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Building materials and products — Procedures for determining declared and design thermal values

Matériaux et produits du bâtiment — Procédures pour la détermination des valeurs thermiques déclarées et utiles

Reference number
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Contents

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 10456 was prepared by Technical Committee ISO/TC 163, *Thermal insulation*, Subcommittee SC 2, *Calculation methods.*

This second edition cancels and replaces the first edition (ISO 10456:1997), of which it constitutes a minor revision.

Building materials and products — Procedures for determining declared and design thermal values

1 Scope

This International Standard specifies methods for the determination of declared and design thermal values for thermally homogeneous building materials and products.

It also gives procedures to convert values obtained under one set of conditions to those valid for another set of conditions. These procedures are valid for design ambient temperatures between –30 °C and +60 °C.

Conversion coefficients for temperature, valid for mean temperatures between 0 °C and 30 °C, and moisture are given in annex A.

This International Standard does not give any conversion coefficients for the effect of ageing or other effects like convection or settlement.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 8301:1991, *Thermal insulation — Determination of steady-state specific thermal resistance and related properties — Heat flow meter apparatus*.

ISO 8302:1991, *Thermal insulation — Determination of steady-state thermal resistance and related properties — Guarded hot plate apparatus*.

ISO 8990:1994, *Thermal insulation — Determination of steady-state thermal transmission properties — Calibrated and guarded hot box*.

3 Terms, definitions and symbols

3.1 Definitions

For the purposes of this International Standard, the following terms and definitions apply.

3.1.1
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;

— corresponding to a reasonable expected service lifetime under normal conditions

3.1.2
design thermal value
value of thermal property of a building material or product under specific external and internal conditions which can be considered as typical of the performance of that material or product when incorporated in a building component

3.1.3
material
piece of a product irrespective of its delivery form, shape and dimensions, without any facing or coating

3.1.4
product
final form of a material ready for use, of given shape and dimensions and including any facings or coatings

3.2 Symbols and units

Table 1 — Symbols, quantities and units

Symbol	Quantity	Unit
F_a	ageing conversion factor	
F_m	moisture conversion factor	
F_T	temperature conversion factor	
f_T	temperature conversion coefficient	1/K
f_u f_ψ	moisture conversion coefficient mass by mass moisture conversion coefficient volume by volume	kg/kg m^3/m^3
R	thermal resistance	$m^2 \cdot K/W$
T	temperature	K
λ	thermal conductivity	$W/(m \cdot K)$
u ψ	moisture content mass by mass moisture content volume by volume	kg/kg m^3/m^3

4 Test methods and test conditions

Measured values from the following methods, or equivalent national methods, shall be used:

— guarded hot plate in accordance with ISO 8302;

— heat flow meter in accordance with ISO 8301;

— hot box in accordance with ISO 8990.

To avoid conversions, it is recommended that measurements be conducted under conditions corresponding to the selected set of conditions given in Table 2.

The mean test temperature should be chosen so that the application of the temperature coefficients does not introduce a change of more than 2 % from the measured value.

The following testing conditions are required:

— measured thickness and density for identification;

— mean test temperature;

— moisture content of the specimen during test.

For aged materials:

— age of the specimen and conditioning procedures before testing.

5 Determination of declared values

The declared value shall be given under one of the sets of conditions **a** or **b** with reference temperature 10 °C (I) or 23 °C (II) in Table 2.

Table 2 — Declared value conditions

Property	**Sets of conditions**			
	I (10 °C)		**II (23 °C)**	
	a	**b**	**a**	**b**
Reference temperature	10 °C	10 °C	23 °C	23 °C
Moisture	u_{dry}	$u_{23,50}$	u_{dry}	$u_{23,50}$
Ageing	aged	aged	aged	aged

u_{dry} is a low moisture content reached by drying.

$u_{23,50}$ is the moisture content when in equilibrium with air at 23 °C and relative humidity of 50 %.

The declared value shall be determined either at a thickness large enough to neglect the thickness effect, or the declared values for smaller thicknesses shall be based on measurements at those thicknesses.

The data used shall be either

— directly measured values according to the test methods given in clause 4, or

— obtained indirectly by making use of an established correlation with a related property such as density.

When all data have not been measured under the same set of conditions, they shall first be brought to one set of conditions (see clause 7). Then a statistical single value estimate shall be calculated. Annex C refers to International Standards on statistics that may be used.

During calculations no value shall be rounded to less than three significant figures.

