

## INTENSITY MODULATED FIBER OPTIC TEMPERATURE SWITCHING IMMERSION PROBE

### FIELD OF INVENTION

5 The present invention relates to an intensity modulated fiber temperature optic switching immersion probe for remote temperature monitoring and switching of an industrial process. The present invention also provides a method for remote sensing of temperature.

### BACKGROUND OF THE INVENTION

10 Conventionally, thermometers, thermocouples and pyrometers are used to measure and control the temperature, but they are not immune to hostile, corrosive and electro-magnetically noisy environment. The novelty about this probe is the use of optical fibers in conjunction with a cell containing a chemical and resulting in a change of light level at its melting point. This arrangement overcomes the above mentioned problems effectively and  
15 provides the added advantage of remote monitoring. The cell is opaque to light at room temperature but becomes transparent at a given higher temperature enabling actuation of a relay to stop the heating process or raise an alarm. There is no electric signal being guided in this probe. It is only the light signal which is guided through optical fibers and is unaffected by the presence of electrical signals.

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### OBJECTS OF THE INVENTION

The main object of the present invention is to provide a reliable, durable, cost-effective and in-situ temperature switching fiber optic immersion probe, which overcomes most of the drawbacks present in conventional temperature probes as detailed above.

25 Another object of the present invention is to provide a method for remote sensing of temperature using this immersion probe.

Further object of the present invention is to provide an immersion probe for remote sensing temperature having a chemical that is non-toxic, non-inductive, non-conductive and non-corrosive.

30 Yet another object of the present invention is to provide an immersion probe for remote sensing of temperature in harsh working conditions.

### SUMMARY OF THE INVENTION

The present invention relates to an intensity modulated fiber optic temperature switching  
35 immersion probe for remote temperature monitoring and switching of an industrial

process. The present invention also provides a method for remote sensing of temperature. The present invention adopts a method wherein the melting of point of the chemical substance determines the switching mode for the device.

#### DETAILED DESCRIPTION OF THE INVENTION

Accordingly, the present invention provides an intensity modulated fiber optic temperature switching immersion probe for remote sensing of temperature, said device comprising:

- (a) a Y-shaped optical fiber light guide encased in a metallic sleeve(8) terminated with a metallic end cap (1);
- (b) the Y-guide having a source arm (2), detector arm (10), a Y-coupler (3), a common arm (9) and a common end cap(4);
- (c) a light source is coupled to the source arm;
- (d) a photo-detector is aligned to the detector arm;
- (e) the Y-guide fits into the common end cap (4) of the metal sleeve;
- (f) an evacuated cell (6) containing a chemical is attached to the common end of Y-guide as means for sensing temperature;
- (g) the cell having a aluminum coating on the outside of the bottom surface forming a concave mirror;
- (h) the cell is covered with a glass plate (5) on the upper side;
- (i) the cell is further bonded and coupled to the metal sleeve by means of a metallic ring (7); and
- (j) a power meter for the processing of electrical signal;

An embodiment of the present invention, wherein the Y-shaped optic guide is encased in a crush resistant metallic sleeve.

Yet another embodiment of the present invention, wherein the optical fiber is made of dielectric material that is non-corrosive, durable and immune to any Electro Magnetic Interference (EMI) and RFI.

Still another embodiment of the present invention, wherein the light source is white light.

Yet another embodiment of the present invention, wherein the detector arm that is coupled to a photo-detector is connected to signal processing electronic circuitry and an output display.

Still another embodiment of the present invention, wherein the chemical used undergoes phase transformation from solid to a liquid phase at its melting point.

Yet another embodiment of the present invention, wherein the chemical is selected from oxalic acid, sodium chloride, paraffin wax and preferably acetamide.

Further embodiment of the present invention, wherein the chemical is non-toxic, non-corrosive and non-inflammable.

Still another embodiment of the present invention, wherein in solid state the chemical is opaque to light and emits a fixed value of optical output and with the increased  
5 temperature the chemical melts and becomes transparent thus generating an increased optical output.

Yet another embodiment of the present invention, wherein the phase transformation at the melting point of the chemical increases the optical output that is used as a detector signal for actuation of alarm or relay.

10 Further embodiment of the present invention, wherein the length of the cell is twice the focal length of the concave mirror.

Still another embodiment of the present invention, wherein the optical signal propagation is secure and without any cross talk or interference problems.

Yet another embodiment of the present invention, wherein the optical signal is unaffected  
15 by the presence of electrical signals.

Still another embodiment of the present invention, wherein the said probe is used for remote sensing of temperature upto a distance of 1 km.

