Hukseflux Thermal Sensors

Window thermal insulation testing

Measuring the R-value of windows using Hukseflux heat flux sensors

Thermal insulation of windows may be tested the same way as that of walls; however, some specific points need attention. First, testing should be done in the dark, for instance working at night only, because windows transmit light. Second, the thermal resistance of windows is typically smaller than that of walls, thus the thermal resistance of heat flux sensors mounted on the window creates a significant error. This error is called the resistance error and must be corrected. Hukseflux sensor model FHF05-85X85 is most suited for testing windows. The sensor is very sensitive and capable of measuring low heat flux levels. It has a low thermal resistance resulting in a low resistance error. This reduces the uncertainty of corrections.

Figure 1 *Model FHF05-85X85 heat flux is most suited for measuring on windows. All models of FHF05 series have a low very thermal resistance.*

Figure 2 *TRSYS20: example of a measuring system for thermal resistance of walls. It consists of 2 HFP01 heat flux sensors and 2 matched thermocouple pairs (in total 4 temperature sensors) connected to the measurement and control unit (MCU).*

Introduction

In building envelopes, heat loss through windows is an important contributor. We offer a wide range of sensors for heat flux and temperature measurement to analyse their impact.

TRSYS20 is an example of a system allowing these sensors to measure the thermal resistance of building envelope components. Designed for measurement on walls, the TRSYS20 system employs heat flux sensors of model HFP01. Heat flux sensors FHF05 series are, because of their low thermal resistance, very suitable for measurement of heat fluxes through windows. Model FHF05-85X85 is most suited because of its high sensitivity.

Night-time testing

When testing windows, we recommend using night-time data only. During daytime, the window material typically transmits solar radiation. Heat flux - and temperature sensors mounted on windows - will absorb this radiation, generating high local heat fluxes and temperatures. Therefore, during daytime, the measurements are not representative of the surface temperature of the window or the heat flux through the window.

Measuring the R-value

R-values describes the effectiveness of insulating material. The higher the R-value, the better the insulation performance of the window. On-site measurements of thermal resistance, or R-value, are often applied in studies of building envelope components. Other possibilities are to measure U-value which includes ambient air boundary layer thermal resistance.

The measurements of all these values are based on simultaneous time-averaged measurement of heat flux Φ in W/m^2 through a window and differential temperature ΔT in K across the window. For the R-value:

$R = \Delta T / \Phi$

ISO 9869, ASTM C0146, and ASTM C1115 standards give detailed directions concerning the measurement method, sensor installation, and data analysis.

Figure 3 *HFP01 heat flux sensor and thermocouples mounted on a wall and measured with the TRSYS20 measuring system.*

Resistance error

A heat flux sensor has a certain thermal resistance. When mounted on an object, this additional thermal resistance may significantly increase the apparent R-value of the object under test, for example, a window.

The presence of the sensor on a window will result in a reduction of the heat flux. This can result in an error in the determination of the R-value of a window. This is called the resistance error. The next paragraphs elaborate on the resistance error in the R-value of windows.

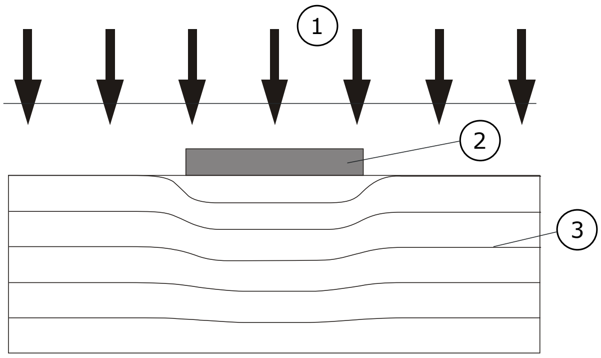

Figure 4 *The resistance error: a heat flux sensor (2) increases the total thermal resistance on which it is mounted. An otherwise uniform heat flux (1) is locally disturbed. Lines (3) represent isotherms. The measured heat flux is smaller than the undisturbed flux.*