The declared value is the estimated value of the statistical single value, rounded according to the following rules:

a) for thermal conductivity given in watts per metre kelvin [W/(m · K)]:

$\lambda \leqslant 0,08$: rounding to nearest higher 0,001 W/(m · K)

$0,08 < \lambda \leqslant 0,20$: rounding to nearest higher 0,005 W/(m · K)

$0,20 < \lambda \leqslant 2,00$: rounding to nearest higher 0,01 W/(m · K)

$2,0 < \lambda$ rounding to nearest higher 0,1 W/(m · K) and/or:

b) for thermal resistance given in square metres kelvin per watt ($m^2 \cdot K/W$) as the nearest lower value rounded to not more than two decimals or three significant figures.

6 Determination of design values

6.1 General

Design values can be obtained from a declared value, measured values or standardized tabulated values.

Measured data can be either

— directly measured values according to the test methods given in clause 4, or

— obtained indirectly by making use of an established correlation with a related property such as density.

If the set of conditions for declared, measured or standardized tabulated values can be considered relevant for the actual application, those values can be used directly as design values. Otherwise, conversion of data shall be undertaken according to the procedure given in clause 7.

The design value shall be rounded according to the rules given in clause 5:

— for thermal conductivity, as the nearest higher value in watts per metre kelvin [W/(m · K)];

— for thermal resistance, as the nearest lower value in square metres kelvin per watt ($m^2 \cdot K/W$).

6.2 Design values derived from declared values

When the design value is calculated from the declared value and is based on the same statistical evaluation, the declared value shall be converted to the design conditions.

Information on how to derive design values based on another statistical evaluation other than the one applicable to the declared value is given in annex C.

6.3 Design values derived from measured values

When necessary all data shall first be converted to the design conditions. Then a statistical single value estimate shall be calculated. Annex C refers to International Standards on statistics that can be used.

6.4 Design values derived from tabulated values

Standardized tabulated values can be used when the set of conditions for them is available.

7 Conversion of available data

7.1 General

Conversion coefficients derived from measured values according to the test methods referred to in clause 4 may be used instead of the values in annex A.

Conversions of thermal values from one set of conditions (λ_1, R_1) to another set of conditions (λ_2, R_2) are carried out according to the following expressions:

$$\lambda_2 = \lambda_1 \cdot F_T \cdot F_m \cdot F_a \quad (1)$$

$$R_2 = \frac{R_1}{F_T \cdot F_m \cdot F_a} \qquad (2)$$

7.2 Conversion for temperature

The factor F_T for temperature is determined by:

$$F_T = e^{f_T (T_2 - T_1)} \qquad (3)$$

where

f_T is the temperature conversion coefficient;

T_1 is the temperature of the first set of conditions;

T_2 is the temperature of the second set of conditions.

7.3 Conversion for moisture

The factor F_m for moisture content is determined as follows.

a) Conversion of moisture content given as mass by mass:

$$F_m = e^{f_u (u_2 - u_1)} \qquad (4)$$

where

f_u is the moisture content conversion coefficient mass by mass;

u_1 is the moisture content mass by mass of the first set of conditions;

u_2 is the moisture content mass by mass of the second set of conditions.

b) Conversion of moisture content given as volume by volume:

$$F_m = e^{f_\psi (\psi_2 - \psi_1)} \qquad (5)$$

where

f_ψ is the moisture content conversion coefficient volume by volume;

ψ_1 is the moisture content volume by volume of the first set of conditions;

ψ_2 is the moisture content volume by volume of the second set of conditions.

7.4 Age conversion

The ageing depends upon the material type, facings, structures, the blowing agent, the temperature and the thickness of the material. For a given material the ageing effect can be obtained from theoretical models validated by experimental data. There are no simple rules to correlate ageing over time for a given material.

No conversion is needed when the measured conductivity or resistance already takes account of ageing effects.

If a conversion factor F_a is used, it shall allow the calculation of the aged value of the thermal property corresponding to a time not less than half the working lifetime of the product in the application concerned.

NOTE 1 The working lifetime is often taken as 50 years.

NOTE 2 No conversion coefficients are given in this International Standard to derive the ageing factor F_a.

Annex A
(normative)

Conversion coefficients

A.1 Use of the values

For conductivities between those given in the tables, use linear interpolation.

Unless otherwise specified the conversion coefficients apply to both factory-made products and loose-fill materials.

Values of thermal conductivity are given as identification parameters only and are not intended for any other purpose.

A.2 Conversion coefficients for temperature

The values in Tables A.1 to A.23 are valid for mean temperatures between 0 °C and +30 °C.

The temperature coefficients in Tables A.4 and A.5 relate to materials blown with CFC only. When other blowing agents are used, temperature conversion coefficients shall be obtained from measurements according to clause 7.