Further embodiment of the present invention, wherein the said probe at an increased temperature provides an increase of 6 times in the output signal over the signal at the room  
20 temperature.

Yet another embodiment of the present invention, wherein said optical probe operates at the melting temperature of the chemical that is in the range of 75-85 °C.

Further embodiment of the present invention, wherein said optical probe is used in monitoring temperature in hostile, inflammable, corrosive and electro-magnetically noisy  
25 environments, preferably in petrochemical industries and power plants.

The present invention also provides a method of sensing temperature through intensity modulation of light signal using an intensity modulated and remote sensing optic fiber temperature switching immersion probe, said method comprising the steps of:

- 30 (a) immersing the probe in a liquid container having a temperature below the melting point of the chemical;
- (b) recording a fixed value of optical signal generated by the chemical in solid state and at the room temperature; and
- (c) detecting the maximum optical signal generated by the chemical at its melting point and in liquid phase;

- (d) detecting the optical signal by means of a photo-detector;
- (e) signal processing by means of an electronic circuitry; and
- (f) enabling actuation of a relay to stop the heating process or raise an alarm.

An embodiment of the present invention, a method wherein the liquid is selected from the group consisting of water, acetone, carbon tetrachloride and transformer oil.

Another embodiment of the present invention, a method wherein the chemical is selected from selected from oxalic acid, sodium chloride, paraffin wax and preferably acetamide.

Still another embodiment of the present invention, a method wherein the chemical having a melting point in the range of 75-85 °C.

Yet another embodiment of the present invention, a method wherein the optical signal propagation is secure and without any cross talk or interference problems.

Still another embodiment of the present invention, a method wherein the optical signal is unaffected by the presence of electrical signals.

Yet another embodiment of the present invention, a method wherein the said probe is used for remote sensing upto a distance of 1 km.

Still another embodiment of the present invention, a method wherein the said probe at an increased temperature provides an increase of 6 times in the output signal over the signal at the room temperature.

Yet another embodiment of the present invention, a method wherein the chemical substance that is opaque at room temperature becomes transparent at a given higher temperature enabling actuation of a relay to stop the heating process or raise an alarm.

The invention is further explained in the form of the following embodiments.

In the present invention a fiber optic temperature switching probe, which comprises a fiber optic Y-shaped light guide and a small cell containing a special chemical/which undergoes solid to liquid phase transformation at its melting point. The cell has a concave mirror on its lower side and a glass plate on the upper side. The chemical identified and experimented for this probe undergoes phase change at a temperature of 78-79 °C. A small amount of the chemical is first transferred into cell and then it is evacuated and properly sealed. The cell is further bonded to a metal tube, which fits tightly on to the common end cap of the Y-guide. A metallic ring is used for coupling the cell to the metal tube. The Y-guide has two arms, termed as a source arm and the detector arm. A white light source is coupled to the source arm while the detector arm is aligned to a PIN photo-detector. The electrical signal is processed and displayed by a powermeter.

In an embodiment of the present invention a suitable chemical has been identified and used to realize the cell for the temperature switching probe. Depending on the identification of a suitable chemical e.g. non-corrosive, non-inflammable, switch probes for different temperatures can be realized.

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In another embodiment of the present invention, fiber optic light guides have been employed which are made of optical glass, a highly durable material being non-conductive and non-inductive in nature.

10 The sensing signal is in the form of intensity modulated light guided by the fiber. The signal propagation is secure without any cross talk or interference problems.

The optical fiber temperature switch probe comprises of an indigenously produced Y-shaped optical fiber light guide/bundle encased in a crush-resistant metallic sleeve with its  
15 ends properly terminated into metallic end caps. A few grams of the commercially available chemical in grainy form is first vacuum dried under clean conditions and then transferred into the cell made from a thin-walled glass test tube. The curved surface at the bottom of the test tube is given a reflective aluminum coating on the outside as to realize a concave mirror while the upper end is covered with a plane glass disc. Considering the  
20 image formation characteristics, the length of the cell is chosen to be twice the focal length of the concave mirror. Proper adhesive sealing is done to make the cell airtight.

With the help of a metallic ring, the cell is firmly coupled onto the common end cap of the Y-guide and in this situation, the common end rests on to the top glass cover of the cell.

