INTERNATIONAL STANDARD

ISO
10077-1

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Thermal performance of windows, doors and shutters — Calculation of thermal transmittance —

Part 1:
Simplified method

Performance thermique des fenêtres, portes et fermetures — Calcul du coefficient de transmission thermique

Partie 1: Méthode simplifiée

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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 member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 10077 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 10077-1 was prepared by the European Committee for Standardization (CEN) in collaboration with ISO Technical Committee TC 163, *Thermal insulation*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this standard, read "...this European Standard..." to mean "...this International Standard...".

ISO 10077 consists of the following parts, under the general title *Thermal performance of windows, doors and shutters — Calculation of thermal transmittance*:

— *Part 1: Simplified method*

— *Part 2: Numerical method for frames*

Annex A forms a normative part of this part of ISO 10077. Annexes B to H are for information only. For the purposes of this part of ISO 10077, the CEN annex regarding fulfilment of European Council Directives has been removed.

Contents

Foreword

The text of EN ISO 10077-1:2000 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 insulation".

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 January 2001, and conflicting national standards shall be withdrawn at the latest by January 2001.

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this standard.

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 standard is one of a series of standards on calculation methods for the design and evaluation of the thermal performance of buildings and building components.

It contains two parts. Part 1 deals with the simplified calculation of the thermal transmittance of windows and doors with or without shutters. Part 2 covers the numerical calculation (two-dimensional) of the thermal transmittance of frame profiles.

Introduction

The method described in this standard is used to evaluate the thermal transmittance of windows and doors, or as part of the determination of the energy use of a building.

An alternative to this calculation method is testing according to EN ISO 12567 "Thermal performance of windows and doors – Determination of thermal transmittance by hot box methods".

In some countries the calculation of the thermal transmittance of windows forms part of their national regulations. Information about national deviations from this standard due to regulations are given in annex ZA.

1   Scope

This standard specifies methods for the calculation of the thermal transmittance of windows and doors consisting of glazed or opaque panels fitted in a frame, with and without shutters.

It allows for:

- different types of glazing (glass or plastics; single or multiple glazing; with or without low emissivity coatings; with spaces filled with air or other gases);
- various types of frames (wood; plastic; metallic with and without thermal barrier; metallic with pinpoint metallic connections or any combination of materials);
- where appropriate, the additional thermal resistance introduced by different types of shutters, depending on their air permeability.

Curtain walls and other structural glazings, which are not fitted in a frame, are excluded from this standard. Roof windows are also excluded because of their complex geometrical frame sections.

Default values for glazings, frames and shutters are given in the informative annexes. Thermal bridge effects at the rebate or joint between the window or door frame and the rest of the building envelope are excluded from the calculation.

The calculation does not include:

– effects of solar radiation;
– heat transfer caused by air leakage;
– calculation of condensation;
– ventilation of air spaces in double and coupled windows.

2 Normative references

This 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 standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publications referred to applies.

EN 673	Glass in building – Determination of thermal transmittance (U value) – Calculation method
EN 674	Glass in building – Determination of thermal transmittance (U value) – Guarded hot plate method
EN 675	Glass in building – Determination of thermal transmittance (U value) – Heat flow meter method
prEN 1098	Measuring method for the determination of the thermal transmittance of multiple glazing (U value) – Calibrated and guarded hot box method
prEN 1279-1	Glass in building - Insulating glass units - Part 1: Generalities and dimensional tolerances
prEN 1279-3	Glass in building - Insulating glass units - Part 3: Initial type testing on gas-filled insulating glass units; gas leakage rate
prEN 12412-2	Windows, doors and shutters - Determination of thermal transmittance by hot box method – Part 2: Frames
EN 12524	Building materials and products – Hygrothermal properties – Tabulated design values
EN ISO 6946	Building components and building elements – Thermal resistance and thermal transmittance – Calculation method (ISO 6946)
EN ISO 7345	Thermal insulation – Physical quantities and definitions (ISO 7345)
prEN ISO 10077-2	Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 2: Numerical method for frames (ISO/DIS 10077-2)
EN ISO 10211-2	Thermal bridges in building construction - Calculation of heat flows and surface temperatures - Part 2: Linear thermal bridges (ISO 10211-2)
ISO 8302	Thermal insulation – Determination of steady-state thermal resistance and related properties – Guarded hot plate apparatus

3   Definitions, symbols and units

3.1   Definitions

For the purposes of this standard, the definitions given in EN 673 and EN ISO 7345 apply.

In clause 4 of this standard, descriptions are given of a number of geometrical characteristics of glazing and frame.

