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

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

Reference number
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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 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 23993 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 89, *Thermal performance of buildings and building components*, in collaboration with ISO 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).

This International Standard is one of a series of standards on methods for the design and evaluation of the thermal performance of building equipment and industrial installations.

This corrected version of ISO 23993:2008 incorporates the following corrections plus other minor editorial modifications.

Clause 4: The following two rows have been added to the table:

N	number of spacers per square metre	—

$\Delta\lambda_{sq}$	thermal conductivity per spacer per square metre	W/(m·K)

Clause 6: Equations (1) and (2) have been re-inserted:

$$\lambda = \lambda_d F + \Delta\lambda \qquad (1)$$

$$F = F_{\Delta\theta} F_m F_a F_C F_c F_d F_j \qquad (2)$$

7.9.2.2: The calculations have been modified as follows (i.e. with the substitution of $\Delta\lambda_{sq}$, the thermal conductivity per spacer per square metre, for $\Delta\lambda$ i.e., with the deletion of "/spacers/m^2" from the units):

Spacers of steel in the form of a flat bar

30 mm × 3 mm $\Delta\lambda_{sq}$ = 0,003 5 W/(m·K)

40 mm × 4 mm $\Delta\lambda_{sq}$ = 0,006 0 W/(m·K)

50 mm × 5 mm $\Delta\lambda_{sq}$ = 0,008 5 W/(m·K)

A new Equation (6) has been added to define the relationship between $\Delta\lambda$ and $\Delta\lambda_{sq}$ and the original Equation (6) renumbered to Equation (7).

7.9.3: The units “W(m·K)” have been corrected to “W/(m·K)”.

A.4.1 (twice) and A.4.2 (twice): The term “specific” has been added to the definition of W, “specific airflow resistance.”

Annex B: The additional subtitles and introductory text, “B.1 Insulation materials” and “B.2 Conditions” have been added. The line “Determination of the conversion factors and $\Delta\lambda$” has been restyled as B.3 and introductory text added.

Table C.1: The vertical line separating the subheadings “calcium-magnesium silicate fibre” and “calcium silicate” and “microporous insulants” each from the subheading “Insulation” has been moved one column to the left, i.e. from between the pictures for the two pipes to between the column “Application...” and the picture of the horizontal pipe (consistent with other similar rows such as that for “mineral wool”).

Table C.1 (four times): The term “airflow resistance” has been replaced with the term “airflow resistivity”.

Introduction

The establishment of design values for thermal conductivity for the calculation of the thermal performance of insulation systems for building equipment and industrial installations requires a consideration of various possible influences affecting the thermal properties of the insulation products employed due to the operational conditions of any individual insulation system.

Among these influences could be:

- the non-linearity of the thermal conductivity curve over the temperature range in which the insulant may be employed;
- the thickness effect;
- the effect of moisture in the insulant;
- ageing effects, beyond those already incorporated in the declared value;
- special installation effects such as single- or multi-layered installation.

In this International Standard, the conversion factors F, that need to be used in a variety of applications for a variety of insulation products, are given and the principles and general equations as well as some guidance for the establishment of design values for the calculation of the thermal performance of insulation systems are described. The conversion factors valid for commonly employed insulation products are given in annexes. They are well established in some cases and for some materials. Where experience is lacking and conversion factors cannot be established accurately, they are given in the form of an "educated estimate" so that the calculation result will be on the safe side, i.e. the calculated heat transfer will be greater than that actually occurring when the calculation has obeyed the rules of this International Standard.

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

1 Scope

This International Standard gives methods to calculate design thermal conductivities from declared thermal conductivities for the calculation of the thermal performance of building equipment and industrial installations.

These methods are valid for operating temperatures from −200 °C to +800 °C.

The conversion factors, established for the different influences, are valid for the temperature ranges indicated in the relevant clauses or annexes.

2 Normative references

The following referenced documents are indispensable for the application 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 insulation — Physical quantities and definitions*

ISO 8497, *Thermal insulation — Determination of steady-state thermal transmission properties of thermal insulation for circular pipes*

ISO 9053, *Acoustics — Material for acoustical applications — Determination of airflow resistance*

ISO 9229, *Thermal insulation — Vocabulary*

ISO 13787, *Thermal insulation products for building equipment and industrial installations — Determination of declared thermal conductivity*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345, ISO 9229 and the following apply.

