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**Thermal insulation — Building  
elements — In-situ measurement  
of thermal resistance and thermal  
transmittance —**

Part 2:

**Infrared method for frame structure  
dwelling**

AMENDMENT 1: Example of calculation  
of uncertainty analysis

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# **Thermal insulation — Building elements — In-situ measurement of thermal resistance and thermal transmittance —**

Part 2:

## **Infrared method for frame structure dwelling**

AMENDMENT 1: Example of calculation of uncertainty analysis

*Annex E*

Replace Annex E with the following annex:

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## Annex E (informative)

### The calculation example of uncertainty analysis

NOTE This is a simplified uncertainty analysis example for illustrative purpose.

#### E.1 Listing of uncertainty factors

[Table E.1](#) shows the listing of uncertainty factors.

**Table E.1 — Uncertainty factors in measuring the thermal transmittance**

Measurement of heat transfer coefficient	Difference in temperature between the heat transfer coefficient sensor and environmental temperature (ET sensor)	Measurement of surface temperature	IR camera specification	Whichever is greater of 2 %, measurement value or $\pm 2$ °C
			Thermo-couple specification	$\pm 0,2$ °C
	Measurement of heat flow meter output of the heat transfer coefficient sensor	Measurement of voltage	Data logger specification	$\pm 6$ $\mu$ V
Heat flow rate	Difference in temperature between the surface temperature of the heat transfer coefficient sensor and environmental temperature (ET sensor)	Measurement of surface temperature	IR camera specification	Whichever is greater of 2 %, measurement value or $\pm 2$ °C
			Thermo-couple specification	$\pm 0,2$ °C
	Measurement of heat flow meter output of the heat transfer coefficient sensor	Measurement of voltage	Data logger specification	$\pm 6$ $\mu$ V
	Measurement of surface temperature of the wall	Measurement of surface temperature	IR camera specification	$\pm 2$ % of measurement value
Thermal transmittance	Difference in temperature between the surface temperature of the heat transfer coefficient sensor and environmental temperature (ET sensor)	Measurement of surface temperature	IR camera specification	Whichever is greater of 2 %, measurement value or $\pm 2$ °C
			Thermo-couple specification	$\pm 0,2$ °C
	Measurement of environmental temperature (measurement of surface temperature of ET sensor)	Measurement of surface temperature	IR camera specification	Whichever is greater of 2 %, measurement value or $\pm 2$ °C
			Thermo-couple specification	$\pm 0,2$ °C
	Measurement of heat flow meter output of the heat transfer coefficient sensor	Measurement of voltage	Data logger specification	$\pm 6$ $\mu$ V

Table E.1 (continued)

	Measurement of surface temperature of the wall	Measurement of surface temperature	IR camera specification	Whichever is greater of 2 %, measurement value or $\pm 2$ °C
			Thermo-couple specification	$\pm 0,2$ °C
	Measurement of outdoor environmental temperature (measurement of surface temperature of ET sensor)	Measurement of surface temperature	Data logger specification	$\pm 0,2$ °C
	Measurement of indoor environmental temperature (measurement of surface temperature of ET sensor)	Measurement of surface temperature	Data logger specification	$\pm 0,2$ °C

## E.2 The example of uncertainty estimation

[Formula \(E.1\)](#) gives the combined standard uncertainty of the thermal conductance:

$$u(U) = \sqrt{c_V^2 \cdot u^2(V) + c_{\Delta\theta_{hs}}^2 \cdot u^2(\Delta\theta_{hs}) + c_{\Delta\theta_{ni,s}}^2 \cdot u^2(\Delta\theta_{ni,s}) + c_{\Delta\theta_n}^2 \cdot u^2(\Delta\theta_n)} \quad (\text{E.1})$$

where

$u(V)$  is uncertainty in measuring the heat flow meter output of the heat transfer coefficient sensor (mV);

$u(\Delta\theta_{hs})$  is uncertainty of the difference between the surface temperature of the heat transfer coefficient sensor and the indoor environmental temperature (K);

$u(\Delta\theta_{ni,s})$  is uncertainty of difference between the surface temperature of the wall and the indoor environmental temperature (K);

$u(\Delta\theta_n)$  is uncertainty of the difference between the indoor and outdoor environmental temperatures (K);

$c_i$  is sensitivity coefficient.

Using the respective values of uncertainty and sensitivity coefficients, calculate the standard uncertainty from [Formula \(E.1\)](#), and use a coverage factor of  $k = 2$  to determine the expanded uncertainty.

## E.3 Preparation of uncertainty calculation sheet

[Tables E.2](#) and [E.3](#) show an example of uncertainties by the measurement results of thermal transmittance.

**Table E.2 — Uncertainty calculation sheet mainly based on IR camera measurement**

Uncertainty elements			Measurement	Sensitivity coefficients of elements $c_i$	Uncertainty $u(x_i)$	Standard uncertainty $c_i \cdot u(x_i)$
Sensitivity coefficient of HFM	$a$	mV/(W/m <sup>2</sup> )	0,011 77	—	—	—
HFM outputs	$V$	mV	0,465	0,89	0,003 46	3,08E-03
Difference between heat transfer coefficient sensor surface temperature and indoor environmental temperature	$\Delta\theta_{hs}$	K	3,59	0,115	2	2,30E-01
Difference between wall surface temperature and indoor environmental temperature	$\Delta\theta_{ni,s}$	K	1,06	0,39	2	7,80E-01
Environmental temperature difference	$\Delta\theta_n$	K	28,2	0,014 7	0,283	4,16E-03
Thermal transmittance	$U$	W/(m <sup>2</sup> K)	0,48	Combined standard uncertainty $u(U)$		0,813
				Expanded uncertainty $k = 2$		1,626
						338 %

**Table E.3 — Uncertainty calculation sheet based on IR camera measurements with calibrated thermocouples**

Uncertainty elements			Measurement	Sensitivity coefficients of elements $c_i$	Uncertainty $u(x_i)$	Standard uncertainty $c_i \cdot u(x_i)$
Sensitivity coefficient of HFM	$a$	mV/(W/m <sup>2</sup> )	0,011 77	—	—	—
HFM outputs	$V$	mV	0,465	0,89	0,003 46	3,08E-03
Difference between heat transfer coefficient sensor surface temperature and indoor environmental temperature	$\Delta\theta_{hs}$	K	3,59	0,115	0,2	2,30E-02
Difference between wall surface temperature and indoor environmental temperature	$\Delta\theta_{ni,s}$	K	1,06	0,39	0,2	7,80E-02
Environmental temperature difference	$\Delta\theta_n$	K	28,2	0,014 7	0,283	4,16E-03
Thermal transmittance	$U$	W/(m <sup>2</sup> K)	0,48	Combined standard uncertainty $u(U)$		0,081
				Expanded uncertainty $k = 2$		0,162
						34 %

**E.4 Uncertainty calculation for different conditions**

The following is an example of uncertainty calculation for different conditions using the mathematical model given by Formula (D.6).