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International Standard 6946/1

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Thermal insulation — Calculation methods — Part 1: Steady state thermal properties of building components and building elements

Isolation thermique — Règles de calcul — Partie 1: Propriétés thermiques des composants et éléments de bâtiment en régime stationnaire

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 6946/1 was prepared by Technical Committee ISO/TC 163, *Thermal insulation.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Thermal insulation — Calculation methods — Part 1 : Steady state thermal properties of building components and building elements

1 Scope and field of application

This part of ISO 6946 lays down fundamental methods of calculating the steady state thermal properties of building components and building elements.

It includes simplified methods for calculations relative to homogeneous plane elements. These methods can be applied where the calculation for the structure in question is not covered by International Standards dealing with thermal bridges (see, for example, ISO 6946/2).

The effect of imperfect workmanship is a variable factor depending upon the type of construction, the combinations of materials used and the control system. It should be taken into account either by using basic data including a correction factor, or by applying a security factor to the result of the computation. These corrections should be given in national standards.

The rules do not take into account the permeation of air through elements, or solar radiation on surfaces or through transparencies.

The rules are based on conventions concerning boundary conditions, not all of which are mentioned here, but which may be considered as typical of practical conditions.

Some values for design guidance are given in the annex.

2 References

ISO 6946/2, *Thermal insulation — Calculation methods — Part 2: Thermal bridges of rectangular sections in plane structures.*

ISO 7345, *Thermal insulation — Physical quantities and definitions.*

3 Definitions and symbols

3.1 Definitions

For the purposes of this part of ISO 6946, the definitions given in ISO 7345 apply.

3.2 Symbols

A:	area	m^2
R:	thermal resistance	$m^2 \cdot K/W$
U:	thermal transmittance	$W/(m^2 \cdot K)$
d:	thickness of a layer	m
λ:	thermal conductivity	$W/(m \cdot K)$
ε:	total hemispherical emissivity for infrared radiation	

3.3 Subscripts

g for an air space

j layer number

n total number of layers

m section (a, b, c, etc.)

s surface

e exterior, for example the colder side of the component

i interior, for example the warmer side of the component

t total, surface-to-surface

T total, environment-to-environment

4 Basic formulae

4.1 Thermal resistance

4.1.1 Homogeneous layers

Values of the thermal resistances, R, based on measured thermal resistances using calibrated test devices should be used when available.

If measured values are not available, tables of standardized practical thermal resistances for different thicknesses shall be used.

Otherwise, the thermal resistance, R, of a homogeneous layer of solid material shall be determined by the formula

$$R = d/\lambda \qquad \ldots (1)$$

where

d is the thickness of the layer;

λ is the design value of the thermal conductivity of the material.

Design values of the thermal conductivities will form the subject of a future International Standard; for the present, they shall be obtained from national standards.

The thermal resistance of a layer of porous or fibrous material can be calculated from formula (1) if design values of the thermal conductivity are determined on the basis of measured values of thermal conductivity at thicknesses that do not differ much from the standard thickness d.

4.1.2 Air spaces

The thermal resistance of an air space (R_g) that is not ventilated shall be obtained from national standards or, if none exist, may be derived from the annex, table 2.

4.1.3 Surfaces

The external surface thermal resistance (R_{se}) and the internal surface thermal resistance (R_{si}) shall be obtained from national standards or, if none exist, may be derived from the annex, table 1.

4.2 Thermal transmittance

The thermal transmittance of components, from environment to environment, is the reciprocal of the total thermal resistance, i.e.

$$U = 1/R_T \qquad \dots (2)$$

5 Thermal resistance of a component

5.1 Components with homogeneous layers

The total thermal resistance of a plane component consisting of homogeneous layers perpendicular to the heat flow is determined by the following formulae:

a) surface-to-surface:

$$R_t = R_1 + R_2 + \dots + R_n + R_{g1} + R_{g2} + \dots + R_{gn} \qquad \dots (3)$$

b) environment-to-environment

$$R_T = R_{si} + R_t + R_{se} \qquad \dots (4)$$

where

R_1, R_2, ..., R_n are the thermal resistances of the homogeneous layers;

R_{g1}, R_{g2}, ..., R_{gn} are the thermal resistances of air spaces.

5.2 Components with homogeneous and inhomogeneous layers

5.2.1 General

It is possible to calculate an upper and a lower limit of the thermal resistance from environment to environment of a component consisting of homogeneous and inhomogeneous layers parallel to the surface. The thermal resistance of the component is estimated by taking the arithmetic mean. The maximum error in such calculations is related to the ratio of the upper limit to the lower limit, minus one.

Calculation of the upper and lower limits is carried out by splitting the component into sections and layers, as shown in the figure, in such a way that the component is divided into parts m_j, which are themselves homogeneous.

The sections m (m = a, b, c, etc.) perpendicular to the surface of the component have an area A_m.

The layers j (j = 1, 2, ... n) parallel to the surfaces have thicknesses d_j.

Each part has a thermal conductivity λ_{mj}, a thickness d_j and a thermal resistance R_{mj}.

The upper limit of the thermal resistance R'_T, is determined by assuming heat flow lines perpendicular to the surface. It is given by the following formula:

$$R'_T = \frac{A_a + A_b + \dots + A_n}{A_a/R_{Ta} + A_b/R_{Tb} + \dots + A_n/R_{Tn}} \qquad \dots (5)$$

where R_{Ta}, R_{Tb}, ..., R_{Tn} are the total thermal resistances from environment to environment for each section, calculated from formulae (3) and (4).

The lower limit R''_T is determined by assuming that all planes parallel to the surface are isotherms.

