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Thermal insulation products for building equipment and industrial installations — Determination of declared thermal conductivity

Produits isolants thermiques pour l'équipement du bâtiment et les installations industrielles — Détermination de la conductivité thermique déclarée

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Foreword

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ISO 13787 was prepared by the European Committee for Standardization (CEN) in collaboration with Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this document, read “...this European Standard...” to mean “...this International Standard...”.

Contents

Foreword

This document (EN ISO 13787:2003) has been prepared by Technical Committee CEN/TC 89 "Thermal performance of buildings and building components", the secretariat of which is held by SIS, in collaboration with Technical Committee ISO/TC 163 "Thermal performance and energy use in the built environment".

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of an identical text or by endorsement, at the latest by September 2003, and conflicting national standards shall be withdrawn at the latest by September 2003.

Annexes A, B and C are informative.

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, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

This standard gives the procedure for the determination of the declared thermal conductivity of thermal insulation materials and products, which are used for the insulation of building equipment and industrial installations.

For this area of application the thermal conductivity values are usually expressed over a wide range of temperatures.

This standard describes the procedure necessary for the determination of the thermal conductivity values, which the manufacturer shall declare.

The values are expressed in the form of a curve or in tabular form which shows thermal conductivity as a function of temperature.

1 Scope

This standard establishes the procedure for the determination and verification of the declared thermal conductivity as a function of temperature of thermal insulating materials and products used for the insulation of building equipment and industrial installations.

The informative annex B also gives an optional method for establishing the thermal conductivity curve or table from measured values.

The standard is not applicable to thermal insulating products used in building envelopes. For the procedures which are used for these products, see ISO 10456, "*Building materials and products – Procedures for determining declared and design thermal values*".

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 (including amendments).

EN 12667	*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 7345:1995	*Thermal insulation - Physical quantities and definitions (ISO 7345:1987).*
EN ISO 8497	*Thermal insulation - Determination of steady-state thermal transmission properties of thermal insulation for circular pipes (ISO 8497:1994).*
prEN ISO 9229:1997	*Thermal insulation - Definitions of terms (ISO/DIS 9229:1997).*
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.*

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN ISO 7345:1995, prEN ISO 9229:1997 and the following apply.

3.1
reference mean temperature
mean temperature selected for use as the basis for physical property measurement and expression of data for those materials where physical properties change with temperature

3.2
declared value
value declared by a manufacturer which is derived from measured values under specified conditions and rules

3.3
declared thermal value
expected value of a thermal property of a building material or product

— assessed from measured data at reference conditions of temperature and humidity;

— given for a stated fraction and confidence level according to the determination method in this standard;

— corresponding to a reasonable expected service lifetime under normal conditions.

NOTE The declared thermal value includes the effects of ageing and dispersion in the measured values.

3.4
declared thermal conductivity curve
curve giving the thermal conductivity at different temperatures for a material or product conditioned in equilibrium with a standard atmosphere (23 °C, 50 % relative humidity) based on the declared thermal values

4 Principles for the determination of declared thermal conductivity

The manufacturer shall present his proposed declared thermal conductivity of the material or product in the form of a curve as a function of the mean temperature or a table with a number of values in accordance with 5.1.

The product shall then be subjected to a test according to clause 5, with test specimens representative of the product.

If the test is passed, the proposed declared thermal conductivity curve or table becomes the declared thermal conductivity curve or table.

NOTE 1 An alternative procedure to the one given in the standard is given in annex A.

NOTE 2 An optional statistical method to establish the declared thermal conductivity curve is given in annex B.

5 Determination and verification of declared thermal conductivity

5.1 Measurement of thermal conductivity

The test specimens shall be aged, if necessary, before measurements are made. As an alternative, a correction factor for ageing shall be applied.

NOTE Ageing procedures are found in product specifications, where relevant.

Measurements shall be carried out in accordance with ISO 8301, ISO 8302 or EN 12667 for flat test specimens and EN ISO 8497 for cylindrical test specimens.

The temperature difference between the hot and cold faces shall range from 10 K to 40 K for flat test specimens. The temperature difference shall be chosen to maximize the accuracy of the measurement. For cylindrical specimens, tested in accordance with EN ISO 8497, these requirements on temperature difference do not apply, but the temperature difference shall not be smaller than 10 K.

