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Thermal insulation of building elements — In-situ measurement of thermal resistance and thermal transmittance — Part 3: Probe insertion method

Part 3: Probe insertion method

FDIS stage

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This document was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee 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~~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 flux per unit area and unit temperature difference in the steady state condition. Since steady state conditions are never encountered on a site in practice, such a simple measurement is not possible. Although various statistical methods have been introduced to address this problem, one of the simplest is the use of 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 nature of the temperature difference between the surroundings on each of the sides thereof.

ISO 9869-1 describes the method used to estimate the thermal steady state properties of a building element from heat flow meter (HFM) measurements through plane building components. ~~Annex B~~Annex B describes the statistical methods of the simple mean and the sophisticated method of dynamic analysis for steady state properties. This document describes a screening test of the insulation condition and thermal resistance of existing building elements by visual observation with a borescope and by measurement of the temperature gradient and heat flow with a temperature sensing rod and HFM. Although the method used in this document is not a non-destructive inspection method, the diameter of the borehole drilled through the building element is approximately less than 2 mm. The method described in this document is intended for use as a practical diagnostic procedure 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 temperature gradient through the building element and the heat flow rate. The thermal transmittance (thermal resistance) of the insulation layer of the building components for the steady state condition can be obtained by using the averages of the observed values over a certain period of time.

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

Part 3: Probe insertion method

1 Scope

This document describes a method for measuring the insulation performance of building elements, e.g. exterior walls, floors, ceilings (hereinafter referred to collectively as "walls~~).~~"). This is done by using the probe insertion method, which gives the temperature distribution in the wall with a temperature sensor in a small diameter borehole in the wall.

The measurement method is divided into a quantitative method, which measures the thermal resistance with a heat flow measurement, and a qualitative method without heat flow measurement.

~~It~~This document describes a screening test that is used for preliminary and practical diagnosis~~ and should not be used for any certification for the performance of thermal insulation of the building components~~.

The method is applicable to plane building components with a light heat capacity, such as those in frame structure dwellings. The measured results give the insulation performance at the local measurement points rather than that of the whole panel including thermal bridges such as studs.

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

IEC 60584~~-~~-1, *Thermocouples–Part 1: EMF specifications and tolerances*

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 terminology databases for use in standardization at the following addresses:

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

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

3.1
borescope
optical device consisting of a rigid or flexible tube with an eyepiece on one end and an objective lens on the other end, linked together by a relay optical system in between, which is ~~is~~ surrounded by optical fibres used for illumination of the remote object

Note 1 to entry: Rigid or flexible borescopes may be fitted with an imaging or video device.

4 Symbols and units

Table 1 — Symbols and units

Symbol	Quantity	Units
k	thermal conductivity	W/(mK)
x	depth from the inner surface of the building element	m
L	thickness of the insulation layer	m
θ	temperature	°C
Q	heat flow rate	W/m^2
R	thermal resistance	(m^{2}K)/W

5 Principle

5.1 General

One of the two following methods shall be applied.

5.2 Method without heat flow measurement

A borehole with an approximately 1 mm diameter is drilled through the interior solid lining material (e.g. Gypsum board). A borescope is inserted and the presence or absence of an insulation layer is confirmed and the type and thickness of the insulation layer can also be observed. After visual inspection, a rod-shaped temperature sensor is inserted, which measures the temperature distribution along the depth of the borehole. The internal and external surface temperatures of the wall are also measured. Based on these measurements, an illustration of the cross-sectional temperature distribution at that location across the wall is made. Although the section temperature distribution obtained in the borehole is not an exact representation of the temperature distribution of the insulation layer, the two-side temperature of the insulation layer can be measured with a certain degree of accuracy. The degree of accuracy depends on the conductance of the rod-shaped temperature sensor, the insulation layer and any other relevant parts. The obtained temperature distribution shall be used as a basis for determining the quality of the insulation layer as follows:

a) ~~a)~~ The thermal performance of the insulation material is evaluated from the ratio of the two-side temperature difference of the insulation layer and that of the internal and external temperatures of the wall (the observed building element).

b) ~~b)~~ The temperature distribution curve prepared based on the measurement results is compared with the expected section temperature distribution assuming that the insulation material is functioning properly. The discrepancy between the two temperature distribution curves provides diagnostic criteria for determining whether, for example, the insulation layer is properly installed or not, or whether the insulation layer has already experienced aging degradation or not.

5.3 Method with heat flow measurement

In addition to the method described ~~in 5.2,~~ in 5.2, the heat flow is measured at the indoor side surface of the wall (building element). The thermal resistance of the insulation layer of the wall or the whole wall is obtained as the quotient of the two-side temperature difference of the measured insulation layer divided by the heat flow rate.

