

TEMPERATURE SENSORS

This invention relates to temperature sensors, and is more particularly but not exclusively concerned with temperature sensors suitable for use in aircraft fire detection systems.

One well known type of temperature sensor for use in aircraft fire detection systems comprises a cable containing two conductors separated by an insulating material whose properties are temperature dependent. The cable is strung out around the area to be monitored for fires, and if a fire occurs in this area, the fire subjects the cable to local heating and so changes the impedance between the wires. Detection of this impedance change thus indicates the presence of a fire.

However, this type of sensor suffers from the drawback that it is difficult to obtain quantitative information from the impedance change that would enable the location of the fire, along the length of the cable, to be readily determined. In an aircraft environment, therefore, where fire extinguishers are typically provided in the area monitored by the cable, all the extinguishers would have to be activated, when perhaps activation of only one of them would have been sufficient to put out the fire. Clearly, the extinguishers which were activated unnecessarily may well cause damage which could have been avoided to equipment, eg electrical equipment, in the area being monitored.

It is therefore an object of the present invention to provide temperature sensors, and fire detection systems using them, in which the abovementioned drawback of the known sensors and systems is alleviated.

According to the present invention, there is provided a temperature sensor comprising an elongate ultrasonic waveguide, and at least one temperature responsive means which is positioned at a predetermined point along the length of the waveguide and which is responsive to a given temperature change to change the acoustic impedance of the waveguide at that point from a first level to a second level, one of said levels (preferably the second) causing at least partial reflection of the ultrasonic pulses at the point.

In one embodiment of the invention, the temperature responsive means comprises a low melting-point material (ie a material having a melting point lower than that of the material of the remainder of the waveguide and falling within the range embraced by said given temperature change), having an acoustic impedance similar to that of the waveguide and disposed in a notch in the waveguide: typically, said material is a low melting-point metal alloy. In this embodiment of the invention, the sensor preferably includes means for retaining the low melting point material in the notch, for example a

protective sheath or coating surrounding the waveguide and covering the notch containing the low melting point material. In the case of a protective sheath, the sheath may be produced by swaging or extruding a tube around the waveguide, while in the case of a protective coating, the coating may be produced by plating.

In a second embodiment of the invention, the temperature responsive means comprises a device for applying a mechanical stress which varies with temperature to the waveguide. In this second embodiment of the invention, the device may conveniently comprise a clamp embracing the waveguide, the clamp being arranged such that its clamping force increases with temperature. Thus the clamp may comprise a first member arranged to trap a second member between itself and the waveguide, the first member having a lower coefficient of thermal expansion than the second.

The sensor preferably comprises a plurality of said temperature responsive means spaced apart along the length of the waveguide.

The invention also includes a temperature sensing system incorporating a temperature sensor in accordance with any of the preceding statements of invention, and further comprising means for launching ultrasonic pulses, for example longitudinal pulses, into one end of the waveguide, and means for detecting

reflected ultrasonic pulses due to said acoustic impedance change. Advantageously, the sensor also includes means for measuring the time interval between each said reflected pulse and the launched pulse which gave rise to it.

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

Figure 1 is a much simplified schematic drawing of a first embodiment of a fire detection sensor and system in accordance with the invention;

Figure 2 is a more detailed view of part of the sensor of Figure 1; and

Figures 3 and 4 show alternative forms of part of the sensor of Figure 1;

The fire detection sensor of Figure 1 is indicated generally at 10, and comprises an elongate ultrasonic waveguide 12 in the form of a cylindrical rod or wire 14 of nickel, or a nickel-based alloy such as INCONEL (R.T.M.) or NICHROME (R.T.M.), or annealed stainless steel. The waveguide 12 is typically between 3 and 10 metres long, and is divided into a plurality of zones, typically each about 5 to 10 cm long, as will hereinafter become apparent.

Coupled to one end 16 of the waveguide 12 is an ultrasonic pulse transmitter and receiver 18, typically comprising a magnetostrictive device which launches longitudinal ultrasonic pulses (also referred

to as compressional or expansional pulses) into the waveguide 12. The transmitter/receiver 18 is also coupled to a timing circuit 20, which is arranged to measure the time interval between each pulse launched into the waveguide 12 and any reflected pulses resulting from that pulse.

Part of the waveguide 12 is shown in more detail in Figure 2, where it can be seen that the wire or rod 14 is divided into the aforementioned zones by equally longitudinally-spaced notches 22, which are filled with a low melting-point metal alloy 24 having an acoustic impedance similar to that of the wire or rod 14; a suitable example of such an alloy is the brazing alloy available under the trade mark "EASYFLOW", consisting of about 50% silver alloyed with copper and zinc. To retain the alloy 24 in the notches even when it has melted, a protective sleeve or tube 26 of stainless steel is swaged over the rod or wire 14, covering the notches and the alloy. Alternatively, after the alloy 24 has been placed in the notches 22, the outside of the rod or wire 14 can be plated with a compatible hard material such as nickel or chrome, this plating extending over the alloy-filled notches, to retain the alloy in the notches.