3.2   Symbols

Symbol	Quantity	Unit
A	area	m^2
R	thermal resistance	m$^2 \cdot$K/W
T	temperature	K
U	thermal transmittance	W/(m$^2 \cdot$K)
b	width	m
d	distance / thickness	m
l	length	m
q	density of heat flow rate	W/m^2
Ψ	linear thermal transmittance	W/(m$\cdot$K)
λ	thermal conductivity	W/(m$\cdot$K)

3.3   Subscripts
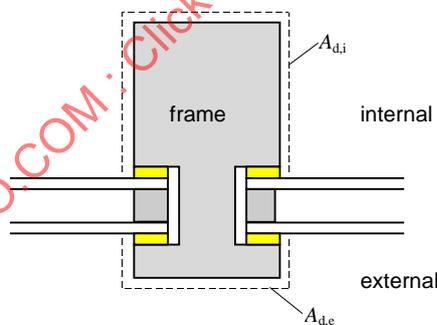
Figure 1 - Internal and external developed area

D	door			
W	window			
WS	window with closed shutter		j	summation index
d	developed		p	panel (opaque)
e	external		s	space (air or gas space)
f	frame		se	external surface
g	glazing		sh	shutter
i	internal		si	internal surface
sa	sash			

4 Geometrical characteristics

4.1 Glazed area, opaque panel area

The glazed area A_g or the opaque panel area A_p of a window or door is the smaller of the visible areas seen from both sides, see figure 2. Any overlapping of gaskets is ignored.

4.2 Total visible perimeter of the glazing

The total perimeter of the glazing l_g (or the opaque panel l_p) is the sum of the visible perimeter of the glass panes (or opaque panels) in the window or door. If the perimeters are different on either side of the pane or panel then the larger of the two shall be used, see figure 2.
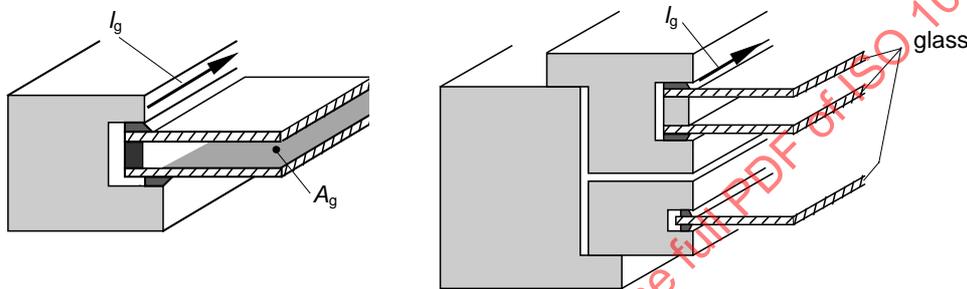

**Figure 2 - Illustration of glazed area and perimeter**

4.3 Frame areas

For the definition of the areas see also figure 3.

$A_{f,i}$ Internal projected frame area
The internal projected frame area is the area of the projection of the internal frame on a plane parallel to the glazing panel.

$A_{f,e}$ External projected frame area
The external projected frame area is the area of the projection of the external frame on a plane parallel to the glazing panel.

A_f Frame area
The frame area is the larger of the two projected areas seen from both sides.

$A_{d,i}$ Internal developed frame area
The internal developed frame area is the area of the frame in contact with the internal air (see figure 1).

$A_{d,e}$ External developed frame area
The external developed frame area is the area of the frame in contact with the external air (see figure 1).