6 Apparatus

6.1 Temperature measuring devices

6.1.1 Type of sensors and accuracy

Thermocouples, resistance thermometers, or thermistors may be used to measure the temperatures inside the wall, on the surface, and in the air. Thermocouples shall be type T and shall satisfy the tolerance of class 1 described in IEC 60584-1. For resistance thermometers or thermistors, the error of temperature measurement converted from the resistance tolerance shall be less than 0,5 °C.

6.1.2 Sensor for measuring temperature distribution in walls

The sensor shall have the following specifications with a rod-like thermometer~~.~~:

a) ~~a)~~ The temperature sensor shall be coated.

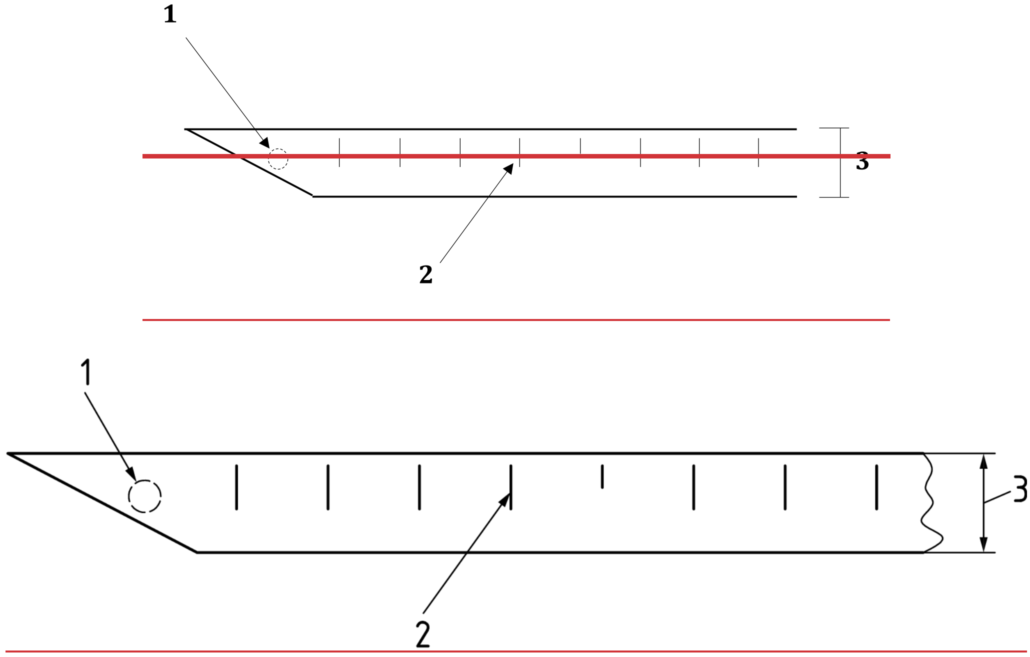
b) ~~b)~~ The tip shall be processed in a needle-like shape, as shown in ~~Figure 1,~~Figure 1, in order to penetrate the insulation material without deforming the installed insulation layer. This type of sensor is already manufactured and is commercially available for food processing applications. A temperature sensor with a hard tube shell, as shown in ~~Figure 2,~~Figure 2, can also be used. The tip of the tube shell shall have a needle shape and the tube shell shall be hard enough to penetrate the insulation layer.

c) ~~c)~~ The diameter of the sensor rod, including the coating, shall be not more than 1,0 mm. The outer diameter of the tube shell, if any, shall not exceed 1,3 mm.

d) ~~d)~~ The sensor rod shall have a scale indicating the insertion depth of the temperature sensing portion.

e) ~~e)~~ The sensor rod may have one or more than one temperature sensing ~~portions~~portion. In sensor rods with multiple sensing portions, the sensing portions shall be arranged at the same interval (not to exceed 15 mm) along the rod, as shown in ~~Figure 3.~~Figure 3. Use of a sensor rod with more than one sensing portion makes it possible to measure the temperature distribution along the borehole without traversing the sensor.

