed in claim 1, in which the thickness of the varnish between the two electric wires is $\frac{1}{10}$ millimeter, the varnish chars at about 287° C.=550° F., and a breakdown voltage of 120 volts is supplied between the said wires.

3. A fire detector as claimed in claim 2, wherein the two wires are of different metals (having very different linear coefficients of expansion) in order to obtain a lateral deflection of one wire with respect to the other, which establishes a mechanical contact between the said electric wires in about one second after the insulation therebetween is burnt.

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