Measurements shall be made at three different mean temperatures at least.

For mean temperatures up to 500 °C, the curve determined in the test shall be based upon measurements at intervals of a maximum of 100 K, over the whole service temperature range stated by the manufacturer.

Thermal conductivity shall also be measured at temperatures close to inflexion points or other irregularities of the curve.

For mean temperatures greater than 500 °C, the curve determined in the test shall be based upon measurements at intervals of a maximum of 200 K.

No extrapolation of test results beyond the measured temperature range is permitted. The measured thermal conductivities shall be rounded up to the nearest 0,001 W/(m·K).

The results shall be expressed either by a temperature/thermal conductivity curve or by a table. The comparison with the proposed curve or table is only made at the temperatures of measurement.

5.2 Procedure for verification

Select three different samples. Take the test specimens from these samples at random, as required.

Measure the thermal conductivity of the test specimen from the first sample in accordance with the method described in 5.1.

Compare the results of the measurements with the values obtained from the proposed curve or table.

— If the measured values are all less than or equal to the thermal conductivities derived from the proposed curve or table, the test is passed and the proposed curve or table becomes the declared curve or table.

— If one or more of the measured values exceeds the corresponding thermal conductivity of the proposed curve or table by 10 % or more, the test has failed.

— If there are measured values above the values on the proposed curve or in the table but none of them exceeds the corresponding thermal conductivity by 10 %, then two new test specimens shall be measured in accordance with the method described in 5.1, one specimen being taken from each of the two remaining samples.

For temperatures ≤ below 100 °C, measure the thermal conductivities of the second and third specimen at temperatures within ± 5 K of the values measured for the first specimen. Increase this to ± 10 K for temperatures above 100 °C.

If none of the new measurements exceeds the proposed curve or table by 10 % or more, the measured thermal conductivities shall be converted to the temperatures at which the measurements for the first curve were made, using the slope of the first curve to make the conversion.

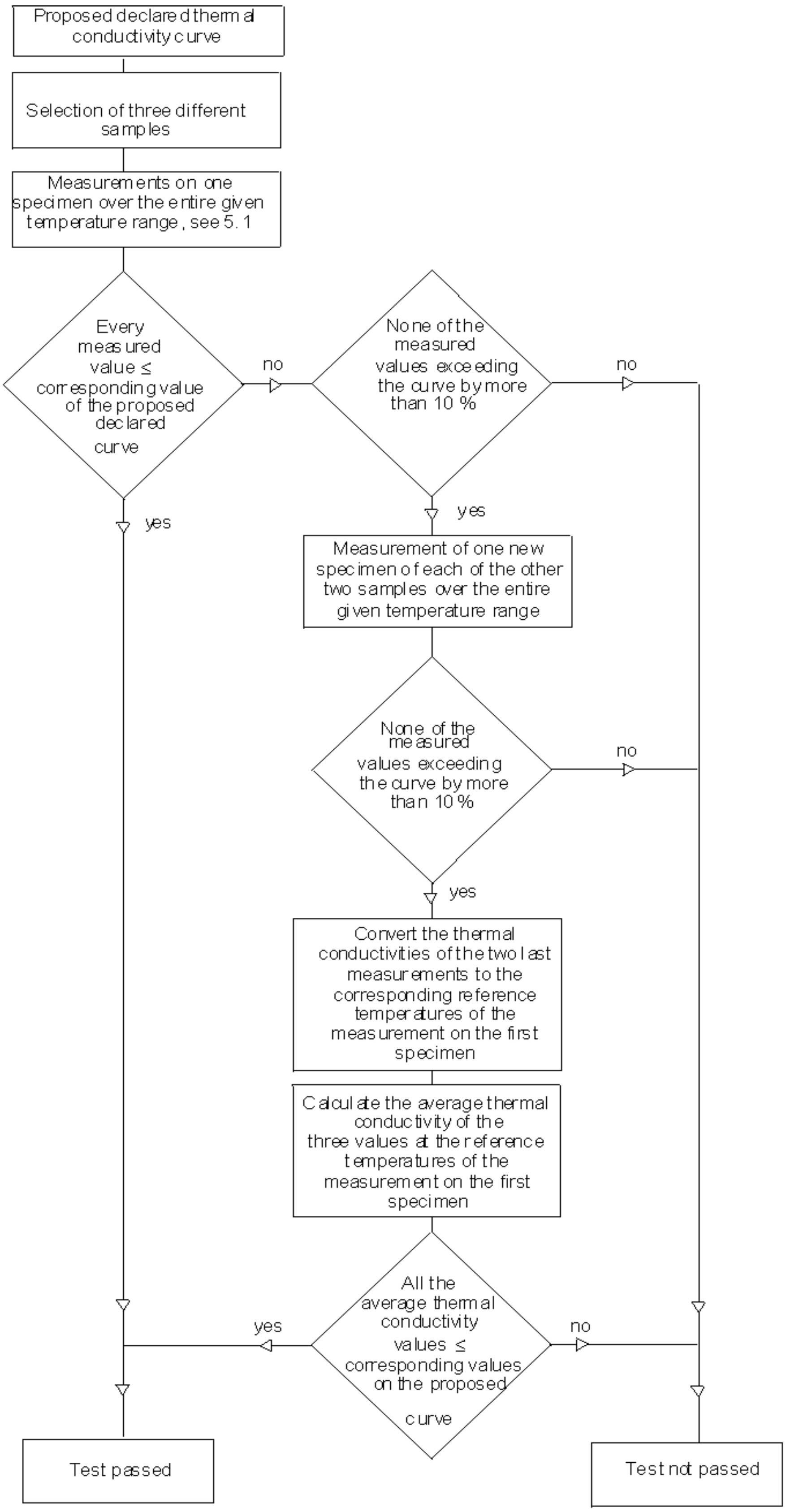
Results of the measurements above the proposed curve or the value in the table by 10% or more shall constitute a failure of the test.