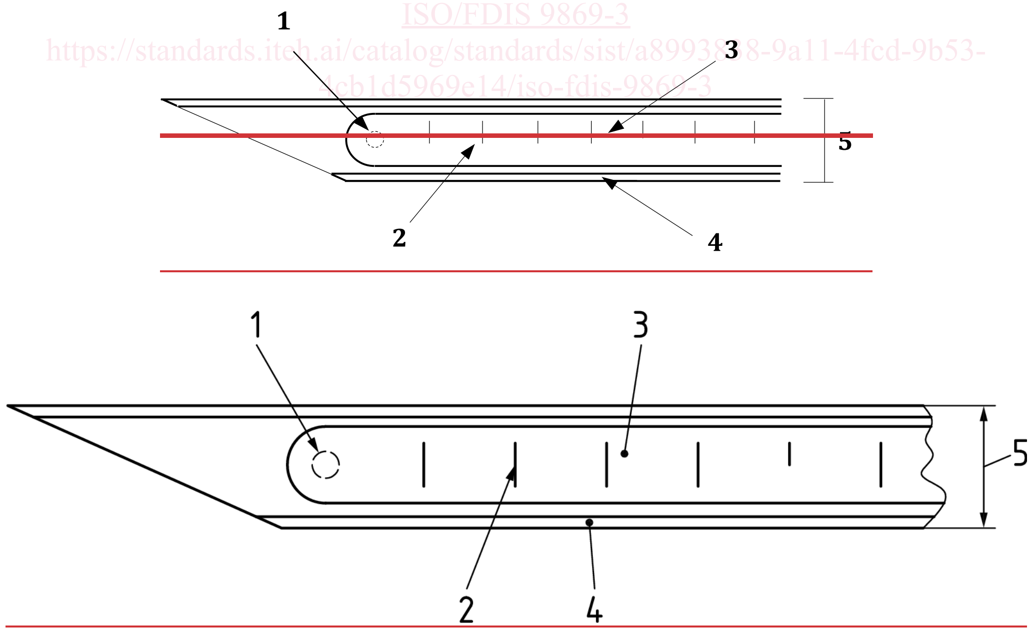
f) ~~f)~~ The thermal bridge effect of the sensor-rod shall be small enough that the value of $N_{c,nom}$ obtained by the calibration method shown in ~~Annex A~~Annex A (normative) is less than 0,5.



Key

1 temperature sensing portion
2 scale
3 diameter of sensor rod

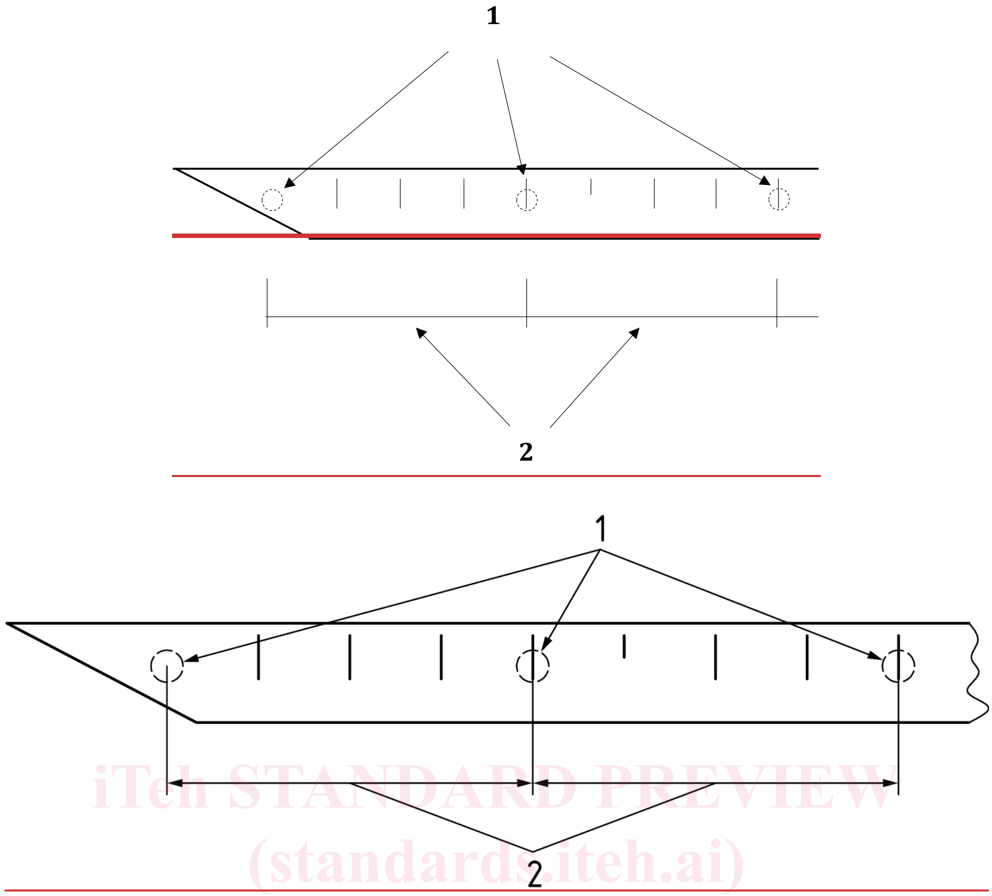
Figure 1 — Temperature sensor with a needle-like shape (tip part)



Key

1 temperature sensing portion
2 scale
3 temperature sensor
4 tube shell
5 outer diameter of tube shell

Figure 2 — Temperature sensor with a hard tube shell (tip part)



Key

1 temperature sensing portions

2 interval of sensing portions

Figure 3 — Temperature sensor having multiple sensing portions (with a needle-like shape, tip part)

6.1.3 Sensors for measuring surface and air temperatures

The sensors for measuring the surface and air temperatures shall be in accordance with ISO 9869-1, except that thermistor sensors can also be used.

