TECHNICAL NOTE

THE VALUE OF FLUOROPTIC® THERMOMETRY:
COMPARISON WITH OTHER TECHNOLOGIES

Why Another Temperature Measurement Technology?

When temperature measurements are needed in electrically hostile environments, conventional electrical temperature measurement techniques utilizing thermocouples, thermistors, or RTD's typically cannot be used. The reasons include artifactual sensor heating and noise pickup by metallic leads in strong RF or microwave fields, the danger of producing shorts during high voltage measurements, and the danger of spark transmission down the metallic leads into a flammable or explosive environment. For such applications, a non-metallic sensor and an electrically inert sensing technique are required.

Electrical sensors with metallic leads can also alter the heating environment. If heating is being done using microwave power, the fields can be reflected by the wires and the heating distribution thereby altered. There are also circumstances where heat conduction by the metallic leads can produce a significant temperature change at the point of measurement, thereby distorting the data. For these reasons, Luxtron's Fluoroptic® temperature measurement technique utilizing optical sensing materials at the end of thermally and electrically non-conducting optica fibers provides a unique solution.

Another particularly important application is the measurement of surface temperature. (The surface temperature measurement application is sufficiently important that it is discussed in more detail in separate technical notes.) Most measurements of the temperature of a solid object involve the measurement of its surface temperature. Only rarely does one have the luxury of drilling a hole in the solid and imbedding the probe in such a way that the sensor is "immersed", or fully surrounded by material at the temperature to be measured. The sensing of the temperature of a surface is particularly difficult, whether the environment is electrically hostile or not. First the sensor must make very good thermal contact with the surface. Second, the thermal mass of the sensor should be small so that the surface temperature is not lowered significantly by heat transfer. Third, no other flow of heat to or from the sensor, such as heat flow down metallic leads, should compete with the thermal equilibration of the sensor with the surface. Most conventional electrical sensors fail to meet these three criteria, especially when fast, convenient measurements are desired. The Fluoroptic® approach automatically meets the second and third requirements and special sensor designs have been developed to meet the first as well.

Another well-known optical temperature measurement technique is infrared radiometry, which is frequently employed for surface temperature measurement. However, infrared radiometers measure the intensity of received infrared radiation. To convert such a measurement to absolute temperature reliably, the infrared emissivity (emission efficiency) of the emitting surface in the wavelength range employed must be accurately known and other sources of infrared background (including reflections) must be excluded.

Infrared systems typically employ large optics and require line-of-sight access to the region of interest. Conventional optical fibers do not transmit in the long-wave infrared and, hence, can only be used at very high temperatures. At moderate to low temperatures, infrared devices do not have much sensitivity. For these reasons, the Fluoroptic® technique is useful in many situations where infrared techniques cannot be used.

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What About Other Fiberoptic Techniques – Why Use Fluorescence?

To be practical, a fiberoptic sensor must meet certain requirements. The optical change with temperature should be sufficient to provide good sensitivity over a wide range. The calibration should be intrinsic to the sensor material, reproducible for given compositions and methods of preparation, and stable over long periods of time. The sensor material should be easy to form and to apply with consistent results. The technology should lend itself to the fabrication of a wide variety of interchangeable sensor designs which should be easy to construct and should have both physical and chemical durability. Preferrably a single fiber will be used for input and output optical signals. Last but not least, there should be some method for eliminating effects produced by changes in the optical signal level as may be caused by changes in source intensity or by variations in transmission brought about by fiber bending. The Luxtron Fluoroptic® thermometry technology, meets all of these requirements. The Fluoroptic® technique is described in more detail elsewhere. Its main features result from the use of a photoluminescent material as the sensor. It is possible to use a single optical fiber to transmit both the exciting radiation and the resultant fluorescence between the instrument and the sensor. This is because the excitation and emission wavelengths differ substantially and can thus be separated easily with filters. The key temperature dependent property, the fluorescent decay time, is intrinsic to the phosphor. The system is essentially signal independent, so the sensor do not have to be precisely identical in size, shape, or luminescent efficiency for reliable temperatures to be derived using standard instrumentation and look-up tables. It is this feature which gives the technology much of its simplicity, reliability, and versatility.