Calculate the values of thermal conductivity at the corresponding temperatures by calculating the mean of the three values measured or converted at each temperature.

— If all these new mean values are lower than or equal to the corresponding thermal conductivities of the proposed declared curve, the test has passed, in which event the proposed declared curve or table becomes the declared curve or table.

— If one or more of the new mean values is higher than the corresponding thermal conductivity of the proposed declared curve or table, the test has failed.

The verification procedure is described in the flow chart in Figure 1 and illustrated in annex C.



NOTE For detailed procedure, see clause 5

Figure 1 - Flow chart for verifying the thermal conductivity

Annex A
(informative)

Verification based on curve comparison

A.1 General

The procedure given in the main body of the standard, to verify by a test that a proposed declared thermal conductivity curve may be used as the declared thermal conductivity curve, is based on a comparison made for a limited number of values. This annex shows how to compare the curves to exclude the possibility that a curve based on the measured values could locally exceed the proposed declared curve and can be used to compare the proposed curve with the curve obtained on the basis of the measured values.

A.2 Principle

The manufacturer proposes the declared thermal conductivity in the form of a curve as a function of the mean temperature.

A test is carried out based on the following principles:

— the thermal conductivity is measured at various temperatures;

— a “best fitting” curve is developed;

— this curve is compared with the proposed declared curve.

A.3 Test

A.3.1 Measurement of thermal conductivity

The thermal conductivity is measured in accordance with 5.1.

A.3.2 Procedure for comparison and decision

Three different samples are selected.

A first test specimen is measured in accordance with the method described in 5.1.

After making the measurements, the results are mathematically described by a formula which is the lowest degree polynomial leading to a coefficient of correlation at least equal to $r = 0{,}95$. For the purpose of this annex, this curve is also the measured curve.

— If the measured curve is always less than or equal to the proposed declared curve, the proposed declared curve becomes the declared curve.

— If at least one point of the measured curve exceeds the proposed declared curve by 10 % or more, the test has failed.

— If the measured curve locally exceeds the proposed declared curve by less than 10 %, two new test specimens are measured in accordance with the method described in 5.1, one specimen being taken from each of the two remaining selected samples.

The results of all the measurements carried out on the three test specimens are mathematically described by a formula which is the lowest degree polynomial leading to a coefficient of correlation at least equal to $r = 0{,}95$. For the purpose of this annex, this curve is also the best fitted curve.

— If the best fitted curve is always lower than or equal to the proposed declared curve, the proposed declared curve is the declared curve.

— If at least one point of the best fitted curve exceeds the proposed declared curve, the test has failed.