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When the probe is immersed in a liquid container at a temperature below the melting point of the chemical, there is a fixed value of the detector signal. The chemical begins to melt as the temperature reaches around 78-79°C and thus more light reaches the detector resulting in an increased output signal. This continues till the chemical has melted completely and  
30 the detector signal has attained a maximum value which takes place at about 83 °C. The probe provides typically 6 times increase in the output signal as compared to the room temperature stage. At any particular value of temperature in this range (75-85°C) corresponding to the level of optical signal available, either an alarm signal could be generated or the process can be shut down automatically as to stop further heating of the  
35 liquid/solvent. Thus the probe can be used as a temperature switch e.g. to stop the process from further heating at any value of temperature in this range.

The probe facilitates sensing of temperature through intensity modulation of light signal. This modulation process is unaffected by a hostile and electrically noisy environment whereas the prior art has to be either properly shielded for gaining this immunity or protection. This is so because optical fibers are made from dielectric materials and therefore, they are both non-inductive and non-conductive in nature thereby bringing immunity to EMI/RFI. Also the basic raw material, optical glass from which fibers are made is quite durable and effectively withstands harsh and corrosive environments encountered in various application areas.

When the probe end is dipped into a liquid whose temperature is to be monitored, the optical signal reaching the detector depends on the transparency to light provided by the cell medium. As the temperature rises, the chemical starts melting beyond a point and transparency to light goes up rapidly thus increasing the detector signal. At a stage, the signal reaches its maximum value when the entire chemical has melted. This level of the signal can be used to raise an alarm or actuate a relay/switch to shut down or start a process at that maximum value of temperature thus working as a temperature switch probe.

This temperature switch probe has been experimented in the laboratory by dipping it in water and other solvents such as acetone, carbon tetrachloride, transformer oil etc to monitor their temperature. The temperature of water and other liquids is recorded with a mercury thermometer. There has been consistency and repeatability in the optical output with temperature within 1°C.

This probe could be beneficially used for starting/closing of a process in an industry. The process monitoring can be carried out remotely by extending the length of optical fiber arms of the bundle. It can be quite a durable and cost-effective device and the process monitoring operation can be made automatic.

A comparison between the present probe and the conventional temperature measuring techniques/ probes is given below:

**COMPARISON CHART**

| S.No | THERMOMETER                                               | THERMOCOUPLE                                                | PYROMETER                                                    | FIBER OPTIC PROBE                                         |
|------|-----------------------------------------------------------|-------------------------------------------------------------|--------------------------------------------------------------|-----------------------------------------------------------|
| 1.   | No point switching                                        | No point switching                                          | No point switching                                           | Point switching                                           |
| 2.   | Immunity to EMI/ RFI and hostile / corrosive environments | Not immune to EMI/ RFI and hostile / corrosive environments | Not immune to, EMI/ RFI and hostile / corrosive environments | Immunity to EMI/ RFI and hostile / corrosive environments |
| 3.   | No remote sensing                                         | No remote sensing                                           | Remote sensing (few 10s of meters)                           | Remote sensing (upto a Km)                                |

## ADVANTAGES

1. It can work for process industry applications where the environment is hostile and electrically noisy.
2. It can monitor the temperature remotely and the process can be made automatic.
- 5 3. A low cost and durable device.
4. The immersion probe is a simple and useful device, which can be employed in harsh environments for in-situ temperature switching applications from a remote location.

10 The drawings provided in the enclosed sheets indicate the configuration of the fiber optic temperature switching immersion probe. It basically comprises of a Y-shaped fiber optic bundle and a small cell made of a thin-walled glass test tube containing a chemical. The bottom surface of the test tube has been given a protective reflective aluminum coating on the outside for realizing as a concave mirror. The Y-shaped fiber optic bundle contains two arms: the source arm and the detector arm. A white light source is coupled to source arm  
15 employing suitable optics while the other arm is aligned to a PIN photo-detector.

The various parts of the probe have been labeled as under:

1. End Cap for Coupling to the Light Source
2. Source Arm
- 20 3. Y-Coupler
4. Common End Cap of the Fiber Bundle
5. Reflective Coating on Outside of the Bottom Surface of the Thin-Walled Glass Cell
6. Cell Containing the Chemical
- 25 7. Metallic Ring for Coupling Cell to the Common End Cap
8. Metallic Tube Tightly Fitting the Common End Cap
9. Common Arm
10. Detector Arm