In use, the waveguide 12 is typically strung around an area which is to be monitored for fire, for example around the outside of an aircraft gas turbine engine, within the engine housing or nacelle, the waveguide being sufficiently flexible to permit this. Care must be taken with mounting the waveguide 12 to ensure that the mounting fixtures used do not introduce unwanted variations in the acoustic impedance of the waveguide.

To monitor for fire, ultrasonic pulses are periodically launched into the end 16 of the waveguide 12 by the transmitter/receiver 18, typically at a frequency of 100 Hz: the propagation speed of the pulses in the waveguide is typically about 5000 m/sec. In the absence of a fire, the alloy filled notches 22 are substantially indistinguishable, from an acoustic impedance standpoint, from the remainder of the rod or wire 14, so each pulse launched by the transmitter/receiver 18 travels to the other end 32 of the waveguide 12, and is then reflected back to and detected by the transmitter/receiver 18. The time interval between the launch of each pulse and the arrival and detection of the corresponding end-reflected pulse is measured by the timing circuit 20, the end-reflected pulses being identifiable as such not only by this time interval (since the length and acoustic properties of the waveguide 12 have known predetermined values), but also by virtue of the fact that they are much larger than intermediate reflected pulses. The failure to detect any significant intermediate reflected pulses before the arrival and detection of the end-reflected pulse indicates the absence of fire along the waveguide 12, while the arrival and detection of the end-reflected pulse indicates that the sensor 10 is operating satisfactorily.

In the event that a fire starts in the area being monitored by the sensor 10, as indicated at 30 in Figure 1, the fire will melt the alloy 24 in at least one of the notches 22, eg the one indicated at 22a. This produces a significant change in the acoustic impedance of the waveguide 12 at the notch 22a, which now causes a partial but significant reflection of each pulse launched into the waveguide by the transmitter/receiver 18. Each notch-reflected pulse arrives at and is detected by the transmitter/receiver 18 prior to the predetermined arrival time of the corresponding end-reflected pulse, which indicates to the transmitter/receiver that the detected pulse is indeed a notch-reflected pulse rather than an end-reflected pulse. Further, the time interval between the launch of each pulse by the transmitter/receiver 18 and the arrival and detection of the corresponding notch-reflected pulse is measured by the timing circuit 20. This time interval not only distinguishes notch-reflected pulses from end-reflected pulses, but also indicates where along the length of the waveguide 12 the fire is located.

The detection of notch-reflected pulses by the transmitter/receiver 18 can be used to trigger a fire alarm and the appropriate one or ones of several fire extinguishers in the area being monitored. Assuming that the fire is then extinguished by the operation of the extinguisher or extinguishers, the

melted alloy 24 in the notch 22a will re-solidify, thus restoring the sensor 10 to its original state, and so capable of detecting a further fire, should one occur.

Figure 3 shows at 50 another waveguide which can be used in place of the waveguide 12 of Figures 1 and 2. The waveguide 50 is just a plain cylindrical rod or wire made from any of the materials specified for the rod or wire 14 of the waveguide 12 (ie it has no notches filled with low melting-point metal alloy), and is provided with devices 52 which are spaced along its length at 5 to 10 cm intervals and which are designed to apply a temperature-dependent stress to it. Thus each device 52 comprises a C-clamp 54 of a metal having a low coefficient of thermal expansion, such as INVAR (R.T.M.), whose lower extremity 56 supports the waveguide 50. The waveguide 50 is clamped against the lower extremity 56 of the C-clamp 54 by means of a rod or bar 58 of stainless steel, which has a significantly higher coefficient of thermal expansion than the C-clamp 54.

At normal temperatures, each of the C-clamps 54 is arranged merely to lightly clamp the waveguide 50, so as not to significantly affect its acoustic impedance. The waveguide 50 thus behaves like the waveguide 12 at these normal temperatures. However, if one or more of the devices 52 is subjected to fire, the rod or bar 58 expands more than the C-clamp 54, and applies a substantial localised stress to the

waveguide 50. This localised stress behaves in a manner analogous to a notch 22 of the waveguide 12, ie it partially reflects ultrasonic pulses travelling along the waveguide, for detection and time measurement by the transmitter/receiver 18 and the timing circuit 20 respectively.

Extinguishing the fire enables the C-clamp 54 and the rod or bar 58 to return to their normal relative proportions, thus eliminating the localised stress in the waveguide 50 and restoring it to its initial operating state.

Figure 4 illustrates, at 60, a variation of the device 52 of Figure 3, in which the C-clamp 54 is replaced by a complete oval or loop 62 which encircles the waveguide 50 and traps the rod or bar 58 thereagainst. The device 60 otherwise operates in the same manner as the device 52: in particular, extinguishing the fire enables the waveguide 50 to return to its initial operating state.

Some or all of the devices 52 and 60 are used for supporting the waveguide 50 along its route through the area to be monitored for fire.

