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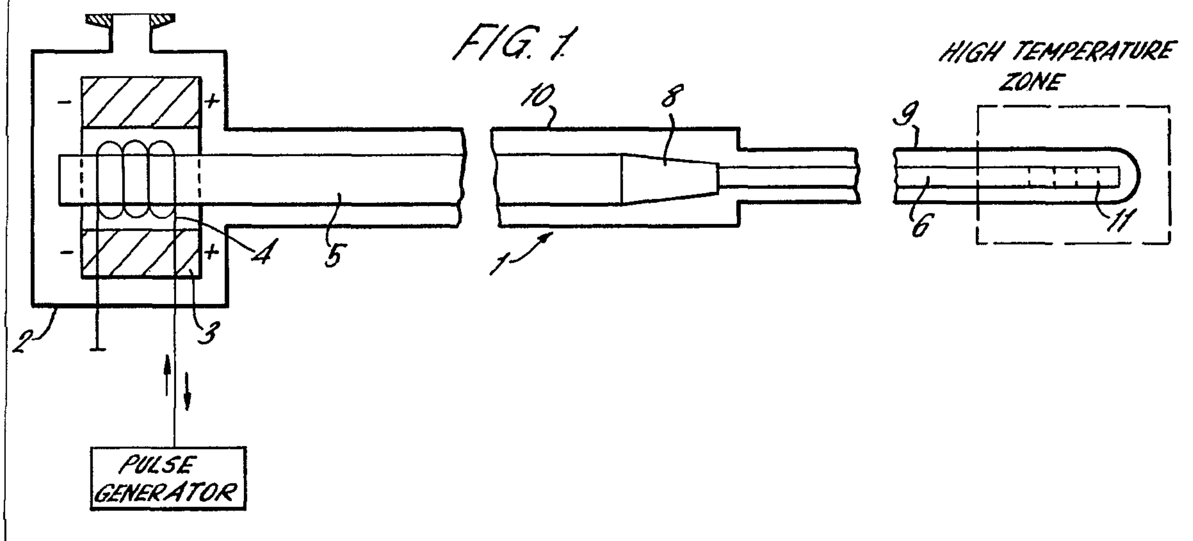
(54) Very high temperature ultrasonic thermometer

