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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

Isolation thermique — Éléments de construction — Mesurage in situ de la résistance thermique et du coefficient de transmission thermique —

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by ISO/TC 163, *Thermal performance and energy use in the built environment*, SC 1, *Test and measurement methods*.

A list of all parts in the ISO 9869 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 9869 series describes the in-situ measurement of the thermal transmission properties of plane building components, primarily consisting of opaque layers perpendicular to the heat flow and having no significant lateral heat flow. The thermal transmittance of a building element (U-value) is defined in ISO 7345 as the “Heat flow rate in the steady state condition divided by area and by the temperature difference between the surroundings on each side of a system”. Since steady state conditions are never encountered on a site in practice, such a simple measurement is not possible and thereby some statistical methods are introduced. One of the simplest methods is using the mean values over a sufficiently long period of time. The required time for observation for reliable measurements depends on the thermal properties of the building components and the natures of the temperature difference between the surroundings on each side of them.

ISO 9869-1 describes the method which is used to estimate the thermal steady-state properties of a building element from heat flow meter (HFM) measurements through plane building components. Annex B describes the statistical methods of simple mean and the sophisticated method of dynamic analysis method for steady state properties. This document, describes the calculation method for the density of heat flow rate through both the evaluation of the internal surface thermal resistance and the measuring of the temperature difference between the indoor surface temperature of the building element and the indoor environmental temperature using an infrared camera (thermo-viewer). It also describes the statistical methods of simple mean with less observing duration considering night observation and building components with light heat capacity.

This document provides a preliminary and handy measuring method for the in-situ measurement of the thermal transmission properties of plane building components and thereby the further simplifications are applied compared with the method described in ISO 9869-1. The method described in this document is expected as a method of a handy diagnostic method of the thermal transmission properties of plane building components with light heat capacity such as those in frame structure dwelling.

The thermal performance of a part of the building element is evaluated by obtaining the heat absorption (heat penetration) at the part of the indoor surface by multiplying the indoor total heat transfer coefficient of the part surface by the difference between the part indoor surface temperature and the indoor environmental temperature. The thermal transmittance (U-value) of the building components for steady state condition can be obtained with the averages of the observed values over the certain period of time.

The indoor surface temperature distribution of the building component is measured using an IR camera. The indoor environmental temperature is measured by installing the environmental temperature sensor (ET sensor) on the surface of the building component, and the indoor total heat transfer coefficient of the surface of the building component is measured using a heat transfer coefficient sensor. Even the indoor measurement is intended to be carried on with less influence of solar radiation so the standard can be used on building elements on which indoor sides are not exposed to direct sunlight through adjacent windows.

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

Part 2: Infrared method for frame structure dwelling

1 Scope

This document describes the infrared method for measuring the thermal resistance and thermal transmittance of opaque building elements on existing buildings when observing high emissivity diffuse surface using an infrared (IR) camera. This document demonstrates a screening test by quantitative evaluation to identify the thermal performance defect area of building elements.

This document aims to measure the thermal transmittance (U-value) of a frame structure dwelling with light thermal mass, typically with a daily thermal capacity calculated according to ISO 13786 below 30 kJ/(m^{2}K).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7345, *Thermal performance of buildings and building components — Physical quantities and definitions*

ISO 8301, *Thermal insulation — Determination of steady-state thermal resistance and related properties — Heat flow meter apparatus*

ISO 8302, *Thermal insulation — Determination of steady-state thermal resistance and related properties — Guarded hot plate apparatus*

ISO 9869-1, *Thermal insulation — Building elements — In-situ measurement of thermal resistance and thermal transmittance — Part 1: Heat flow meter method*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
thermography
image of a specific band of surface radiance detected with an *infrared camera* (3.2)

Note 1 to entry: On known and uniform high emissivity surfaces, with known and controlled irradiance from the background, and with the proper instrument calibration and operator compensation, the radiance image can be converted to a temperature distribution.

3.2
infrared camera
instrument that collects the infrared radiant energy from a target surface and produces an image in monochrome (black and white) or colour, where the grey shades or colour hues are related to target surface apparent temperature distribution

3.3
total heat transfer coefficient
sum of the convective heat transfer coefficient and the radiative heat transfer coefficient of the surface of a building element

Note 1 to entry: It is assumed to be measurable using the heat transfer coefficient sensor.