Annex B
(informative)

Statistical method to establish the declared thermal conductivity curve

B.1 General

This annex describes a statistical method which may be used to establish the declared thermal conductivity curve for a product and a procedure for its verification. Moreover, it should be noted that it is aimed at establishing the proposed declared curve (named here the declared curve) and then at verifying it.

The aim of this approach is to establish a declared curve with a probability of 90 % and a confidence level of 90 % that the measured values will be below or equal to this declared curve.

Two basic cases for the establishment of the declared values or curve are possible.

1) A large number of thermal conductivity results ($n \geq 50$) are available, so that the mean value, Λ, and standard deviation, σ, of the basic distribution are known;

2) A small number of thermal conductivity results ($n < 50$) are available, so that the mean value of the thermal conductivity, λ, and the standard deviations, s, are used to estimate Λ and σ.

B.2 Symbols and units

Symbol	Definition	Unit
k_{2n}	statistical coefficient	-
$n_{1 \ldots n}$	number of measurements carried out on the randomly chosen samples	-
$s_{1 \ldots n}$	estimators of the standard deviation of the randomly chosen samples	-
σ	standard deviation of the basic distribution	W/(m·K)
$\bar{\lambda}_1$	mean thermal conductivity of the randomly chosen sample taken from the basic distribution (estimation of Λ)	W/(m·K)
$\bar{\lambda}_2$	mean thermal conductivity of the randomly chosen sample used in examining the basic distribution	W/(m·K)
Λ_n	mean thermal conductivity out of the basic distribution n	W/(m·K)
k_{1n}	statistical coefficient (listed in Table B.1)	-
θ_{mn}	mean temperature	°C

B.3 Establishment of declared values

B.3.1 A large number of thermal conductivity results are available (*n* > 50 at each temperature)

The mean value, Λ_n, and the standard deviation, σ_n, at the mean temperature, θ_{mn}, are available.

1st point: temperature θ_{m1}: $\lambda_{\theta_{m1}} = \Lambda_1 + \sigma_1 k_{11}$

2nd point: temperature θ_{m2}: $\lambda_{\theta_{m2}} = \Lambda_2 + \sigma_2 k_{12}$

3rd point: temperature θ_{m3}: $\lambda_{\theta_{m3}} = \Lambda_3 + \sigma_3 k_{13}$

If a linear relationship is confirmed between thermal conductivity and mean temperature, the standard deviation and *k* coefficient of the basic distribution at one temperature may be assumed for all temperatures. The *k* coefficient depends on the number of tests at the various temperatures. For k_{1n}, see Table B.1.

B.3.2 A small number of data are available ($n \leq 50$)

The mean values, $\lambda_{1..n}$, and the standard deviations, $s_{1..n}$, of these data for the mean temperatures, $\theta_{m1..n}$, are used for estimating the mean values, $\Lambda_{1..n}$, and standard deviations, $\sigma_{1..n}$, of the basic distributions for the relevant mean temperatures.

1st point: temperature θ_{m1}: $\lambda_{\theta_{m1}} = \lambda_1 + k_{21} s_1$

2nd point: temperature θ_{m2}: $\lambda_{\theta_{m2}} = \lambda_2 + k_{22} s_2$

3rd point: temperature θ_{m3}: $\lambda_{\theta_{m3}} = \lambda_3 + k_{23} s_3$

$\lambda_{1..n}$ and $s_{1..n}$ are established by at least three measurements at the mean temperatures $\theta_{m1..n}$.

The declared curve is based on the calculated values, using an appropriate polynomial function. For k_{2n}, see Table B.1.

B.4 Verification of the declared curve

a) A test specimen is measured at temperatures close to those which were taken for the establishment of the declared curve, the temperature difference not exceeding ± 5 K for temperatures lower than or equal to 100 K and ± 10 K for higher temperatures.

b) The results are converted to the temperatures which were taken for the establishment of the declared curve, using the slope of the declared curve.

c) The measured value is deemed to have passed the test if the converted value is less or equal to the declared value at the same temperature.

d) If one or more measured values exceed the declared curve, further tests are performed to assess whether or not the basic distribution used to determine the declared curve is still valid. The hypothetical agreement between this new mean value, $\overline{\lambda}_2$, of *n* (≥ 3) samples and the mean value used in determining the declared values is examined at a 10 % probability error level.

