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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:

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 ±2 °C
			Thermo-couple specification	±0,2 °C
	Measurement of heat flow meter output of the heat transfer coefficient sensor	Measurement of voltage	Data logger specification	±6 µV
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 ±2 °C
			Thermo-couple specification	±0,2 °C
	Measurement of heat flow meter output of the heat transfer coefficient sensor	Measurement of voltage	Data logger specification	±6 µV
	Measurement of surface temperature of the wall	Measurement of surface temperature	IR camera specification	±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 ±2 °C
			Thermo-couple specification	±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 ±2 °C
			Thermo-couple specification	±0,2 °C
	Measurement of heat flow meter output of the heat transfer coefficient sensor	Measurement of voltage	Data logger specification	±6 µV

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 ±2 °C
			Thermo-couple specification	±0,2 °C
	Measurement of outdoor environmental temperature (measurement of surface temperature of ET sensor)	Measurement of surface temperature	Data logger specification	±0,2 °C
	Measurement of indoor environmental temperature (measurement of surface temperature of ET sensor)	Measurement of surface temperature	Data logger specification	±0,2 °C

E.2 The example of uncertainty estimation

Formula (E.1) gives the combined standard uncertainty of the thermal conductance:

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

where

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

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

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

$u(\Delta\theta_{\mathrm{n}})$ 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^2)	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^{2}K)	0,48	Combined standard uncertainty $u(U)$		0,813
				Expanded uncertainty		1,626
				k = 2		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^2)	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^{2}K)	0,48	Combined standard uncertainty $u(U)$		0,081
				Expanded uncertainty		0,162
				k = 2		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).

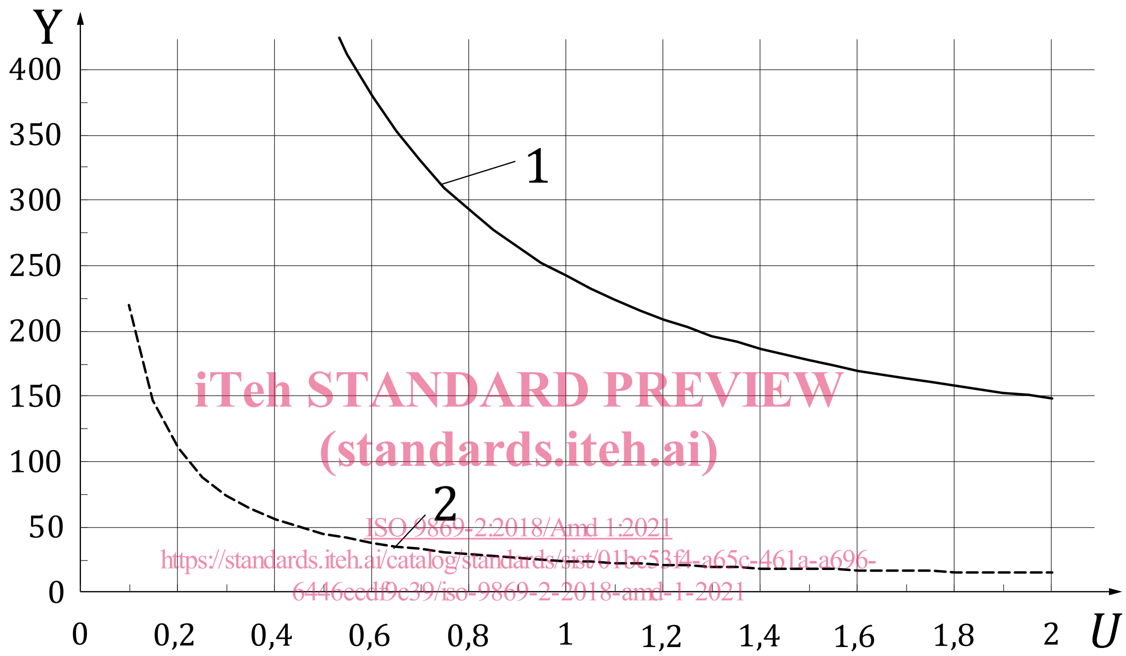
The following conditions are assumed for uncertainty estimation by calculation:

— the surface temperature of the heat transfer coefficient sensor is 4 °C higher than the indoor environmental temperature;

— the heat transfer coefficient has a constant value of 11,0 [W/(m^{2}K)];

— the temperature calculated from the thermal transmittance of the wall, the heat transfer coefficient, and the indoor and outdoor environmental temperatures is used as the surface temperature of the wall to be measured.

Figure E.1 shows the examples of calculation for the environmental temperature differences of 20 K using the thermal transmittance as the parameter.



Key

U thermal transmittance, W/(m^{2}K)

Y expanded uncertainty, %

1 uncertainty calculation mainly based on IR camera

2 uncertainty calculation based on IR camera with calibrated with thermo-couples

NOTE Environmental temperature difference of 20 K: inside environmental temperature is set constant at 20 °C; outside environmental temperature is set constant at 0 °C.

Figure E.1 — Results of uncertainty calculation

E.5 Conclusions and recommendations

The accuracy of the thermal transmittance depends upon the measurement apparatus, measurement conditions, operating procedure and various factors. By conducting an uncertainty analysis of a specific test apparatus, the measurement uncertainty can be estimated. Even though the measurement with only a thermo-viewer produces an error of 40 %, this document can secure accuracy by appropriate calibration using a thermocouple (see 7.5 and 7.6).

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