(57) An ultrasonic thermometer (1) comprises an electric pulse transducer head (2), a pulse transmission line (5), a notched sensor wire (6) attached to and extending along the axis of said transmission line (5), and a sheath (9) enclosing the transmission line (5) and the sensor wire (6), a portion of the interior face of the sheath (9) being covered by a stuffing material along at least the length of the notched part of the sensor wire (6), such that contact between the sensor wire (6) and the stuffing material does not substantially give rise to reflection of an ultrasonic pulse at the point of contact.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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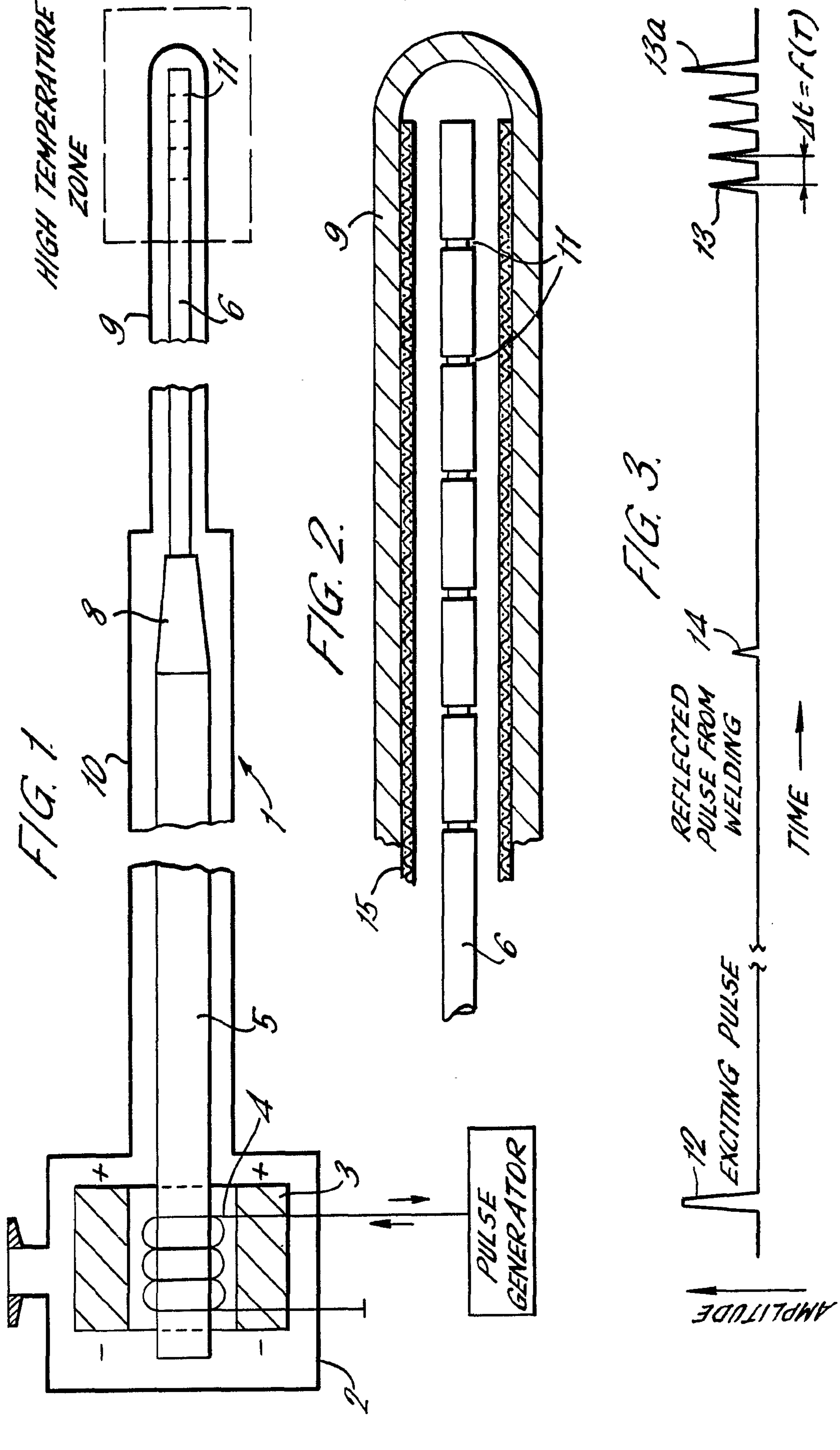
HIGH TEMPERATURE ZONE
PULSE GENERATOR
FIG. 1.
FIG. 2.
FIG. 3.
REFLECTED PULSE FROM WELDING
TIME
EXCITING PULSE
AMPLITUDE
Δt = f(T)

SPECIFICATION

Very high temperature ultrasonic thermometer

The present invention relates to an improved ultrasonic thermometer for use for example in the measurement of high temperatures.

Ultrasonic thermometry (UST) is based upon the phenomemon of the temperature dependence of acoustic velocity in a material. By measuring the time required for an acoustic signal to travel between two points in a material, in which material the temperature dependence of acoustic velocity is well-characterised, the average temperature of that portion of the material between the two points can be measured.

UST is typically used in applications where thermo-couple or pyrometric thermometry are unsuitable, either because of the limited temperature range of measurement, the lack of optical access to the region to be measured or the presence of vapours or aerosols in the region to be measured. UST may be used, for example, in the measurement of temperatures in nuclear fuel elements or in molten nuclear fuels, in which materials the temperature may exceed, for example, 2800°C.

In a known ultrasonic thermometer, a short-duration ultrasoinc pulse is generated in a thin wire, composed of a magnetostrictive material, by a short-duration magnetic field pulse produced by an exciting coil. The ultrasonic pulse can propagate along the length of the thin wire and thence along a sensor wire, the sensor wire being attached to the thin wire. The sensor wire has a number of acoustic discontinuities along its length, preferably near an end of the sensor wire distal from the junction of the sensor wire with the thin wire. A fraction of the ultrasonic pulse energy is reflected at each disconuity and is sensed by the exciting coil, the exciting coil thereby producing an electrical signal. The electrical signal is detected by signal detection means and the time of travel of the ultrasonic pulse along the said wires in the thermometer between generation and detection may be determined. Since the velocity of the ultrasonic pulse is a function of the temperature of the sensor wire, the difference in detection time for reflection from adjacent discontinuities can be related to the average temperature of the sensor wire between the respective discontinuities. A number of discontinuities may be provided along a sensor wire, thereby allowing a temperature profile along a portion of the sensor wire to be determined.

