www.FluxTeq.com info@fluxteq.com

Thermal Insulation R-Value Measurement Instruction Manual

Introduction

Heat flux sensors can be used to measure and quantify the thermal energy per unit area moving through a surface of a system. They are the only sensors that can be used to take in-situ measurements of material thermal resistance, commonly referred to as R-Value. Other methods are either destructive to the material or are unable to a provided quantitative R-value numbers. Even using original manufacturer's specifications for a material does not account for factors that affect the thermal performance such as degradation over time, humidity or physical damage.

The PHFS product line of heat flux sensor utilize a differential-temperature thermopile design to measure the movement of thermal energy per unit area, or heat flux, through the sensor surface. Each PHFS sensor includes an integrated thermocouple that can be used for sensor temperature measurements. For measuring relatively low heat fluxes usually seen in R-value measurement applications, FluxTeq recommends using either our PHFS-09 or PHFS-09e heat flux sensors that have excellent sensitivity.

Theory Behind R-value Measurements

The R-value of thermal insulation can be determined through a few simple measurements that are made possible using the PHFS heat flux sensors. A diagram of heat transfer through a building wall is shown below.

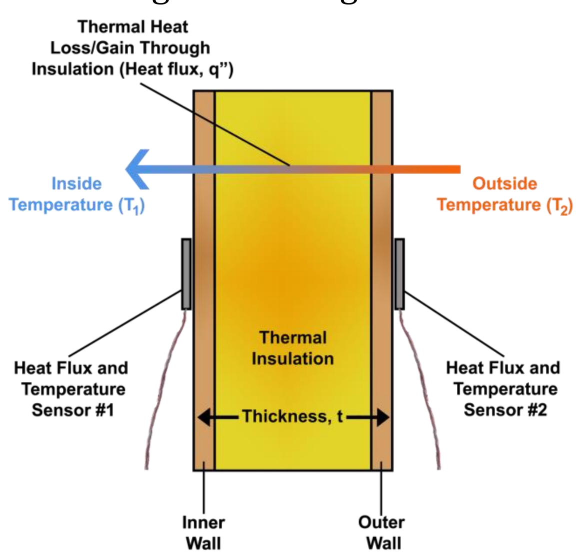

Figure 1. Diagram of conductive heat flow through a material and the necessary experimental setup to determine R-value of the material.

The underlying equation for determining the R-value of a material originated from Fourier's law of conduction that assumes steady-state one-dimensional heat transfer through the material.

$$q" = \frac{k}{t}(T_{2,outside} - T_{1,inside}) = \frac{(T_{2,outside} - T_{1,inside})}{R_{Value}} \tag{1}$$

Where *q"* is the one-dimensional heat flux through the material, *k* is the thermal conductivity, and *t* is the thickness. By manipulating the equation Therefore the thermal insulation's thermal resistance or R-value is as follows

$$R_{value} = \frac{\Delta T}{q"} = \frac{(T_{2,outside} - T_{1,inside})}{q"} \tag{2}$$

From the above equation it can be seen that there exists three unknown variables, heat flux (q"), $T_{2,outside}$, and $T_{1,inside}$, that are required in order to determine the material's thermal resistance R-value. All of these values can be obtained using measurement from 2 PHFS heat flux sensors that are positioned on both the inside and outside surfaces of the material being tested. Note: The measurement of R-value can be taken using a single PHFS heat flux sensor located on one side of the material surface with just a surface temperature sensor located on the opposite wall but FluxTeq recommends using two to double-check that the heat flux is approximately one-dimensional/equal through both measurement surfaces.

The measurements should be taken over an extended period of time and then analyzed to determine the overall effective R-value of the material. There are a few different methods analyzing the measurement data. One equation for doing so is listed below.

$$R_{value-tot} = \frac{\sum_{t=0}^{t=final} T_{2,outside,\ t} - \sum_{t=0}^{t=final} T_{1,inside,\ t}}{q"_t}$$

Measuring the Thermal Conductance (U-value)

If you are attempting to measure the thermal conductance, or U-value, of a material opposed to the thermal resistance then the same measurements are required. The U-value is simply the reciprocal of the R-value and is calculated as shown in the equation below.

$$U_{value} = \frac{q"}{\Delta T} = \frac{q"}{(T_{2,outside} - T_{1,inside})} = \frac{1}{R_{value}}$$

Standards Describing In-situ R-value Measurement Practices

Organizations such as the American Society of the International Association for Testing and Materials (ASTM) and the International Organization for Standardization (ISO) have written standards that describe the procedures for taking in-situ measurements of the thermal resistance using heat flux sensors. Some of the various standards that are directly related to this procedure are listed below.

ASTM 1046 - Standard Practice for In-Situ Measurement of Heat Flux and Temperature on Building Envelope Components

ASTM 1155 - Practice for Determining Thermal Resistance of Building Envelope Components from In-Situ Data

ISO 9869 - In-situ measurement of thermal resistance and thermal transmittance

ASTM 1041 - Standard Practice for In-Situ Measurements of Heat Flux in Industrial Thermal Insulation Using Heat Flux Transducers

Tips for Taking Accurate Measurements and Data Analysis

1. Do not place either heat flux sensor near an air vent. The fluctuations in heat flux caused by the air vent will cause unstable and inaccurate measurements.
2. Avoid placing the sensors within direct sunlight to reduce significance of solar radiation. Try to find a consistently shady or interior location for placing the sensors.
3. The recommended testing duration for taking measurements is at least 48 hours but measurements have shown to be effective in as little as 1 hour.
4. Maintain a significantly large temperature difference of at least 10 °C across the material for the entire duration of the test. The more stable the temperature difference is then the more accurate the measurements will be.

Importance of Stable Testing Conditions

Since equation 2 used to calculate R-value from heat flux and temperature measurements made the assumption of steady-state one-dimensional heat flux it is important to take into account any changes in heat flux through the material over the duration of the material testing.

When measuring the R-value of the materials with relatively large thermal resistance such as building walls or other envelope components it is important that the material is approximately experiencing steady state heat transfer. Steady state takes some time to achieve due to the long response time of the material to changes in heat flux. The time the material takes to reach steady state is a function of the thickness, placement, and thermal diffusivity of each constituent layer of the item.

Contact Information for Additional Questions

For additional information about PHFS heat flux sensor specifications, applications, or general inquires use the following contact information or visit the FluxTeq website at www.FluxTeq.com

Direct general inquiries to - info@FluxTeq.com