**CLAIMS**

1. An intensity modulated optic fiber temperature switching immersion probe for remote sensing of temperature, said device comprising:
  - (a) a Y-shaped optical fiber bundles light guide encased in a crush-resistant metallic sleeve(8) terminated with a metallic end cap (1);
  - (b) the Y-guide having a source arm (2), detector arm (10), a Y-coupler (3), a common arm (9) and a common end cap(4), said Y-guide is constructed of half the transmitting fibers and half the receiving fibers such that the image of the illuminating fibers is formed by the mirror on to receiving fibers;
  - (c) a white light source is coupled to the source arm;
  - (d) a photo-detector is aligned to the detector arm;
  - (e) the Y-guide fits into the common end cap (4) of the metal sleeve;
  - (f) an evacuated cell (6) containing a chemical is attached to the common end of Y-guide as means for sensing temperature;
  - (g) the cell having a reflective coating on the outside of the bottom surface forming a concave mirror with a focal length equal to half the length of the cell;
  - (h) the cell is covered with a glass plate (5) on the upper side;
  - (i) the cell is further bonded and coupled to the metal sleeve by means of a metallic ring(7); and
  - (j) a power meter for the processing of electrical signal;
2. The device according to claim 1, wherein the optical fiber is made of dielectric material that is non-corrosive, durable and immune to any Electro Magnetic Interference (EMI) and RFI.
3. The device according to claim 1, wherein the detector arm that is coupled to a photo-detector is connected to signal processing electronic circuitry and an output display.
4. The device according to claim 1, wherein the chemical used undergoes phase transformation from solid to a liquid phase at its melting point.
5. The device according to claim 1, wherein the chemical is selected from oxalic acid, sodium chloride, paraffin wax and preferably acetamide.
6. The device according to claim 1, wherein the chemical is non-toxic, non-corrosive non-conductive and non-inductive in nature and non-inflammable.
7. The device according to claim 1, wherein in solid state the chemical is opaque to light and emits a fixed value of optical output and with the increased temperature the

chemical melts and becomes transparent thus generating an increased optical output.

8. The device according to claim 1, wherein the phase transformation at the melting point of the chemical increases the optical output that is used as a detector signal for actuation of alarm or relay.
9. The device according to claim 1, wherein said reflective coating on the outer surface of the cell is an aluminum coating.
10. The device according to claim 1, wherein the optical signal propagation is secure and without any cross talk or interference problems.
11. The device according to claim 1, wherein the optical signal is unaffected by the presence of electrical signals.
12. The device according to claim 1, wherein the said probe is used for remote sensing of temperature upto a distance of 1 km.
13. The device according to claim 1, wherein the said probe at an increased temperature provides an increase of 6 times in the output signal over the signal at the room temperature.
14. The device according to claim 1, wherein said optical probe operates at the melting temperature of the chemical that is in the range of 75-85 °C.
15. The device according to claim, wherein said optical probe is used in monitoring temperature in hostile, inflammable, corrosive and electro-magnetically noisy environments, preferably in petrochemical industries and power plants.
16. A method for remote sensing of temperature using intensity modulated optical fiber temperature switching immersion probe as claimed in claim 1 to 15, said method comprising the steps of:
  - (a) immersing the cell of the probe in a liquid container having a temperature below the melting point of the chemical;
  - (b) passing the light from the white light source to the photo detector;
  - (c) recording a fixed value of optical signal generated by the chemical in solid state present in the evacuated cell and at the room temperature; and
  - (d) detecting the maximum optical signal generated by the chemical at its melting point and in liquid phase;
  - (e) detecting the optical signal by means of a photo-detector;
  - (f) signal processing by means of an electronic circuitry; and
  - (g) enabling actuation of a relay to stop the heating process or raise an alarm.

17. The method as claimed in claim 16, wherein passing of light from the light source to the detector comprises transmission of light through the source arm, reflection from the surface of the chemical contained in the cell and movement of reflected optical wave through the detector arm to the detector.
18. The method according to claim 16, wherein the liquid is selected from the group consisting of water, acetone, carbon tetrachloride and transformer oil.
19. The method according to claim 16, wherein the chemical is selected from selected from oxalic acid, sodium chloride, paraffin wax and preferably acetamide.
20. The method according to claim 16, wherein the chemical having a melting point in the range of 75-85 °C.
21. The method according to claim 16, wherein the optical signal propagation is secure and without any cross talk or interference problems.
22. The method according to claim 16, wherein the optical signal is unaffected by the presence of electrical signals.
23. The method according to claim 16, wherein the said probe is used for remote sensing upto a distance of 1 km.
24. The method according to claim 16, wherein the said probe at an increased temperature provides an increase of 6 times in the output signal over the signal at the room temperature.
25. The method according to claim 16, wherein the chemical substance that is opaque at room temperature becomes transparent at a given higher temperature enabling actuation of a relay to stop the heating process or raise an alarm.