In known ultrasonic thermometers, for accurate temperature determinations, the sensor wire used is preferably very thin, typically having a diameter of less than 1mm and is enclosed in a protecting sheath, which protects the sensor wire from physical and chemical degradation. Preferably, the sheath is as narrow as possible in order to reduce errors in the measured temperatures which are a result of axial and radial heat transfer in the sheath.

At high temperatures, creep of the sensor wire can occur over extended operating periods, thus leading to contact between the sensor wire and the inner surface of the sheath. Due to the high temperatures of operation which temperatures are, for example, above 1800°C, contact between the sensor wire and the inner surface of the sheath can result in a phenomenon known as "sticking" wherein a weld is formed at the point of contact, the weld being a diffusion weld. This weld formation results in an acoustic discontinuity being formed in the wire, at which discontinuity reflection of an ultrasonic pulse passing along the sensor wire can occur, thereby giving rise to errors in temperature measurements, which errors may be of the order of 300°C. This reflection phenomenon can give rise to reflected ultrasonic pulses passing along the sensor wire which are in addition to those ultrasonic pulses which have been reflected from the known discontinuities spaced along the sensor wire and can also suppress those ultrasonic pulses which have been reflected from those known discontinuities.

A material having apparently desirable physical properties for use in an ultrasonic thermometer as a sensor wire for high temperature measurements above 2600°C is thoriated tungsten, with the sensor wire being surrounded by a sheath of tungsten or thorium. However, the undesirable property of ThO_2 makes it difficult to handle without stringent safety precautions and the presence of stainless steel in reactor core components reduces the applicability of tungsten as the sheath material, when the ultrasonic thermometer is to be used in this type of application, due to problems associated with degradation of the material properties of the sheath.

It has been proposed to use sheaths composed of ThO_2, but at the high temperatures of operation the ThO_2 may sublime and the resulting ThO_2 vapour in the enclosed space between the sheath and the sensor wire may subsequently condense on the sensor wire at a low temperature position on the sensor wire, away from the high temperature region of measurement, thereby giving rise to an acoustic discontinuity in the sensor wire.

It has also been proposed to use small tungsten stand-offs which have been laser-welded to the sensor wire at spaced intervals along the sensor wire. However, it has been found that at high temperatures the tungsten stand-offs, may be diffusion welded to the tungsten sheath at a point of contact between the sheath and the stand-off, thereby giving rise to acoustic discontinuities on the sensor wire leading to a degradation in temperature measurement performance.

It has further been proposed to coat the sensor wire electrophoretically with a thin layer of ThO_2, but due to the high vapour pressure of the ThO_2 at elevated temperatures, such as, for example, above 2600°C, the layer readily sublimes and persists for only a short time relative to the proposed temperature measurement period.

The present invention relates to an improved ultrasonic thermometer in which spurious reflections of ultrasonic pulses at acoustic discontinuities on the sensor wire due to the contact of the sensor wire and the protecting sheath are substantially absent.

The present invention accordingly provides an ultrasonic thermometer, comprising an electric pulse transducer head, a pulse transmission line, a notched sensor wire attached to and extending along the axis of said transmission line, and a sheath enclosing the transmission line and the sensor wire, a position of the interior face of the sheath being covered by a stuffing material at least the length of the notched part of the sensor wire, such that contact between the sensor wire and the stuffing material does not substantially give rise to reflection of an ultrasonic pulse at the point of contact.

Preferably in an ultrasonic thermometer according to the invention the stuffing material is formed by a mesh of tungsten wire.

Preferably the mesh is made of a strip of 4 mm width, wound helically under tension to a 1mm wire rod with a pitch greater than 4mm, inserted into the tungsten sheath and released so as to contact and cover a portion of the inner wall of said sheath.

An embodiment of the present invention will now be described by way of example with reference to and as illustrated in the accompanying drawings, in which:—

Figure 1 shows a plane section through an ultrasonic thermometer according to a preferred embodiment of the present invention, which section is parallel to the longitudinal axis of the thermometer.