3.1
declared thermal conductivity
value of the thermal conductivity of a material or product used for building equipment and industrial installations:

— based on measured data at reference conditions of temperature and humidity;

— given as a limit value, in accordance with the determination method in ISO 13787;

— corresponding to a reasonable expected service lifetime under normal conditions

3.2
design thermal conductivity
value of thermal conductivity of an insulation 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 equipment or industrial installation

4 Symbols

Symbol	Quantity	Unit
a_C	compressibility coefficient	$m^3/(kg·K)$
D	internal diameter of the layer	m
d	layer thickness	m
d_g	system thickness including air gap	m
F	overall conversion factor for thermal conductivity	—
F_a	ageing conversion factor	—
F_C	compression conversion factor	—
F_c	convection conversion factor	—
F_d	thickness conversion factor	—
f_d	thickness conversion coefficient	—
F_j	joint factor	—
F_m	moisture conversion factor	—
f_ψ	moisture conversion coefficient volume by volume	m^3/m^3
$F_{\Delta\theta}$	temperature difference conversion factor	—
N	number of spacers per square metre	—
u	moisture content mass by mass	kg/kg
θ	Celsius temperature	°C
λ_d	declared thermal conductivity	W/(m·K)
λ	design thermal conductivity	W/(m·K)
$\bar{\lambda}$	integrated thermal conductivity	W/(m·K)
$\Delta\lambda$	additional thermal conductivity due to thermal bridges, such as spacers, which are regular parts of the insulation	W/(m·K)
$\Delta\lambda_{sq}$	thermal conductivity per spacer per square metre	W/(m·K)
ρ	apparent density	kg/m^3
ψ	moisture content volume by volume	m^3/m^3

5 Determination of declared thermal conductivity

Declared thermal conductivities shall be determined as given in ISO 13787.

The product shall be described by its characteristics including a clear identification of the materials, the type of facing if any, the structure, the blowing agent, the thickness and any other parameters having a possible influence on thermal conductivity.

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

6 Determination of the design value of thermal conductivity

The design value of thermal conductivity shall be determined from the declared thermal conductivity for the set of conditions corresponding to the conditions of the expected application. Possible influences include the following:

a) the average operating temperature, together with the hot and cold surface temperatures;

b) the average moisture content expected when the material is in equilibrium with a defined atmosphere (temperature and relative humidity);

c) the ageing effect according to the application, if not included in the declared value;

d) the compression applied in the application;

e) the convection effect in the material;

f) the thickness effect;

g) the open joint effect;

h) the insulation-related thermal bridges, (thermal bridges that are regular part of the insulation system, e.g. spacers), which are taken into account via a term $\Delta\lambda$.

The design value of thermal conductivity shall be obtained either

— from a declared thermal conductivity converted to the conditions of the application using Equation (1):

$$\lambda = \lambda_d F + \Delta\lambda \qquad (1)$$

where the additional term $\Delta\lambda$ is obtained as given in 7.9 and the overall conversion factor F is given by:

$$F = F_{\Delta\theta} F_m F_a F_C F_c F_d F_j \qquad (2)$$

— or from values measured under application conditions.

NOTE Approximate values for F can be found in the informative Annex C.

7 Conversion of available data

7.1 General

Values of the different conversion factors for some insulating materials and operating conditions are given in Annex A. Conversion factors derived from measured values according to the appropriate test methods, e.g. EN 12667 or ISO 8497, may be used instead of the values in Annex A. If the material does not correspond to the conditions for which the factors are given in Annex A, then the conversion factors derived from measured values shall be used.

7.2 Conversion factor for temperature difference

If the design thermal conductivity is requested at the same reference mean temperature and if the hot and cold surface temperatures are the same as for the declared thermal conductivity, no conversion is needed ($F_{\Delta\theta} = 1$).

In the case of thermal conductivity measurement made with the pipe tester (ISO 8497), no conversion is needed when the measurement is carried out with the full temperature difference $\Delta\theta$.

If the design thermal conductivity is to be determined at another temperature from declared thermal conductivities given in the form of a table of values at different temperatures, interpolation between values in the table shall be based on the use of a best-fit equation such as a regression polynomial, of an order sufficient to provide a correlation coefficient, $r \geqslant 0{,}98$.

If the design thermal conductivity is needed at the same reference mean temperature, but for another hot and cold surface temperature difference, than that used for determining the declared thermal conductivity, the conversion factor $F_{\Delta\theta}$ shall be determined according to the procedure as given in A.1.

If the thermal conductivity measurement has been carried out with the full temperature difference, $F_{\Delta\theta} = 1$. If the thermal conductivity measurement has been carried out with a $\Delta\theta$ not exceeding 50 K, the procedure for non-linearity applies.

If the design thermal conductivity is needed at another mean temperature than that of the declared thermal conductivity and with another temperature difference, the procedures outlined above shall be followed successively. As an alternative, the influence of the non-linearity of the thermal conductivity curve may be taken into account by integrating the measured curve as given by Equation (3):

$$\bar{\lambda} = \frac{1}{\theta_2 - \theta_1} \int_{\theta_1}^{\theta_2} \lambda(\theta)\,\mathrm{d}\theta \qquad (3)$$

The temperature difference conversion factor is given by:

$$F_{\Delta\theta} = \frac{\bar{\lambda}}{\lambda(\theta)} \qquad (4)$$

where $\lambda(\theta)$ is the value read on the curve at the reference temperature.