3.4
heat transfer coefficient sensor
sensor to approximately measure the *total heat transfer coefficient* (3.3) of the surface of a building element which can measure the total heat transfer coefficient in the neighbourhood of a section of the building element

3.5
environmental temperature
conceptual temperature taking account of the indoor and outdoor air temperatures and radiant heat of a building element used for calculating the thermal transmittance (thermal resistance) of the building element

Note 1 to entry: A temperature measured by an *environmental temperature sensor* (3.6) is treated as the environmental temperature.

3.6
environmental temperature sensor
ET sensor
sensor that takes an approximate measure of the indoor and outdoor environmental temperatures of a building element to be measured

4 Symbols and units

Symbol	Quantity	Units
A	heat transfer area of the region	m^2
A_j	region area of the region with surface temperature θ_{sj}	m^2
h	total heat transfer coefficient	$W/(m^2K)$
θ_n	environmental temperature	°C
θ_s	surface temperature	°C
θ_a	inside air temperature	°C
θ_{ni}	inside environmental temperature of the region to be measured	°C
θ_{ne}	outside environmental temperature of the region to be measured	°C
θ_{sj}	surface temperature of section j	°C
θ_{hs}	surface temperature of heat transfer coefficient sensor	°C
θ_{rj}	plane radiant temperature of section j	°C
Q	heat flow rate	W
q	heat flow of the heat transfer coefficient sensor	W/m^2

Symbol	Quantity	Units
r_j	area ratio of the heat transfer area of section j	—
R_T	total thermal resistance	$(m^2K)/W$
U	thermal transmittance	$W/(m^2K)$

5 Principle

This method (illustrated in Figure 1) measures the amount of irradiance of regions in contact with the outside air from the surface temperature, total heat transfer coefficient and environmental temperature. The difference between the inside and outside temperature is then used to determine thermal transmittance/thermal resistance of the regions that are in a steady-state.

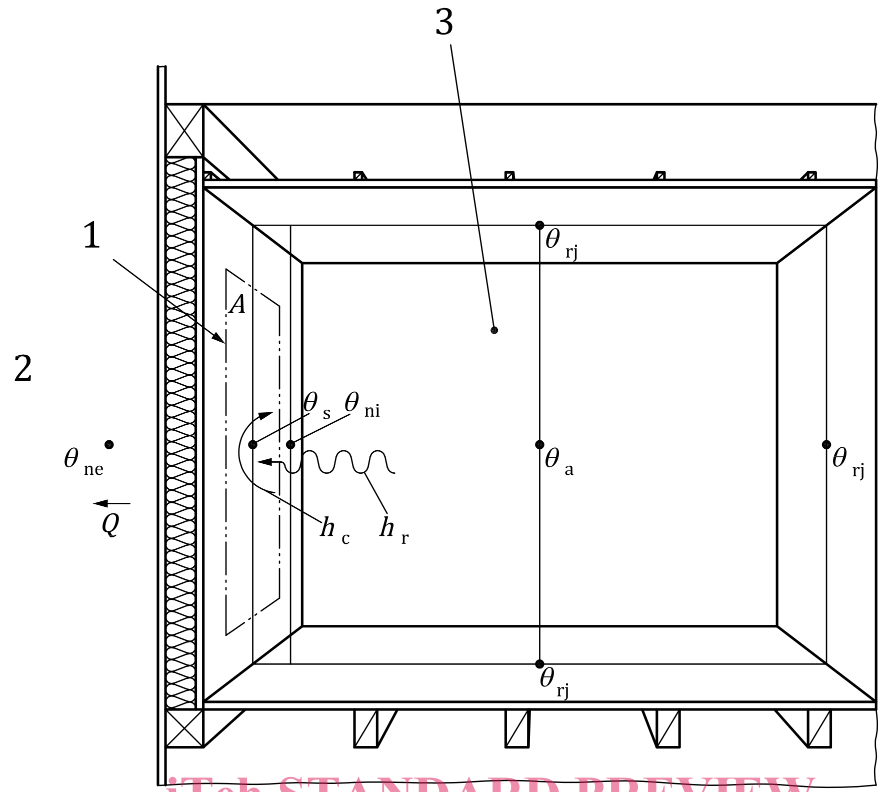
The amount of irradiance of regions in contact with the outside air when being heated is derived from Formula (1) in relation to the inside temperature (Annex A).

$$Q = h\left(\theta_n - \theta_s\right)A \quad (1)$$

The amount of irradiance of the region can be determined using Formula (1) and the measurement of the temperature of the inside surface temperature of the region made with an infrared camera, together with the readings of the total heat transfer coefficient and environmental temperature obtained from the heat transfer coefficient sensor and ET sensor mounted near the region. If the surface temperature of the region being measured varies, the average temperature is used by taking the temperature of each area of the region. This method defines the environmental temperature as a value approximately measured by an ET sensor. The method to obtain the environmental temperature is shown in Annex B.

