SLOVENSKI STANDARD
SIST EN 1946-5:2001

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Toplotne značilnosti gradbenih proizvodov in delov stavb - Posebna merila za ocenjevanje laboratorijev, ki merijo lastnosti pri prenosu toplote - 5. del: Merjenje s cevno napravo

Thermal performance of building products and components - Specific criteria for the assessment of laboratories measuring heat transfer properties - Part 5: Measurements by pipe test methods

Wärmetechnisches Verhalten von Bauprodukten und Bauteilen - Technische Kriterien zur Begutachtung von Laboratorien bei der Durchführung der Messungen von Wärmeübertragungseigenschaften - Teil 5: Messungen nach dem Rohrprüfgerät-Verfahren

Performance thermique des produits et composants pour le bâtiment - Criteres particuliers pour l'évaluation des laboratoires mesurant les propriétés de transmission thermique - Partie 5: Mesurage selon les méthodes d'essai des conduites

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ICS:

91.100.60	Materiali za toplotno in zvočno izolacijo	Thermal and sound insulating materials
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Thermal performance of building products and components - Specific criteria for the assessment of laboratories measuring heat transfer properties - Part 5: Measurements by pipe test methods

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This European Standard was approved by CEN on 10 April 2000.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 89, "Thermal performance of buildings and building components, the secretariat of which is held by SIS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2000, and conflicting national standards shall be withdrawn at the latest by November 2000.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

This European Standard is divided into parts. The first part covers common criteria applicable to all heat transfer property measurements; each subsequent part covers the specific technical criteria applicable to each heat transfer property measurement method described in appropriate standards.

The following parts have been developed:

- Part 1: Common criteria
- Part 2: Measurements by the guarded hot plate method
- Part 3: Measurements by the heat flow meter method
- Part 4: Measurements by hot box methods
- Part 5: Measurements by pipe test methods

Annex A of this European Standard is normative, the annexes B and C are informative.

1 Scope

This part 5 of this standard provides specific technical criteria for the assessment of laboratories to undertake steady-state heat transfer property measurements on circular pipe insulation according to EN ISO 8497:1994.

It complements the common criteria in part 1. Guidance is given on the organization and contents of the equipment manual, the calibration and maintenance files and the measurement procedure document.

It provides information on mandatory equipment performance specifications, on equipment description and on calculations for the equipment design and error analysis based on both EN ISO 8497:1994 on circular pipe apparatus and on part 2 of this standard on the assessment of guarded hot plate apparatus.

It gives information on experimental procedures suitable for the assessment of equipment accuracy, based on both EN ISO 8497:1994 on circular pipe apparatus and on part 2 of this standard on the assessment of guarded hot plate apparatus.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 1946-1:1999	Thermal performance of building products and components - Specific criteria for the assessment of laboratories measuring heat transfer properties - Part 1: Common criteria
EN 1946-2:1999	Thermal performance of building products and components - Specific criteria for the assessment of laboratories measuring heat transfer properties - Part 2: Measurements by guarded hot plate method
EN 12667[1)]	Thermal performance of building materials and products - Determination of thermal resistance by means of guarded hot plate and heat flow meter methods - Products of high and medium thermal resistance
EN ISO 7345	Thermal insulation - Physical quantities and definitions (ISO 7345:1987)
EN ISO 8497:1994	Thermal insulation - Determination of steady-state thermal transmission properties of thermal insulation for circular pipes (ISO 8497:1994)
prEN 13467:1999	Thermal insulating products for building equipment and industrial installations - Determination of dimensions, squareness and linearity of preformed pipe insulation

3 Definitions

For the purposes of this part of the standard, the terms and definitions given in part 1 of this standard, EN ISO 7345 and EN ISO 8497:1994 apply.

1) To be published

4 Equipment manual

4.1 General

The equipment manual shall provide the information specified in 5.2.2 to 5.2.5 of part 1 of this standard and the information specified in this clause.

NOTE Information common to more than one piece of equipment need not be duplicated, e.g. the principle, details of the design and operation of two pieces of equipment built to a common design.

Annex A gives all limiting values indicated in EN ISO 8497:1994 for equipment performance and testing conditions. This annex shall be used as a check list during the assessment process by the parties concerned to ensure compliance with all EN ISO 8497:1994 requirements.

4.2 Equipment performance specifications

The upper and lower limits of the relevant tested properties and testing conditions, including possible interactions between them, shall be specified:

- minimum and maximum external diameter of the specimen;
- minimum and maximum specimen thermal resistance;
- minimum and maximum temperature difference across the specimen;
- minimum cold side temperature;
- maximum hot side temperature;
- surrounding environment (temperature, relative humidity) at the ends of the specimen during the test, if required.