7.3 Conversion factor for moisture

The conversion factor F_m for volume-related moisture content shall be determined as follows:

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

where

f_ψ is the moisture content conversion coefficient volume by volume;

ψ_1 is the moisture content volume by volume for the determination of declared value of thermal conductivity;

ψ_2 is the moisture content volume by volume for the actual application.

The content of moisture in a given application shall be determined either

— by measurements carried out in the conditions of the expected application, or

— by theoretical calculations using proven methods such as those given in ISO 15758 based on measured values as described in ISO 12572, provided the assumptions on which they are based are met.

NOTE A possible test method to determine moisture content is given in EN 12088. If needed for the application, the time period indicated in EN 12088 can be extended.

Some values of the coefficient f_ψ are given in A.2.

7.4 Conversion factor for ageing

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 (see procedure in the product standard, where applicable).

No conversion is needed when the declared thermal conductivity or resistance already takes account of ageing or when the ageing effect has been determined in conditions which do not significantly differ from the design set of conditions.

If the set of conditions for the design thermal conductivities significantly differs from that in which the ageing effect of the declared thermal conductivity has been determined, an ageing test in the set of conditions of the design thermal conductivities shall be carried out.

If a conversion factor F_a is used, it shall allow for 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 for building equipment is often taken as 50 years.

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

No ageing conversion factor shall be used for mineral wool, ceramic fibre, calcium-magnesium silicate fibre, calcium silicate, flexible elastomeric foam and cellular glass.

7.5 Conversion factor for compression

For compressible insulation products, the apparent density may change when the product is subject to load. The influence on the thermal conductivity shall be taken into account by the factor F_C, which shall be calculated as given in A.3.

7.6 Conversion factor for convection

The effect of convection in the case of vertical insulation layers shall be taken into account by a convection factor F_c.

The factor F_c shall be calculated as given in A.4.

7.7 Conversion factor for thickness effect

For insulation materials permeable to radiation, the thermal conductivity changes with increasing thickness. If the design thermal conductivity is needed at other thicknesses than those of the declared thermal conductivity, the factor F_d shall be determined as given in A.5.

7.8 Conversion factor for regular joints

The influence of joints on the design thermal conductivity shall be addressed by the conversion factor F_j, which shall be calculated as given in A.6.

The conversion factor F_j shall be applied if the thermal conductivity has been measured in accordance with ISO 8497, with a pipe tester having fewer joints than the actual application.

7.9 Additional thermal conductivity for regularly insulation-related thermal bridges, e.g. spacers

7.9.1 General

Components in the insulating layer which are regularly-spaced insulation-related thermal bridges like spacers are taken into account by adding $\Delta\lambda$ to the corrected thermal conductivity λ_d of the installed insulation product as given in Equation (1).

Plant-related and irregularly-spaced insulation-related thermal bridges, e.g. pipe mountings, supports, armatures and frontal plates are thermal bridges which have to be considered as additional heat losses, e.g. as described in ISO 12241.

7.9.2 Spacers

7.9.2.1 Spacers for sheet metal pipeline jackets

The additional thermal conductivity depends on a number of variables. The values indicated in the following are approximate values and apply to common insulating layer thicknesses from 100 mm to 300 mm and common insulation systems for heat protection.

NOTE 1 Reference [9] in the Bibliography provides possible procedures for special insulation systems.

Additions to thermal conductivity

for steel spacers	$\Delta\lambda$ = 0,010 W/(m·K)
for austenitic steel spacers	$\Delta\lambda$ = 0,004 W/(m·K)
for ceramic spacers	$\Delta\lambda$ = 0,003 W/(m·K)

NOTE 2 These values can be used in the range of 50 mm to 200 mm, see Reference [10].

7.9.2.2 Spacers for sheet metal jackets for walls

Spacers of steel in the form of a flat bar

30 mm × 3 mm	$\Delta\lambda_{sq}$ = 0,003 5 W/(m·K)
40 mm × 4 mm	$\Delta\lambda_{sq}$ = 0,006 0 W/(m·K)
50 mm × 5 mm	$\Delta\lambda_{sq}$ = 0,008 5 W/(m·K)

Additions $\Delta\lambda$ to thermal conductivity to account for spacers for sheet metal jackets for walls depend on the number of spacers per square metre (m^2). The total addition is calculated by:

$$\Delta\lambda = N\,\Delta\lambda_{sq} \tag{6}$$

where

N is the number of spacers per square metre (m^2);

$\Delta\lambda_{sq}$ is the thermal conductivity per spacer per square metre.