Many modifications can be made to the described embodiments of the invention. In particular, to facilitate assembly and maintenance, the waveguides 12 and 50 can each be connected to the transmitter/receiver 18 by means of an ultrasonic waveguide connector of the kind described in our

co-pending United Kingdom patent application entitled "Ultrasonic Waveguide Connector", filed simultaneously herewith under Application No. 8814246 (Serial No. 2222354).

Additionally, suitable materials other than those specifically cited can be used to make the waveguides 12 and 50, and shapes other than cylindrical, eg rectangular-section or flat ribbon shapes, can also be used for these waveguides. For example, although the invention has been described in the context of an aircraft fire detection sensor, it can be used more generally as a distributed temperature threshold detector. Typical applications could include an overheating detector, for use e.g. in an aircraft context, to detect temperatures in excess of say 200°C (as opposed to the fire detection context, where temperature in excess of say 350°C are normally being detected), or a refrigeration detector, for detecting when the temperature at any of a number of distributed points in a cold storage facility exceeds -20°. These lower temperature applications open the possibility of using glass, optical fibre or plastics for the ultrasonic waveguide, and/or extruded plastics coatings (instead of swaged metal coatings) for the metal waveguides with fusible or metal inserts or cores described hereinbefore. Another possible application is in distributed temperature sensing

along pipes which have to be uniformly heated along their length, to prevent a fluid which is only liquid at the temperature to which the pipe is heated from solidifying in, and therefore blocking, the pipe. In these other applications, lengths of the waveguide of up to 100 metres can be contemplated, and/or the waveguide can be made in sections connected by ultrasonic waveguide connectors of the kind described in our aforementioned co-pending United Kingdom patent application.

Further, for some shapes of waveguide, ultrasonic pulses other than longitudinal pulses can be used, for example torsional pulses, and the pulses can in some cases be produced by a piezoelectric device rather than a magnetostrictive device.

Finally, information concerning the mean temperature throughout the area being monitored can be derived from variations in the arrival time of the end-reflected pulses, since the speed of propagation of the pulses in the various waveguides is a function of the temperature of the material of the waveguide, and therefore of the mean temperature of the surroundings of the waveguide; or alternatively, in the notched waveguide embodiment, some of the notches can be left unfilled, in which case the respective mean temperatures of the areas between adjacent unfilled notches can be derived from the time intervals between the reflections from these notches.



CLAIMS

1. A temperature sensor comprising an elongate ultrasonic waveguide, and at least one temperature responsive means which is positioned at a predetermined point along the length of the waveguide and which is responsive to a given temperature change to change the acoustic impedance of the waveguide at that point from a first level to a second level, one of said levels causing at least partial reflection of ultrasonic pulses arriving at the point.
2. A temperature sensor as claimed in claim 1, wherein the temperature responsive means comprises a low melting-point material having an acoustic impedance similar to that of the waveguide and disposed in a notch in the waveguide.
3. A temperature sensor as claimed in claim 2, wherein said low melting-point material is a metal alloy.
4. A temperature sensor as claimed in claim 2 or claim 3, further including means for retaining the low melting-point material in the notch.
5. A temperature sensor as claimed in claim 4, wherein the retaining means comprises a protective sheath produced by swaging or extruding a tube around the waveguide.
6. A temperature sensor as claimed in claim 4, wherein the retaining means comprises a protective coating applied to the waveguide by plating.
7. A temperature sensor as claimed in claim 1, wherein the temperature responsive means comprises a device for applying a mechanical stress which varies with temperature to the waveguide.
8. A temperature sensor as claimed in claim 7, wherein the device comprises a clamp embracing the



waveguide, the clamp being arranged such that its clamping force increases with temperature.

9. A temperature sensor as claimed in claim 8, wherein the clamp comprises a first member arranged to trap a second member between itself and the waveguide, the first member having a lower coefficient of thermal expansion than the second.

10. A temperature sensor as claimed in any preceding claim, comprising a plurality of said temperature responsive means spaced apart along the length of the waveguide.

11. A temperature sensing system comprising a temperature sensor in accordance with any preceding claim, means for launching ultrasonic pulses into one end of the waveguide, and means for detecting reflected ultrasonic pulses due to said acoustic impedance change.

12. A temperature sensing system as claimed in claim 11, further comprising means for measuring the time interval between each said reflected pulse and the launched pulse which gave rise to it.

13. A temperature sensing system as claimed in claim 11 or claim 12, wherein said ultrasonic pulse launching means is arranged to produce longitudinal ultrasonic pulses.

14. A temperature sensing system as claimed in any one of claims 11 to 13, wherein said ultrasonic pulse launching means includes a magnetostrictive device.

15. A temperature sensing system substantially as herein described with reference to Figures 1 and 2 of the accompanying drawings.

16. A temperature measuring system substantially as herein described with reference to Figures 1 and 2, as modified by Figure 3 or Figure 4, of the accompanying drawings.

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