Figure 2 shows in greater detail a portion of the ultrasonic thermometer of Fig. 1.

Figure 3 shows the relationship between amplitude and time for a generated ultrasonic pulse and reflected ultrasonic pulses in the ultrasonic thermometer of Fig. 1.

Fig. 1 shows an ultrasonic thermometer 1 having at one end a transducer head 2, the transducer head 2 comprising a polarised permanent magnet 3 and a coil 4; a magneto strictive transmission wire 5, which is magnetically coupled with magnet 3 and coil 4, and sensor wire 6, which is attached to transmission wire 5 at weld 7, and the ultrasonic thermometer 1 is arranged as shown.

As shown in Fig. 2, the free end of sensor wire 6 has a number of notches 11 in its surface. Notches 11 act as spaced acoustic discontinuities, at which discontinuities an ultrasonic pulse can be reflected. The regions between adjacent notches 11 constitute individual temperature zones, over which zones an average temperature measurement can be made.

Fig. 3 shows the relationship between amplitude and time for an exciting pulse 12, generated by the pulse generator, and reflected pulses 14, 13, 13a which reflected pulses 14, 13, 13a are detected by transducer head 2. The first reflected ultrasonic pulse detected by transducer head 2 is pulse 14, which is that fraction of exciting ultrasonic pulse 12 which has been reflected from the weld 7 situated between transmission wire 5 and sensor wire 6. Subsequent pulses detected by transducer head 2 are pulses 13, which are those fractions of exciting ultrasonic pulses 12 which have been successively reflected from notches 11 and are correspondingly successively detected by transducer head 2. Pulse 13a is that corresponding to that fraction of exciting ultrasonic pulse 12 which has been reflected from the free end of sensor wire 6.

Preferably, sensor wire 6 is composed of thoriated tungsten wire, having a diameter of 0.6mm and a length of approximately 500mm. The length of the wire may be varied according to the intended use of the ultrasonic thermometer 1. Preferably, notches 11 are formed by grinding, and are spaced a distance of 20mm apart, with the notch 11 which is nearest to the free end of sensor wire 6 being 20mm from that end. As shown in Fig. 2, there are preferably six notches 11, giving rise to six temperature zones, although a larger or smaller number of notches 11 may be provided in sensor wire 6 according to the particular intended use of the ultrasonic thermometer 1.

In operation, preferably the temperature zone between the free end of the sensor wire 6 and the first notch 11 from that end is not considered due to the fact that the ultrasonic pulse 13a, reflected from that end has an amplitude which is considerably greater than that of each ultrasonic pulse 13, reflected from a respective notch 11.

Preferably, the depth to which each notch 11 is ground is varied between successive notches 11 so as to produce approximately the same amplitude for each of the ultrasonic pulses 13 reflected from the respective notches 11.

As an alternative to having the temperature zones defined by ground notches 11, the temperature zones may be defined by welding stand-offs or loops onto the tungsten wire or by reducing the diameter of the sensor wire 6 successively in a step-wise manner towards the free end of sensor wire 6.

Sensor wire 6 is surrounded and protected by a cylindrical sheath 9, along its length.

Preferably, sheath 9 and sensor wire 6 are approximately equal in length. Preferably sheath 9 is composed of tungsten.

Sheath 9 has as low a radius as possible to reduce errors in temperature measurement resulting from axial and radial heat transfer in the sheath.

In order to present "sticking" or high temperature contact welding by diffusion it must be ensured that sensor wire 6 does not contact the internal surface of sheath 9. This can be ensured by completely coating the internal cylindrical surface of sheath 9 adjacent the notched position of sensor wire 6 with a material such that contact of the sensor wire 6 with the material does not give rise to a "sticking" effect.

As shown clearly in Fig. 2, "sticking" between sheath 9 and sensor wire 6 is prevented by the provision of stuffing 15 between sheath 9 and sensor wire 6, preferably at least over the internal surface of sheath 9 which covers the notches section of sensor wire 6.

The stuffing 15 is composed, preferably, of tungsten and is preferably in the form of a wire-cloth. The thickness of the stuffing 15 is varied according to the intended temperature values to be measured and the intended length of measurement time.