6.2 Borescope

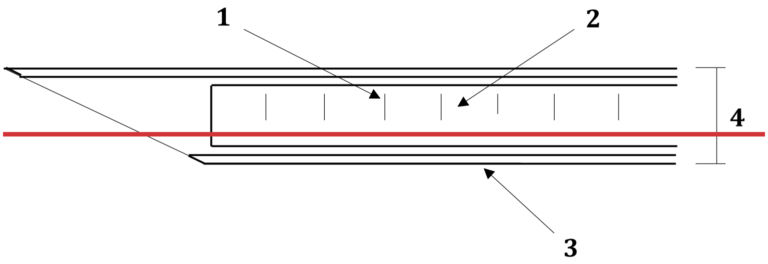
A borescope is used to visually check the condition of insulation installation and the thickness of the insulation layer in the wall (building element).

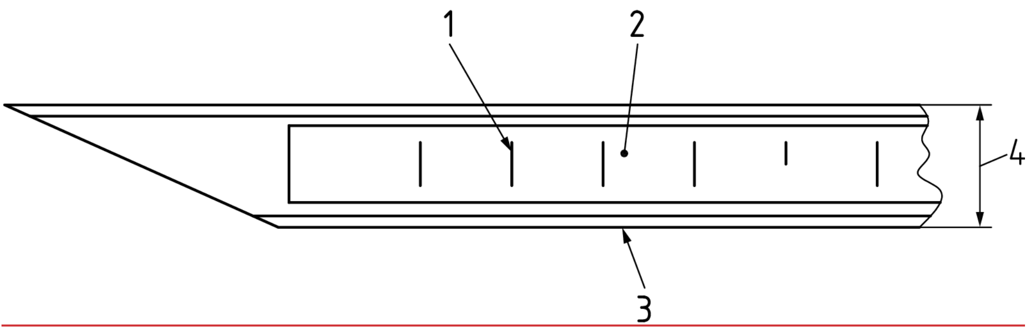
a) ~~a)~~ The borescope shall have an illumination device. The viewing angle shall be sufficiently wide and the visual resolution shall be sufficiently fine to determine reliably whether insulation material is present in the wall (building element) or not;

b) ~~b)~~ The borescope itself shall have a needle tip shape that can penetrate the insulation layer. A borescope with a hard tube shell can be also used, as shown in ~~Figure 4.~~Figure 4. The tip of the tube shell shall have a needle shape and the tube shell shall be hard enough to penetrate the insulation layer;

c) ~~c)~~ The outer periphery of the borescope shall have a scale indicating the insertion depth;

d) ~~d)~~ The borescope shall have a diameter of not more than 1,5 mm, including the tube shell, and a length greater than the thickness of the targeted wall (building element).





Key

1 scale

2 borescope

3 tube shell

4 diameter of borescope including tube shell

~~Figure~~ Figure 4 — Borescope with a hard tube shell (tip part)

6.3 Heat flow meter (HFM)

An HFM is required when measuring the thermal resistance of the insulation layer and shall be the same as that described in ISO 9869-1.

7 Locations of the measured area and sensor installation

~~Figure 5~~Figure 5 shows the schematic of the measured area and the measurement apparatus. The measured area of the targeted wall (building element) shall be sufficiently larger than 400~~×~~ × 400 mm and shall face indoors. The measured area shall not include the frame section or other elements which cause heat bridges. The measured area should be chosen in advance based on the drawings of the building or thermal images acquired with an infrared camera.

The temperature sensor(s) on the internal and, if possible, on the external surface of the wall is (are) installed in the vicinity of the centre of the measured area. When heat flow measurements are made, ~~a~~an HFM shall also be installed in the vicinity of the centre on the interior surface of the wall. In addition to the surface temperature measurement, temperature sensors shall also be installed in the room and on the opposite side of the wall to measure the air temperature. If it is difficult to install a sensor on the opposite side of the wall, for example, when measuring a floor or ceiling, the sensor ~~is to~~shall be installed outside the building in a well-ventilated area that is not affected by solar radiation.

The number of test positions for observing the interior of the wall with a borescope and measuring the temperature distribution inside the wall shall be more than one, and the thermal conditions of all test positions should be assumed to be the same. It is recommended that the test positions be separated as far as possible from each other within the measured area. The distance between the borehole and the