Table A.1 — Mineral wool

Product type	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
Bats, mats and loose fill	0,035 0,040 0,045 0,050	0,004 6 0,005 6 0,006 2 0,006 9
Boards	0,032 0,034 0,036 0,038	0,003 8 0,004 3 0,004 8 0,005 3
Rigid boards	0,030 0,033 0,035	0,003 5 0,003 5 0,003 1

Table A.2 — Expanded polystyrene

Thickness d mm	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
$d \leqslant 20$	0,032 0,035 0,040 0,043	0,003 1 0,003 6 0,004 1 0,004 4
$20 < d \leqslant 40$	0,032 0,035 0,040	0,003 0 0,003 4 0,003 6
$40 < d \leqslant 100$	0,032 0,035 0,040 0,045 0,050	0,003 0 0,003 3 0,003 6 0,003 8 0,004 1
$d > 100$	0,032 0,035 0,040 0,053	0,003 0 0,003 2 0,003 4 0,003 7

Table A.3 — Extruded polystyrene

Product type	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
Without skin	0,025 0,030 0,040	0,004 6 0,004 5 0,004 5
With skin, fine cell products without skin	0,025 0,030 0,035	0,004 0 0,003 6 0,003 5
With impermeable cover	0,025 0,030 0,035 0,040	0,003 0 0,002 8 0,002 7 0,002 6

Table A.4 — Polyurethane foam

Product type	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
All products	0,025 0,030	0,005 5 0,005 0

Table A.5 — Phenolic foam

Product type	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
All products	0,020	0,004 0
	0,032	0,002 9

Table A.6 — Cellular glass

Product type	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
All products	0,035 0,040 0,045 0,050 0,055	0,004 3 0,003 7 0,003 3 0,003 0 0,002 7

Table A.7 — Rigid boards of perlite, fibres and binders

Product type	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
All products	all	0,003 3

Table A.8 — Wood wool boards

Product type	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
All products	0,070 0,080 0,090	0,004 0 0,004 1 0,004 6

Table A.9 — Cork boards

Product type	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
All products	all	0,002 7

Table A.10 — Concrete, fired clay and mortar

Product type	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
Lightweight concrete	0,100 0,150 0,400	0,003 0,002 0,001
Dense concrete, fired clay and mortar	all	0,001

Table A.11 — Calcium silicate

Product type	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
All products	all	0,003

Table A.12 — Loose-fill expanded perlite

Product type	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
All products	0,040 0,050	0,004 1 0,003 3

Table A.13 — Loose-fill expanded clay

Product type	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
All products	0,070 to 0,150	0,004

Table A.14 — Loose-fill exfoliated vermiculite

Product type	Conductivity λ W/(m·K)	Conversion coefficient, f_T 1/K
All products	all	0,003

A.3 Conversion coefficients for moisture

The effect of mass transfer by liquid water and water vapour is not covered by these data.

The moisture content is the range for which the coefficients are valid.

Table A.15 — Mineral wool

Product type	Moisture content, ψ m^3/m^3	Conversion coefficient, f_ψ m^3/m^3
All products	< 0,15	4

Table A.16 — Cellular plastics

Type of plastic	Moisture content, ψ m^3/m^3	Conversion coefficient, f_ψ m^3/m^3
Expanded polystyrene	< 0,10	4
Extruded polystyrene	< 0,10	2,5
Polyurethane foam	< 0,15	6
Phenolic foam	< 0,15	5

Table A.17 — Wood based products

Product type	Moisture content, ψ m³/m³	Conversion coefficient, f_ψ m³/m³
Wood wool boards	< 0,1	1,8
Wood	< 0,1	2,2
Cork	< 0,1	6,0

Table A.18 — Cellular glass

Product type	Moisture content, u kg/kg	Conversion coefficient, f_u kg/kg
All products	0,0	0,00

Table A.19 — Rigid boards of perlite, fibres and binders

Product type	Moisture content, u kg/kg	Conversion coefficient, f_u kg/kg
All products	0 to 0,04	0,8

Table A.20 — Masonry and masonry products

Product type	Moisture content, u kg/kg	Conversion coefficient, f_u kg/kg
Concrete units with:		
— expanded clay as the predominant aggregate	0 to 0,25	4
— no aggregate other than expanded clay	0 to 0,25	2,6
— more than 70 % expanded blast-furnace slag aggregate	0 to 0,25	4
— the predominant aggregate derived from pyroprocessed colliery material	0 to 0,25	4
Autoclaved aerated concrete	0 to 0,25	4,0
	ψ m³/m³	f_ψ m³/m³
Clay units (fired clay)	0 to 0,25	10
Calcium silicate units	0 to 0,25	10
Dense aggregate concrete units and manufactured stone units	0 to 0,25	4
Concrete units with:		
— no aggregate other than pumice	0 to 0,25	4
— polystyrene aggregate	0 to 0,25	5
— other lightweight aggregates	0 to 0,25	4
Mortar (masonry mortar and rendering mortar)	0 to 0,25	4