4.3 Equipment description

The following information shall be documented and shall be available for examination during the assessment:

- principle of operation (see clause 1 of EN ISO 8497:1994);
- type of apparatus: guarded-end apparatus, see 7.3 of EN ISO 8497:1994, or calibrated/calculated-end apparatus, see 7.4 of EN ISO 8497:1994;
- principal dimensions of apparatus, in particular length of test pipe centre, test pipe guard, test pipe diameter and gap width;
- simple diagrams illustrating the design of the equipment with special attention to the gap design (see clause 7.3 of EN ISO 8497:1994), cap design (if applicable, see 7.4 of EN ISO 8497:1994), jacket or added insulation (if applicable see 7.11 of EN ISO 8497:1994);
- position, connections and numbering of temperature sensors (see 7.6 of EN ISO 8497:1994);
- ambient control and main ancillary equipment (see 7.8 to 7.10 of EN ISO 8497:1994);
- details of data acquisition system and related computer programs for data analysis.

To avoid duplication, reference may be made to manuals supplied by the instrument manufacturers or to relevant clauses of EN ISO 8497:1994.

4.4 Equipment design and error analysis

4.4.1 General

With reference to the performance specification given in 4.2, details shall be given in the equipment manual on the design guidelines followed, and the error analysis.

Some guidelines on error analysis are given in this subclause; more specific information on some errors is supplied in annex B, while error calculations are supplied in annex C for some typical cases. For equipment having characteristics exactly as indicated in this subclause, or design details as indicated in annex C, no further calculations are needed. In other circumstances similar calculations can be performed by analogy.

4.4.2 Axial heat flow rate and maximum specimen thickness

4.4.2.1 General

The axial heat flow rate from the test section to the guard sections of the specimen affects the maximum specimen thickness. The axial heat flow rate shall not exceed that permitted by 9.5.2.2 of EN ISO 8497:1994 (1 % of heat flow rate of the test section, i.e. the end heat loss error shall be less than 1 %).

4.4.2.2 Guarded-end apparatus

Table 1 shows for some apparatus having an overall pipe length of 1000 mm and other dimensions as given in the table, the maximum allowed specimen thickness according to the equations proposed in annex B. Those expressions are based on 2.2.1 of ISO 8302:1991, see [1] in the Bibliography, when there is no end insulation and when the end temperature ratio, e, is 0; e is defined as $(T_e - T_2)/(T_1 - T_2)$, where T_1 and T_2 are respectively the temperatures of the hot and cold surfaces of the specimen, and T_e is the temperature at the ends of the specimen, assumed to be uniform.

NOTE The end heat loss error is zero for homogeneous isotropic specimens when e is close to 0,5; the absolute value of the edge heat loss error increases almost symmetrically when e deviates on either side from 0,5. In the range $0 \leq e \leq 1$, this error is maximum for for $e = 0$.

EXAMPLE A temperature of the specimen ends of 50 °C, a temperature of the specimen cold side of 50 °C (so that the temperature difference between the ends and the cold side of the specimen is 0 °C) and a temperature of the specimen hot side of 150 °C (so that the temperature difference between the hot and cold side of the specimen is 100 °C) corresponds to $e = 0$. If the temperature of the specimen ends were of 60 °C, then it would be $e = 0,1$.

The data of the table can be applied to apparatus and specimens having all the dimensions multiplied by the same factor. Interpolation is allowed.

EXAMPLE By considering a multiplying factor of 2,4, an apparatus has an overall pipe length of 1 000 × 2,4 = 2 400 mm, the pipe centre length of 800 × 2,4 = 1 920 mm and a pipe diameter of 100 × 2,4 = 240 mm. The resulting maximum specimen thickness, see the third line of table 1, is 70 × 2,4 = 170 mm (rounded to two significant figures).

Table 1 - Maximum allowed specimen thickness for guarded end apparatus

Dimensions in millimetres

Overall pipe length	Pipe centre length	Pipe guard width	Pipe diameter	Maximum specimen thickness
1 000 1 000 1 000	400 700 800	300 150 100	100 100 100	125 90 70
1 000 1 000 1 000	400 700 800	300 150 100	50 50 50	110 75 60
1 000 1 000 1 000	400 700 800	300 150 100	25 25 25	90 65 50
1 000 1 000 1 000	400 700 800	300 150 100	12,5 12,5 12,5	80 55 45
1 000 1 000 1 000	400 700 800	300 150 100	6 6 6	65 45 35

Larger specimen thicknesses can be used for some specimens if insulation or temperature control is used at the ends of the specimen, or if auxiliary guards are installed.