e) The new mean value, $\overline{\lambda}_2$, and the standard deviation, s_2, are calculated.

f) The relevant criteria of acceptability are calculated:

— A large number of data are available

Λ and σ are known:

$$c = \frac{\bar{\lambda}_2 - \Lambda}{\sigma / \sqrt{n_2}} \tag{B.1}$$

— A small number of data are available

Then, for all θ_m, equation (B.2) is used:

$$t = \frac{\left(\bar{\lambda}_1 - \bar{\lambda}_2\right)\sqrt{n_1 n_2 \left(n_1 + n_2 - 2\right)}}{\sqrt{\left(n_1 - 1\right)s_1^2 + \left(n_2 - 1\right)s_2^2} \cdot \sqrt{n_1 + n_2}} \tag{B.2}$$

where

n_1 is the number of measurements carried out on the randomly chosen sample taken from the basic distribution used in establishing or verifying the declared curve;

n_2 is the number of measurements carried out on the randomly chosen sample used in examining the basic distribution;

s_1 is the estimator of the standard deviation of the randomly chosen sample taken from the basic distribution (estimation of σ);

s_2 is the estimator of the standard deviation of the randomly chosen sample used in examining the basic distribution (estimation of σ).

The hypothesis that the same distribution is still valid and in line with the establishment of the original declared curve is rejected if $|c|$ or $|t|$ is greater than the corresponding probability listed in Tables B.2 and B.3, respectively. The probable error level of this decision is 10 %.

B.5 Examples

B.5.1 Establishment of the declared curve

B.5.1.1 The basic distribution is known at the mean temperature, θ_m, from a large number of test results (n > 50).

$n \geq 50$ for all θ_m

Λ_1 (0 °C) = 0,035 W/(m·K)

σ_1 (0 °C) = 0,0011 W/(m·K)

Λ_2 (10 °C) = 0,036 W/(m·K)

σ_2 (10 °C) = 0,0012 W/(m·K)

Λ_3 (40 °C) = 0,0395 W/(m·K)

σ_3 (40 °C) = 0,0012 W/(m·K)

Declared curve (90/90):

1st point: λ_{decl} (0°C) = 0,035 + 1,28 × 0,0012 = 0,0365 W/(m·K)

2nd point: λ_{decl} (10°C) = 0,036 + 1,28 × 0,0012 = 0,0375 W/(m·K)

3rd point: λ_{decl} (40°C) = 0,0395 + 1,28 × 0,0012 = 0,0410 W/(m·K)

NOTE If there is a known linear relationship between thermal conductivity and mean temperature for this product, it is possible to use the standard deviation from the measurements at 40 °C for all temperatures.

B.5.1.2 A small number of data are available ($n \leq 50$ at mean temperature).

It was found:

$\bar{\lambda}_1$ (0°C) = 0,035 and s = 0,0010 W/(m·K) with n = 5

$\bar{\lambda}_2$ (10°C) = 0,036 and s = 0,0013 W/(m·K) with n = 5

$\bar{\lambda}_3$ (40°C) = 0,040 and s = 0,0012 W/(m·K) with n = 5

1st point: λ_{decl} (0°C) = 0,035 + 2,74 × 0,0010 = 0,0377 W/(m·K)

2nd point: λ_{decl} (10°C) = 0,036 + 2,74 × 0,0013 = 0,0396 W/(m·K)

3rd point: λ_{decl} (40°C) = 0,040 + 2,74 × 0,0012 = 0,0433 W/(m·K)