An equivalent thermal resistance R_j is calculated for each inhomogeneous layer using the following formula:

$$R_j = \frac{A_a + A_b + \dots + A_n}{A_a/R_{ja} + A_b/R_{jb} + \dots + A_n/R_{jn}} \qquad \dots (6)$$

Alternatively, R_j may be determined by calculating an equivalent thermal conductivity for the inhomogeneous layer using the following formula:

$$R_j = d_j/\lambda''_j \qquad \dots (7)$$

where the equivalent thermal conductivity λ''_j is as given in the following formula:

$$\lambda''_j = \frac{\lambda_a A_a + \lambda_b A_b + \dots + \lambda_n A_n}{A_a + A_b + \dots + A_n} \qquad \dots (8)$$

using d_j/R_{gj} for the apparent thermal conductivity of an air space.

The lower limit is then determined using formulae (3) and (4), i.e.

$$R''_T = R_{se} + R_{si} + R_1 + R_2 + \dots + R_n \qquad \dots (9)$$

5.2.2 Estimated value of thermal resistance

This estimated value is the arithmetic mean of the upper and lower limit, i.e.

$$R_T = \frac{R'_T + R''_T}{2} \qquad \dots (10)$$

The maximum relative error E_m, as a percentage, when using this approximation is given by the following formula:

$$E_m = \frac{100 \left(\frac{R'_T}{R''_T} - 1 \right)}{2} \qquad \dots (11)$$

Example: If the ratio of the upper limit to the lower limit is 1,5, the maximum possible error is 25 %. The actual error is usually much less than the maximum.

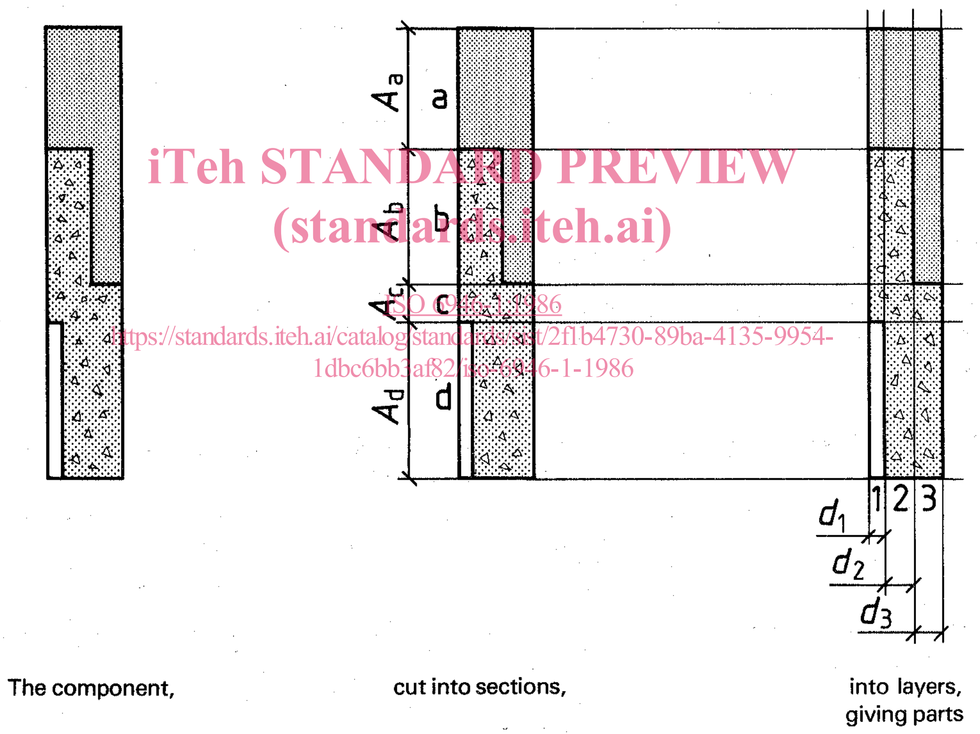

Figure — Sections and layers of an inhomogeneous component

Annex

Some values for design guidance

(This annex does not form part of the Standard.)

A.1 Surface resistance

The surface resistance varies according to a number of parameters, such as the properties of the surface, especially emittance, air velocity along the surface, and the temperatures of the surface, the surrounding air, and the surrounding surfaces.

For heat transfer estimation under ordinary building conditions, the seasonal mean values given in table 1 can be used.

Table 1 — Surface resistance

R_{si}, $m^2 \cdot K/W$			R_{se}, $m^2 \cdot K/W$		
Direction of heat flow			Direction of heat flow		
Horizontal	Up	Down	Horizontal	Up	Down
0,13	0,10	0,17	0,04	0,04	0,04

A.2 Plane, unventilated air space resistance

The values of thermal resistance of enclosed air spaces in table 2 apply for a mean air space temperature between 0 and + 20 °C, and with a temperature difference between the bounding surfaces of less than 15 °C.

Table 2 — Thermal resistance of plane, unventilated air spaces having widths much greater than their thicknesses

Nature of air space surfaces[1]	Thickness of air space, mm	Thermal resistance R_g, $m^2 \cdot K/W$		
		Direction of heat flow		
		Horizontal	Up	Down
No reflective surface (general case) $\varepsilon > 0,8$	5 10 20 50 to 100	0,11 0,14 0,16 0,17	0,11 0,13 0,14 0,14	0,11 0,15 0,18 0,21
One reflective surface $\varepsilon < 0,2$	5 10 20 50 to 100	0,17 0,29 0,37 0,34	0,17 0,23 0,25 0,27	0,17 0,29 0,43 0,61

1) ε is the total hemispherical emissivity at about 280 K. The values for air spaces with one reflective surface can be used only if the emissivity of the surface is controlled and can be expected to stay clean and free from dust, grease or water condensation.