Table A.21 — Loose-fill expanded perlite

Product type	Moisture content, u kg/kg	Conversion coefficient, f_u kg/kg
All products	0 to 0,02	3

Table A.22 — Loose-fill expanded clay

Product type	Moisture content, u kg/kg	Conversion coefficient, f_u kg/kg
All products	0 to 0,02	4

Table A.23 — Loose-fill exfoliated vermiculite

Product type	Moisture content, u kg/kg	Conversion coefficient, f_u kg/kg
All products	0 to 0,02	2

Annex B
(informative)

Sample calculations

This annex gives three examples illustrating the procedure for deriving declared or design values from available data. Numerical inputs which are not taken from this International Standard are purely indicative.

B.1 Declared value determined from 10 measured samples

A mineral wool manufacturer has measurements of 10 samples from mineral wool boards. The measurements were conducted at a mean temperature of 11 °C. The samples were conditioned at a temperature of 23 °C and relative humidity of 50 %.

The declared value is to be given for a temperature of 10 °C and a moisture content equal to the one the material has when in equilibrium with air at 23 °C and relative humidity of 50 %.

The measurements are as follows:

Table B.1 — Measured conductivities ([W/(m·K)]

n	1	2	3	4	5	6	7	8	9	10
λ	0,033 1	0,034 3	0,034 6	0,033 8	0,033 6	0,034 1	0,033 4	0,034 2	0,033 5	0,033 9

The declared value is to be a 90 % fractile with 90 % confidence. The statistical formula used to find the limit for this one sided statistical tolerance interval is given in ISO 3207:1975, Table 3:

$$L_s = \bar{x} + k_2(n, p, 1-\alpha) \cdot s$$

The mean value is calculated as:

$$\bar{x} = \frac{\sum x_i}{10} = 0{,}033\ 85$$

In annex C the coefficient k_2 is 2,07 for n = 10.

The standard deviation is calculated as:

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} = 0{,}000\ 460$$

The limit value for the tolerance interval is then:

$$L_s = 0{,}033\ 85 + 2{,}07 \times 0{,}000\ 460 = 0{,}034\ 802$$

This value is then converted to 10 °C using equation (1):

$$\lambda_2 = \lambda_1 \cdot F_T$$

The conversion factor is calculated from equation (3):

$$F_T = e^{f_T (T_2 - T_1)}$$

The conversion coefficient for mineral wool boards with a conductivity of 0,034 W/(m·K), is given in Table A.1:

$$f_T = 0{,}004\ 3$$

The conversion factor then becomes:

$$F_T = e^{0{,}004\ 3(10-11)} = 0{,}995\ 71$$

The converted value then becomes:

$$\lambda_2 = 0{,}034\ 802\ 2 \times 0{,}995\ 71 = 0{,}034\ 652\ 9$$

The declared value is rounded to the nearest, higher 0,001 W/(m·K) which means that

λ = 0,035 W/(m·K)

can be used as the declared value for this product.

B.2 Determination of design value from declared value

An expanded polystyrene board will be used in an application where the moisture content is assumed to be 0,02 (m^3/m^3). The declared value for this product, being a 90/90 value, is 0,036 W/(m·K).

Two different design values are required, one representing the same fractile as the declared one and another representing a mean value.

B.2.1 90 % fractile

The only conversion necessary is for the moisture content. This is calculated by equation (5):

$$F_m = e^{f_\psi (\psi_2 - \psi_1)}$$

The moisture conversion coefficient is given in Table A.16:

$$f_\psi = 4{,}0$$

Then the conversion factor becomes:

$$F_m = e^{[4{,}0(0{,}02-0)]} = 1{,}083\ 3$$

And the converted thermal conductivity becomes:

$$\lambda_2 = 0{,}036 \times 1{,}083\ 3 = 0{,}038\ 998\ 8$$

The design value is the nearest value rounded to 0,001 W/(m·K):

λ = 0,039 W/(m·K)

B.2.2 Mean value

A mean value can be found using the equation (C.1) from annex C:

$$\bar{\lambda} = \lambda_{90} - \Delta\lambda$$