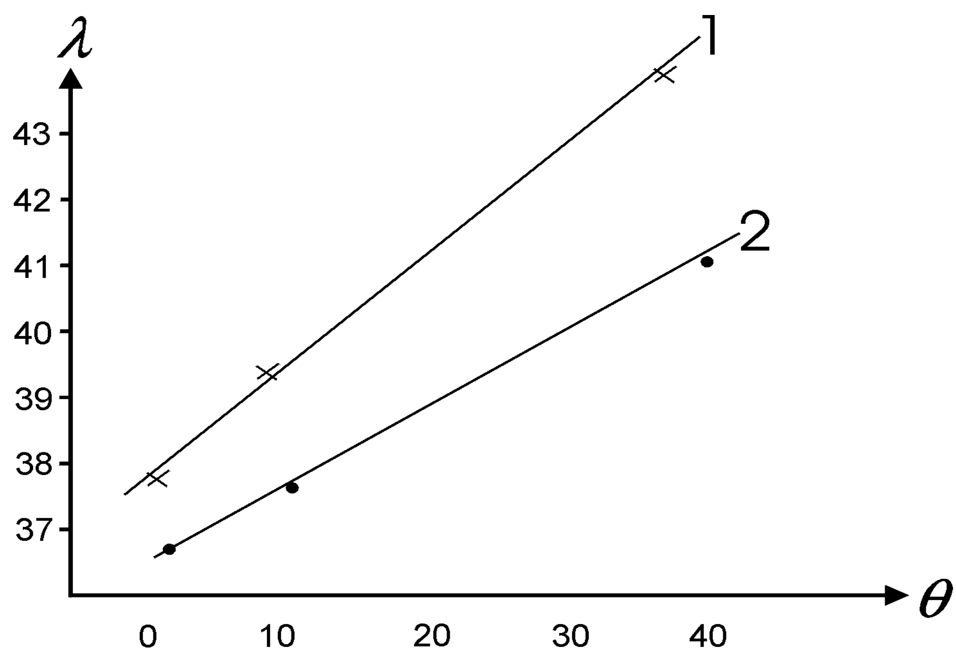


Figure B.1 – Established limit curves concerning procedures B.5.1.1 (curve a) and B.5.1.2 (curve b)

B.5.2 Verification of the declared curve

B.5.2.1 Declared curve obtained from a large number of test results

Declared curve (90/90):

1st point: λ_{decl} (0°C) = 0,035 + 1,28 × 0,0011 = 0,0364 W/(m·K)

2nd point: λ_{decl} (10°C) = 0,036 + 1,28 × 0,0012 = 0,0375 W/(m·K)

3rd point: λ_{decl} (40°C) = 0,0395 + 1,28 × 0,0012 = 0,0410 W/(m·K)

a) a value of λ = 0,041 W/(m·K) at 40 °C was found, so the test is passed;

b) a value of λ = 0,042 W/(m·K) at 40 °C was found, so that it is necessary to check whether or not the basic distribution is still valid, using five test specimens.

Five test specimens taken from randomly chosen samples whose measured thermal conductivities at 40 °C were:

0,042 W/(m·K)
0,040 W/(m·K)
0,041 W/(m·K)
0,038 W/(m·K)
0,037 W/(m·K)

$\overline{\lambda}_2$ = 0,0396 W/(m·K) s = 0,0021 W/(m·K)

Hypothesis: the mean value, $\overline{\lambda}$, of the basic distribution, from which the randomly chosen sample whose estimated value is $\overline{\lambda}_2$ was taken, is equal to the mean value, Λ, of the basic distribution used for establishing/determining the declared curve.

— null hypothesis H_0: Λ = 0,00395 W/(m·K)

— error probability α = 10 % (if the hypothesis is rejected, the probability of being wrong is 10 %)

— $c = \dfrac{\lambda_2 - \Lambda}{\sigma / \sqrt{n}} = \dfrac{0{,}0396 - 0{,}0395}{0{,}0012 / \sqrt{5}} = 0{,}19$

— $u(z)$ = 1 – 0,10 = 0,90; Table B.2: z = 1,28 (one-sided test)

— 0,19 < 1,28 so that the hypothesis is accepted. It is likely that the five measurements do originate from the basic distribution used for the declared curve.

B.5.2.2 The declared curve was obtained from an estimation of a small number of test results

Declared curve:

1st point: λ_{decl} (0°C) = 0,035 + 2,74 × 0,0010 = 0,0377 W/(m·K)

2nd point: λ_{decl} (10°C) = 0,036 + 2,74 × 0,0013 = 0,0396 W/(m·K)

3rd point: λ_{decl} (40°C) = 0,040 + 2,74 × 0,0012 = 0,0433 W/(m·K)

A value of thermal conductivity of 0,044 W/(m·K) at 40 °C was found.

For four additional test specimens, taken from randomly chosen samples, the thermal conductivities measured at 40 °C were:

$\overline{\lambda_2}$ = 0,0410 and s_2 = 0,00184 W/(m·K) with n = 5

Hypothesis: randomly chosen sample 1 out of the basic distribution with the mean value Λ_1, the estimated value, $\overline{\lambda_1}$, of which is known, and randomly chosen sample 2 of the basic distribution with the mean value Λ_2, the estimated value, $\overline{\lambda_2}$, of which is known, are samples out of the same basic distribution with the mean value Λ.