The amount of irradiance of the region is measured when it is in a constant state away from direct sunlight at night for at least three hours, and calculated using Formula (2) and the difference between the inside and outside environmental temperature.

$$U = \frac{Q}{\left(\theta_{ni} - \theta_{ne}\right) \cdot A} \quad (2)$$



Key

1 measurement area

2 outside

3 inside

Figure 1 — Outline of measurement principle

6 Requirements for apparatus

6.1 General

The necessary apparatus for in-situ measuring thermal resistance and thermal transmittance are as following:

6.1.1 Infrared camera.

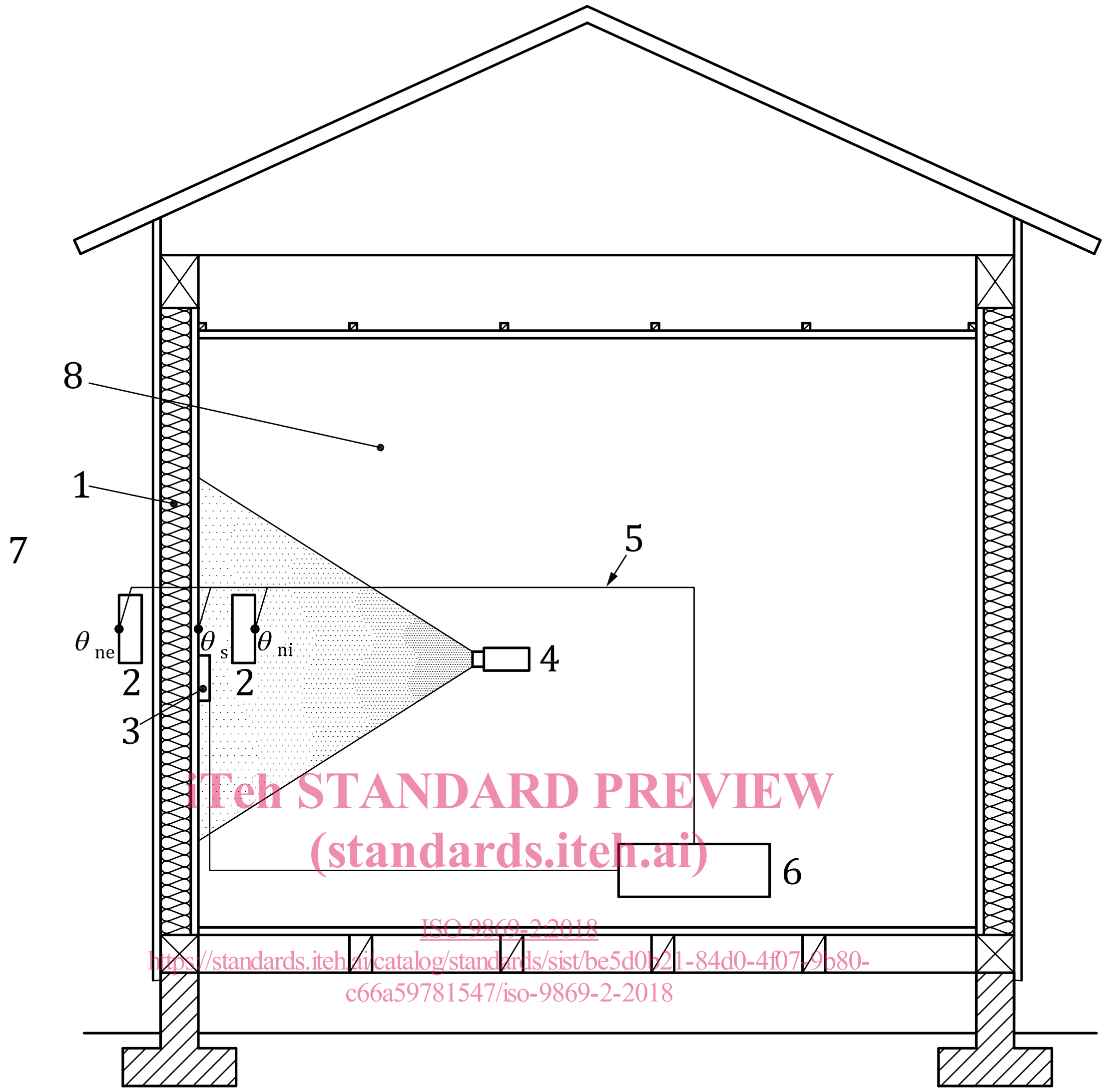
6.1.2 Heat transfer coefficient sensor.