When the maximum specimen thickness to be specified according to 4.2 exceeds the appropriate value given in table 1, the axial heat flow rate shall be calculated. If, according to these calculations, the axial heat flow rate exceeds the values permitted by EN ISO 8497:1994, the performance check data shall be examined and, if no experimental evidence exists to substantiate the claimed maximum specimen thickness, the maximum specimen thickness to be specified according to 4.2 shall be reduced.

4.4.2.3 Calibrated or calculated-end type apparatus

When corrections are applied for axial heat flow rate either through the calibration procedure indicated in 10.1 of EN ISO 8497:1994 or through the calculations indicated in 10.2 of EN ISO 8497:1994, the correction should not be larger than 3 % of the heat flow rate supplied to the specimen by the test pipe centre.

NOTE This limit implies that the accuracy of the correction is 33 % or better. This figure is intended to make allowance for a similar difference between the thermal conductivity of the end cap and that of the specimen. Larger corrections are acceptable, provided that the uncertainty in the corrected heat flow rate supplied to the specimen by the test pipe centre is within the 1 % required by 9.5.2.2 of EN ISO 8497:1994.

4.4.3 Maximum gap width and minimum specimen thickness

The gap width, g, in guarded-end apparatus should be less than 1 % of the length of the test pipe centre.

NOTE Considering that the test section length, L, is defined (in 9.1.1 of EN ISO 8497:1994) as the distance from gap centre to gap centre, the above requirement keeps within 1 % the uncertainty in the definition of the area through which the heat flow at the rate Φ passes, supplied to the specimen by the test pipe centre, even when the specimen thickness is comparable or less than the gap width. In this situation the area through which the heat flow rate supplied by the test pipe centre passes approaches that of the test pipe centre itself from gap edge to gap edge. When, on the other hand, the specimen thickness is far larger than the gap width (e.g. 10 times) the border of this area is defined by the lines passing through the centre of the gaps, i.e. the uncertainty on the test section, L, is in any case less than the gap width, g.

The minimum specimen thickness shall also be checked against the expected air gap between the specimen and the apparatus, see 4.4.9.

4.4.4 Imbalance error

The imbalance heat flow rate, Φ_g, through both the specimen and the apparatus (both gaps) shall be less than 1 % of the heat flow rate, Φ, supplied to the specimen by the test pipe centre (according to 9.4 of EN ISO 8497:1994).

The imbalance heat flow rate Φ_g can be expressed as follows (according to 4.4.4 of part 2 of this standard):

$$\Phi_g = (\Phi_o + \lambda c) \Delta T_g \qquad (1)$$

where Φ_o, representing the heat flow rate for a 1 K gap imbalance through the apparatus itself, is the sum of:

- Φ_a through the air in the gap;
- Φ_r by radiation through the gap;
- Φ_m through the mechanical connections through the gap;
- Φ_c through copper wires;
- Φ_w through metal wires (excluding copper)

and λc is the heat flow rate through the specimen (both gaps) due to a 1 K gap imbalance with c expressed by the following equation:

$$c = (2 d_o) \ln (4/(1 - \exp(- \pi g/d)) \qquad (2)$$

In equation (2) d_o is the outer diameter of the test pipe, g is the gap width and d is the maximum expected specimen thickness.

ΔT_g shall be such that Φ_g in equation (1) is less than 1 % of the heat flow rate Φ.

NOTE To calculate the components of Φ_o, the elementary equations of heat transfer through a plane layer can be used.

The calculation of Φ_g changes according to the gap design and is the most critical part of the evaluation of pipe test apparatus accuracy. Some example calculations are given in annex C.

Because the balancing thermopile detects a temperature difference that does not correspond exactly with the actual temperature imbalance through the pipe surfaces facing the gaps and in contact with the specimen, the maximum acceptable value for ΔT_g shall be larger than the uncertainty in the imbalance detection. Detailed information on the imbalance detection through the gap is given in 2.1.1.5 of ISO 8302:1991 on the guarded hot plate apparatus, see [1] in the Bibliography. Those considerations are equally applicable to the pipe test apparatus.

When the balancing thermopile is placed directly within the metal pipe, see the equivalent situation described by figure D.3 a) of EN 12667 on the guarded hot plate apparatus, the density of heat flow rate crossing the gaps during the tests shall be evaluated and the corresponding temperature drop through the metal pipe computed. If this temperature difference is less than ΔT_g, the gap design is acceptable without further checks, otherwise the tolerances for the positions of thermopile junctions within the metal plates shall be checked to ensure that the uncertainty in the temperature imbalance detection is less than ΔT_g.

When the balancing thermopile is embedded in plastic sheets, either placed between the metal pipe and the heaters, or between the metal pipe and the specimen, the effect of the resistances between the metal pipe and the thermopile junctions due to the plastic sheets, and possible air pockets, shall be evaluated as a temperature difference resulting from the product of the relevant thermal resistance and the density of heat flow rate passing through it.