1) H_0: $\Lambda_1 = \Lambda_2$

2) α = 10 %

3) $$t = \left(\overline{\lambda}_1 - \overline{\lambda}_2\right)\sqrt{\frac{n_1 n_2 (n_1 + n_2 - 2)}{(n_1 + n_2)\left[(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2\right]}} \quad \text{(B.3)}$$

$$t = (0{,}041 - 0{,}040)\sqrt{\frac{5 \times 5(5 + 5 - 2)}{(5 + 5) \times \left[(5 - 1) \times 0{,}0012^2 + (5 - 1) \times 0{,}001842^2\right]}}$$

4) Table 3: with $f = n_1 + n_2 - 2 = 8$ and $1 - \alpha$ = 0,90 (one-sided test): c^* = 1,397

5) t = 1,0 < c = 1,397 so that the hypothesis is accepted: the measured values originate from the same basic distribution.

Table B.1 - Coefficients for one-sided tolerance interval [1]

Size of sample	k_{1n}	k_{2n}
	$1 - \alpha$ = 0,90	$1 - \alpha$ = 0,90
n	p = 90 %	p = 90 %
3	2,02	4,26
5	1,88	2,74
7	1,77	2,33
10	1,69	2,07
15	1,61	1,87
20	1,57	1,77
50	1,46	1,56
∞	1,28	1,28

k_1 is the coefficient to be used when the standard deviation is known;

k_2 is the coefficient to be used when the standard deviation is estimated.

Table B.2 - Accumulated Gaussian distribution [2]

z	*u(z)*
0,0	0,5000
0,1	0,5398
0,2	0,5793
0,3	0,6179
0,4	0,6554
0,5	0,6915
0,6	0,7257
0,7	0,7580
0,8	0,7881
0,9	0,8159
1,0	0,8413
1,1	0,8643
1,2	0,8849
1,3	0,9032
1,4	0,9192
1,5	0,9332
1,6	0,9452
1,7	0,9554
1,8	9,9641
1,9	0,9713
2,0	0,9772
2,1	0,9821
2,2	0,9861
2,3	0,9893
2,4	0,9918
2,5	0,9938
2,6	0,9953
2,7	0,9965
2,8	0,9974
2,9	0,9981
3,0	0,9987

z is the standard normal variable

$$\frac{x - \Lambda}{\sigma}$$

u(z) is the area under the Gaussian curve corresponding to the value *z* of the standard normal variable. It indicates the probability that a value smaller than *z* occurs.

Table B.3 - *t*-distribution [1]

***p* = 0,9**	
f	***c****
1	3,078
2	1,886
3	1,638
4	1,533
5	1,476
6	1,440
7	1,415
8	1,397
9	1,383
10	1,372
20	1,325
40	1,303
60	1,296
120	1,289
∞	1,282
f is the degree of freedom.	

Table B.3 shows the probability *p* that the parameter *t* is smaller than the value in the table.

Annex C
(informative)

Illustration of the procedure to verify thermal conductivity

The procedure outlined in 5.2 can be illustrated by the following.

Table C.1 - Proposed declared values

Temperature	θ_1	θ_2	θ_3	θ_4	θ_5
Thermal conductivity	λ_1	λ_2	λ_3	λ_4	λ_5

Table C.2 - First series of measurements

Temperature	θ_1'	θ_2'	θ_3'	θ_4'	θ_5'
Measured thermal conductivity	λ_{11}	λ_{21}	λ_{31}	λ_{41}	λ_{51}

with $\theta_1 - 5 \leq \theta'_1 \leq \theta_1 + 5$ if $\theta_1 \leq 100$ °C

$\theta_1 - 10 \leq \theta'_1 \leq \theta_1 + 10$ if $\theta_1 > 100$ °C

Table C.3 – Converted results of the first series of measurements

Temperature	θ_1	θ_2	θ_3	θ_4	θ_5
Thermal conductivity	λ'_{11}	λ'_{21}	λ'_{31}	λ'_{41}	λ'_{51}

Conversion formula $\lambda'_{11} = \lambda_{11} + \alpha(\theta_1 - \theta'_1)$, where α is the slope of the curve between the two temperatures of measurement.