U-value

Like the R-value, the U-value measures how effective a material is as an insulator. The lower the U-value, the less heat is lost and the more insulation the material provides. Contrary to the R-value, the U-value includes an ambient air boundary thermal layer at the inside and outside of a glass window. It can be calculated from the sum of the thermal resistances:

$$U_{value} = \frac{1}{\Sigma R + R_{ambient\ air\ boundary\ layer}}$$

Where ΣR is the total thermal resistance of the window. $R_{ambient\ air\ boundary\ layer}$ is the thermal resistance of the ambient air boundary layer. Typically, this value is 30 W/m^2·K for ventilated windows.

Single glass versus double glass

In this section, the resistance error of measuring on a single glass window is compared to a double glass window.

Suppose you have a single glass window with a thickness of $t = 6 \times 10^{-3}$ m. Glass has a thermal conductivity of around $\lambda = 0.8$ W/(m·K). With a ventilated ambient air layer, the thermal transmittance for single glass is U = 13.48 W/(m^2·K).

A double glass window consists of an air layer with a thickness of 10×10^{-3} m, and two times single glass. Air has a thermal conductivity of $\lambda = 0.025$ W/(m·K). The thermal transmittance for double glass is U = 1.39 W/(m^2·K).

Table 1 *Thermal resistances error of U-values of single glass or double glass windows versus Hukseflux FHF05-85X85 or HFP01 heat flux sensors.*

Object	U-value	Sensor model	R-value sensor	Resistance error
	[W/m²·K]		[K·m²/W]	[%]
single glass	13.48	FHF05-85X85	0.0011	1.5 %
		HFP01	0.0071	9.6 %
double glass	1.39	FHF05-85X85	0.0011	0.2 %
		HFP01	0.0071	1.0 %

Table 1 gives the thermal resistances error if the single or double glass windows are measured with a thin FHF05 ($t = 0.4 \times 10^{-3}$ m) or a thicker HFP01 sensor ($t = 5.4 \times 10^{-3}$ m). The estimated errors show that making an accurate measurement on single glass windows is difficult, even with FHF05.

Corrections, reducing uncertainty

Table 1 gives the resistance errors. Correcting for the resistance errors is possible and reduces uncertainty.

As seen in Table 1, single glass situations with HFP01 give significant errors of 9.6 %. Single glass with FHF05-85X85 gives an error of 1.5 %. ISO 9869-1 annex D elaborates on different correction measures. A first-order correction can be made by subtracting the thermal resistance of the sensor from the measured resistance:

$$R = \frac{\Delta T}{\Phi} - R_{\text{heat flux sensor}}$$

See ISO 9869-1 for more complex solutions.

For double glass situation, the additional resistance of the sensor has less influence on the distortion of the heat flux. Review your own measurement setup to see if correction for thermal resistance is needed.

In both cases reviewed, the corrections for the resistance error with FHF05-85X85 are much smaller than those required for HFP01. Therefore, FHF05-85X85 provides a more accurate measurement when measuring glass.

Conclusions

Hukseflux heat flux sensors and measuring systems are suited for window thermal insulation testing. However, we recommend the following:

- test only during night-time
- review your test setup to see if correction for thermal resistance errors is needed
- for window insulation testing heat flux sensor model FHF05-85X85 is most suited. The sensor measures low heat fluxes like in building envelope components. FHF05-85X85 has a low thermal resistance which results in a low resistance error

See also

- our YouTube video: how to measure heat flux
- FHF05 series general purpose heat flux sensors
- TRSYS20 high accuracy in-situ building R-value measuring system

About Hukseflux

Hukseflux is the leading expert in measurement of energy transfer. We design and manufacture sensors and measuring systems that support the energy transition. We are market leaders in solar radiation- and heat flux measurement. Customers are served through the main office in the Netherlands, and locally owned representations in the USA, Brazil, India, China, Southeast Asia and Japan.

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