Preferably, stuffing 15 is constituted by a tungsten wire mesh, the wire having a diameter of approximately 0.05mm, and preferably for an ultrasonic thermometer 1 as described hereinabove the mesh is cut from a strip 4mm wide and is wound helically under tension to a 1mm diameter tube, the spiral preferably being wound so as to have a pitch greater than 4mm so as to prevent overlap of the wire mesh. When a sufficient length of a tube of stuffing 15 has been wound to surround the high temperature zone of sensor wire 6, sensor wire 6, together with stuffing 15, is inserted into sheath 9. After insertion into the desired portion of sheath 9, stuffing 15 will expand radially outwardly so as to be closely disposed against inner surface of sheath 9, as shown in Fig. 2.

In normal use of the ultrasonic thermometer, or in the event of bending of the sheath 9, if sensor wire 6 touches stuffing 15, "sticking" between sensor wire 6 and stuffing 9 will not occur, and thus no significant acoustic discontinuity will be present at the point of contact to deteriorate performance of the ultrasonic thermometer 1. The provision of stuffing 15 prevents any contact between sensor wire 6 and sheath 9.

It has been found that, with an ultrasonic thermometer 1 having stuffing 15 as described hereinabove, satisfactory and accurate operation at temperature of up to 3000°C for extended measurement times has been achieved.

In the ultrasonic thermometer 1 according to the present invention, the transmission wire 5 is made of a magnetostrictive material which material is required for the transformation of an electric pulse, which electric pulse is induced in the magnetostrictive material by a sensor electric pulse passing through coil 4, into an acoustic pulse which may propagate along transmission wire 5. Preferably, transmission wire 5 has a diameter of approximately 1mm and a length of approximately 1mm, which length depends on the intended use of the ultrasonic thermometer 1. Preferably the transmission wire 5 has been worked at 8 for matching to the sensor wire 6 at weld 7, which weld 7 is formed by, for example, resistance percussive welding. As shown in Fig. 1 the end of the transmission wire 5 is tapered at 8 so as to acoustically match sensor wire 6 and transmission wire 5 in order that the amplitude of ultrasonic pulse 14 caused by reflection of a fraction of existing ultrasonic pulse 12 at weld 7 is reduced to an amplitude value, typically, of below 10% that of the existing pulse 12, and the matching is achieved by way of diameter matching and shaping of transmission wire 5 and sensor wire 6.

In transducer head 2, permanent magnet 3 is preferably a ferrite cylinder with axial polarisation and preferably has an outer diameter (D) of 15 mm, an inner diameter (d) of 3 mm and a length (l) of 3 mm. Coil 4 is preferably positioned concentrically with and inside magnet 3 and has a length of 1.5 mm, being arranged to be as short as possible so as to give a very short ultrasonic pulse length. Preferably, the magnetic field produced by the arrangement of magnet 3 and coil 4 is restricted in the axial direction in transducer head 2 by the provision of a pair of ferrite discs (not shown), one disc being positioned at each end of magnet 3.

Transmission wire 5 and transducer head 2 are preferably protected by a cladding 10, as shown in Fig. 1, which cladding 10 is preferably composed of stainless steel. The cladding 10 reduces undesirable reflection and attenuation of the ultrasonic pulses, passing through ultrasonic thermometer 1, which are due to acoustic interference.

CLAIMS

1. An ultrasonic thermometer, comprising an electric pulse transducer head, a pulse transmission line, a notched sensor wire attached to and extending along the axis of said transmission line and a sheath enclosing the transmission line and the sensor wire, a portion of the interior face of the sheath being covered by a stuffing material along at least the length of the notched part of the sensor wire, such that contact between the sensor wire and the stuffing material does not substantially give rise to reflection of an ultrasonic pulse, at the point of contact.

2. An ultrasonic thermometer according to Claim 1 wherein the stuffing material is formed by a mesh of tungsten wire.

3. An ultrasonic thermometer according to Claim 2, wherein the mesh is made of a strip of 4mm width, wound helically under tension to a 1mm wire rod with a pitch greater than 4mm, inserted into the tungsten sheath and released so as to contact and cover a portion of the inner wall of said sheath.

4. An ultrasonic thermometer substantially as hereinbefore described with reference to and as illustrated in Fig. 2.

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