Comparison and decision:

first case: $\lambda'_{11} \leq \lambda_1$

and $\lambda'_{21} \leq \lambda_2$

and $\lambda'_{31} \leq \lambda_3$ test is passed.

and $\lambda'_{41} \leq \lambda_4$

and $\lambda'_{51} \leq \lambda_5$

second case: $\lambda'_{11} \geq 1,1\ \lambda_1$

and/or $\lambda'_{21} \geq 1,1\ \lambda_2$

and/or $\lambda'_{31} \geq 1{,}1\ \lambda_3$ test failed, if the results correspond to

and/or $\lambda'_{41} \geq 1{,}1\ \lambda_4$ one or more of these inequalities.

and/or $\lambda'_{51} \geq 1{,}1\ \lambda_5$

intermediate case: $\lambda_1 < \lambda'_{11} < 1{,}1\ \lambda_1$

and $\lambda_2 < \lambda'_{21} < 1{,}1\ \lambda_2$

and $\lambda_3 < \lambda'_{31} < 1{,}1\ \lambda_3$ proceed to measurement on the two new test and $\lambda_4 < \lambda'_{41} < 1{,}1\ \lambda_4$ specimens.

and $\lambda_5 < \lambda'_{51} < 1{,}1\ \lambda_5$

Table C.4 - Results of measurements on the second test specimen

Temperature	θ''_1	θ''_2	θ''_3	θ''_4	θ''_5
Measured thermal conductivity	λ_{21}	λ_{22}	λ_{23}	λ_{24}	λ_{25}

with $\theta_1 - 5 \leq \theta''_1 \leq \theta_1 + 5$ if $\theta_1 \leq 100$ °C

$\theta_1 - 10 \leq \theta''_1 \leq \theta_1 + 10$ if $\theta_1 > 100$ °C

Table C.5 - Converted results of the second test specimen

Temperature	θ_1	θ_2	θ_3	θ_4	θ_5
Converted thermal conductivity	λ'_{21}	λ'_{22}	λ'_{23}	λ'_{24}	λ'_{25}

Conversion formula:

$$\lambda'_{21} = \lambda_{21} + \alpha\,(\theta_1 - \theta''_1) \qquad \text{(C.3)}$$

where α is the slope of the curve between the two temperatures of measurement.

Table C.6 - Results of measurements on the third test specimen

Temperature	θ'''_1	θ'''_2	θ'''_3	θ'''_4	θ'''_5
Measured thermal conductivity	λ_{31}	λ_{32}	λ_{33}	λ_{34}	λ_{35}

with $\theta_1 - 5 \leq \theta'''_1 \leq \theta_1 + 5$ if $\theta_1 \leq 100$ °C

$\theta_1 - 10 \leq \theta'''_1 \leq \theta_1 + 10$ if $\theta_1 > 100$ °C

Table C.7 - Converted results of the third test specimen

Temperature	θ_1	θ_2	θ_3	θ_4	θ_5
Converted thermal conductivity	λ'_{31}	λ'_{32}	λ'_{33}	λ'_{34}	λ'_{35}

Conversion formula:

$$\lambda'_{31} = \lambda_{31} + \alpha\,(\theta_1 - \theta'''_1) \qquad \text{(C.4)}$$

where α is the slope of the curve between the two temperatures of measurement.

Table C.8 - Mean results of the three test specimens

Temperature	θ_1	θ_2	θ_3	θ_4	θ_5
Mean thermal conductivity	λ_{1m}	λ_{2m}	λ_{3m}	λ_{4m}	λ_{5m}

with

$$\lambda_{1m} = \frac{\lambda'_{11} + \lambda'_{21} + \lambda'_{31}}{3} \qquad \text{(C.5)}$$

Comparison and decision:

if $\lambda_{1m} \leq \lambda_1$

and $\lambda_{2m} \leq \lambda_2$

and $\lambda_{3m} \leq \lambda_3$ test is passed.

and $\lambda_{4m} \leq \lambda_4$

and $\lambda_{5m} \leq \lambda_5$

if one $\lambda_{im} > \lambda_i$ test has failed. (i equals 1, 2, 3, 4 or 5)

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