6.1.3 ET sensor.

6.1.4 Thermocouple thermometer.

6.1.5 Data logger.

Configuration of the apparatus is shown in Figure 2.



Key

1 measurement area
2 ET sensor
3 heat transfer coefficient sensor
4 IR camera
5 thermocouple
6 data logger
7 outside
8 inside

Figure 2 — Measurement outline (cross-section)

6.2 Infrared camera

Infrared cameras detect infrared radiation on the surface of the object being measured, with the intensity distribution being displayed as a thermal image. The range of wavelength that can be measured is the same as normal thermal radiation at 8 µm to 13 µm. The camera shall be capable of detecting temperatures between the overall blackbody temperature range of at least −20 °C to 100 °C.

Thermal sensitivity shall not be worse than 80 mK on a 30° blackbody object temperature. Measurements can be made at regular intervals for automatic logging of temperature. Infrared cameras that come with software that processes and displays the measured temperature data as an image are preferable.

6.3 Heat transfer coefficient sensor

The heat transfer coefficient sensor is used to estimate the total heat transfer coefficient of the surface of the region of the object being measured. It has an insulating plastic foam backing and has a heating sheet connected to a heat flow meter. The surface of the heating sheet is copper sheet, with the heat flow meter attached to the front of the copper sheet. A sheet type electrical heater is used to heat the copper sheet in a uniform fashion. The surface of the cooper sheet is finished with a matte black coating (with an emittance greater than 0,9), and a thermocouple (with a diameter of less than 0,2 mm or a thermocouple for surface measurements) is attached to the surface. The sensor shall have a size of 200 × 200 mm with a thickness of 25 mm as a standard.

Using the heat flow meter stretched on the heating sheet before building it into the heat transfer coefficient sensor, calibrate the relation of the heat flow density to the output, following the procedure specified in ISO 8301 or in ISO 8302. The structure and calibration of heat transfer coefficient sensor is shown in Annex C.

6.4 ET sensor

The ET sensor is used to measure the environmental temperature of the regions of the object to be measured. The size of the meter is approximately 200 × 200 mm with a thickness of 50 mm, consisting of an insulating plastic foam and attached on the surface of copper sheet finished with a matte black coating (with an emittance greater than 0,9). A thermocouple (with a diameter of less than 0,2 mm or a thermocouple for surface measurements) is attached to the surface. The construction of the ET sensor is shown in Annex B.

6.5 Thermocouple

The recommended temperature sensor is the type T thermocouple (copper/constantan) according to IEC 60584-1 made from wire with diameter not greater than 0,25 mm. The temperature range available consists of a standard temperature gauge and corrected for use with a data logger. If alternative sensors are used, they should be at least as accurate as the above-mentioned, not subject to drift or hysteresis.

6.6 Data logger

The data logger automatically records the measured data of the temperature and heat flow from this experiment with the required accuracy at regular intervals.

7 Measurement method

7.1 Building

The measurement object shall be a frame structure dwelling with a relatively small heat capacity [a heat capacity per unit area of about 30 kJ/(m^2K) or less]. It is preferable if the details of the buildings are researched thoroughly in advance using floorplans. Visual observations are made in-situ before the measurements are made in order to select the appropriate regions for measurement.

7.2 Location of the measured area

The measurement position shall be selected according to the purpose of the test. The measured area shall not be under the direct influence of either a heating or a cooling device or under the draught of a fan. And the measurement area should be free of all visual interference from curtains, wall hangings, furnishings, plants, light fixtures and anything that impedes the field of view for the IR imager.