The electrical instrumentation used for the imbalance detection shall be capable of detecting voltages less than ΔT_g multiplied by the number of elements of the balancing thermopile and by the thermoelectric power of each element. The electrical balance maintained during the tests shall therefore be better than the voltage computed in this way. If this requirement is not met, the measured data of the performance check, see the fourth dash of 4.5, shall be verified and if the sensitivity of the instrumentation for the imbalance detection is still not satisfactory, better instrumentation shall be chosen or the balancing thermopile design shall be reviewed. Particular care shall also be taken to ascertain that the quality of the electrical connections and the switches (with reference, in particular, to thermal electromotive forces) is compatible with the level of imbalance to be detected.

4.4.5 Error in measured electrical power

The uncertainty in the measurement of electrical power shall be within 0,5 %, to comply with clause 7.9 of EN ISO 8497:1994.

4.4.6 Error in the definition of the area of the test section

The area of the test section is defined as the area enclosed by the line defining the centre of the gaps (see 9.1.1 of EN ISO 8497:1994). This area is not equal in all testing conditions to the actual area of the specimen crossed by the heat flow rate supplied by the test pipe centre, see 4.4.3; to this uncertainty shall be added the uncertainty in the measurement of the dimensions of the apparatus. An uncertainty due to mechanical tolerances in the measurement of the centre-gap to centre-gap distance up to 0,1 % can be accepted.

4.4.7 Error in the temperature difference

Whatever heat transfer property is measured with the pipe apparatus, the difference between the pipe surface temperature T_0 (see 7.5 of EN ISO 8497:1994) and the temperature T_2 of the outside surface of the specimen (see 8.6 of EN ISO 8497:1994) shall be measured. The total error in the temperature difference (T_0 - T_2) is made up as follows:

- calibration of thermocouples (or other temperature sensors): typically less than 0,4 %, see NOTE 1;
- accuracy of measuring instruments: typically less than 0,2 %;
- temperature uniformity of the test pipe centre: typically better than 0,5 K;
- temperature uniformity of the external surface of the specimen: typically 0,7 K, see NOTE 4; for this temperature uniformity see also 7.11 of EN ISO 8497:1994;
- temperature fluctuations of the ambient air: ± 1 K or ± 1 % of the temperature difference between the test pipe and the ambient, according to 9.2 of EN ISO 8497:1994.

NOTE 1 When special grade thermocouples (see 4.4.7 of part 2 of this standard) mounted differentially are used, as in figure D.5 of EN 12667, and no additional wire connections between the junctions are made, no calibration is required. For example an uncertainty of 0,4 % at room temperature can be achieved using type T thermocouples.

NOTE 2 The absence of additional wire connections between two thermocouple junctions (or an extremely high quality of the fabrication of these junctions) and keeping them as isothermal as possible during the tests, are more important than the thermocouple calibration itself. Bad thermocouple connections can induce errors that will change for different testing conditions, so reducing the accuracy of the calibrations.

NOTE 3 The uncertainty in the definition of the point where the surface temperature of the pipe is measured can be assumed to cause an error in the temperature reading not greater than the temperature drop through the thickness of the metal part of the pipe apparatus when thermocouples are mounted in grooves in this part. When thermocouples are mounted in thin sheets, the uncertainty for the surface temperature of the pipe becomes critical and can be assumed to be equal to the temperature drop through a layer of sheet of thickness equal to the diameter of the thermocouple junction. According to 7.6 of EN ISO 8497:1994, the maximum allowed thermocouple diameters when measuring metallic or non-metallic surface temperatures are 0,63 mm and 0,4 mm, respectively.

NOTE 4 The temperature non-uniformity on the external surface of the specimen is partly due to the temperature non-uniformity of the air surrounding it and to the local non-uniformities of the surface coefficient of heat transfer. This coefficient is the result of heat transfer by combined natural convection and radiation, whenever a liquid-cooled jacket is not mounted on the external surface of the specimen, see B.2. The temperature non-uniformity on the external surface of the specimen is also due to the uneven thickness and/or air gaps, see also 4.4.9, between the specimen and the apparatus.

NOTE 5 The difference between the pipe surface temperature T_0 and the temperature T_2 of the outside surface of the specimen is the appropriate temperature difference when the thermal resistance of a product is being measured. When the thermal conductivity of the material is to be measured, the appropriate temperature difference should be the one between the inside and outside surface of the specimen. If the temperature difference (T_0 - T_2) is used instead, additional errors occur due to contact thermal resistances or through mounting techniques of the specimen on the apparatus, see NOTE 1 of 4.4.9.