4.4 Window area

The window area A_w is the sum of the frame area A_f and the glazing area A_g (or the panel area A_p).
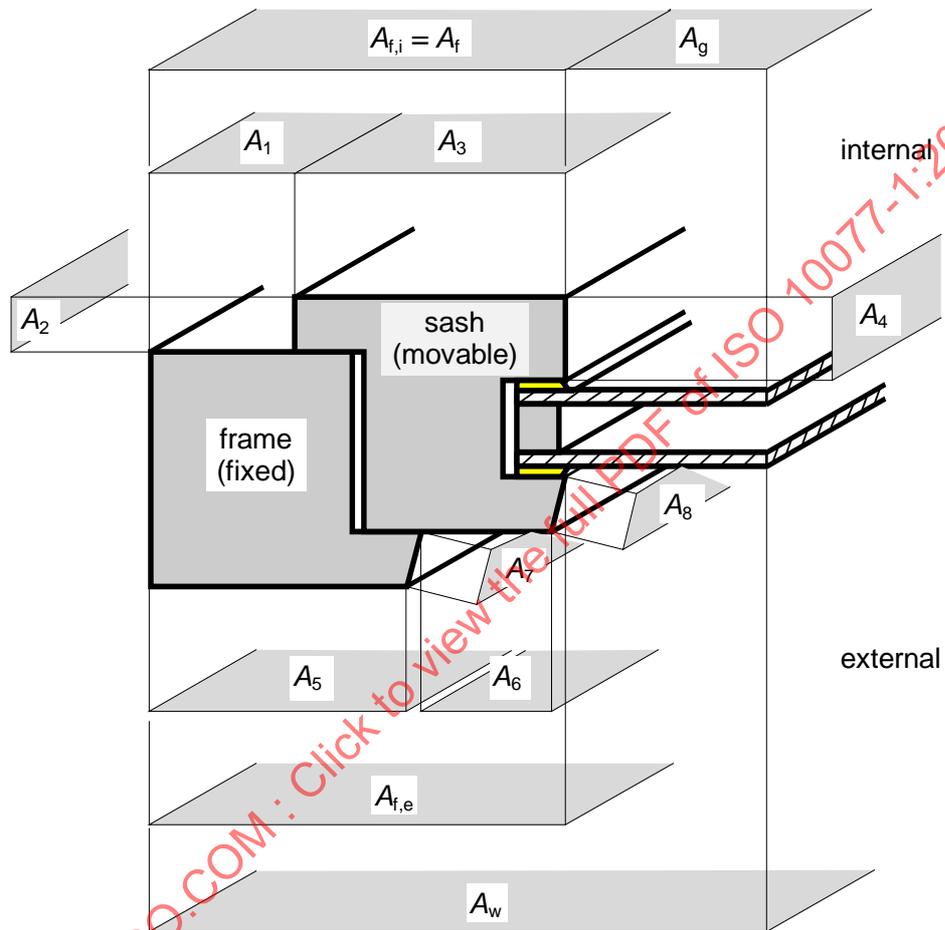
NOTE A_f = max $(A_{f,i}; A_{f,e})$
A_w = $A_f + A_g$
$A_{d,i}$ = $A_1 + A_2 + A_3 + A_4$
$A_{d,e}$ = $A_5 + A_6 + A_7 + A_8$

Figure 3 - Illustration of the various areas

5 Calculation of thermal transmittance

5.1 Windows
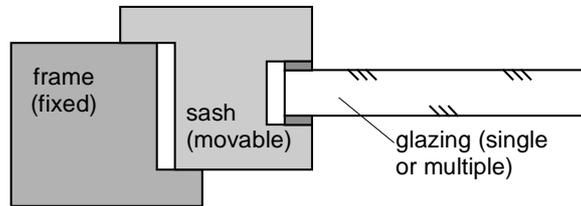
5.1.1 Single windows

Figure 4 - Illustration of single window

The thermal transmittance of a single window U_w shall be calculated using equation (1):

$$U_W = \frac{A_g U_g + A_f U_f + l_g \Psi_g}{A_g + A_f} \qquad (1)$$

where

U_g is the thermal transmittance of the glazing;

U_f is the thermal transmittance of the frame;

Ψ_g is the linear thermal transmittance due to the combined thermal effects of glazing, spacer and frame;

and the other symbols are defined in clause 4.

In the case of single glazing the last term of the numerator in equation (1) shall be taken as zero (no spacer effect) because any correction is negligible.

When opaque panels are used instead of some of the glazing, U_w is calculated as follows:

$$U_W = \frac{A_g U_g + A_p U_p + A_f U_f + l_g \Psi_g + l_p \Psi_p}{A_g + A_p + A_f} \qquad (2)$$

where

U_p is the thermal transmittance of the opaque panel(s);

Ψ_p is the linear thermal transmittance for the opaque panel(s).

If the opaque panel is thermally bridged at the edge by a less insulating spacer, the effect of the bridging shall be taken into account in the same way as for glazing; otherwise $\Psi_p = 0$.

> NOTE Typical values of the linear thermal transmittance are given in annex E.
> prEN ISO 10077-2 gives a method for calculating linear thermal transmittance.
> prEN 12412-2 gives a method for measuring the linear thermal transmittance.
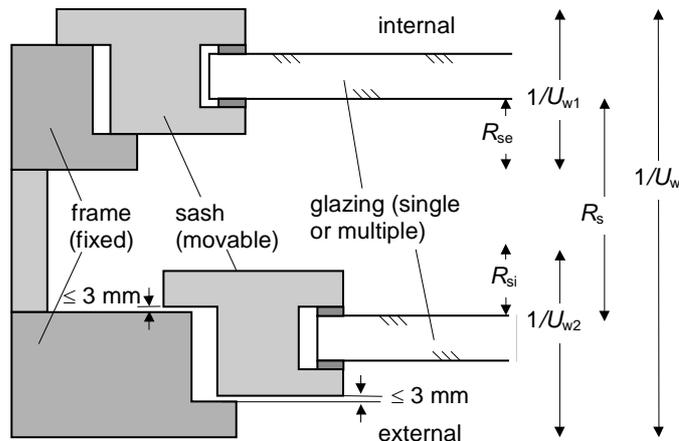
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5.1.2 Double windows

Figure 5 - Illustration of double window

The thermal transmittance U_w of a system consisting of two separate windows shall be calculated by the following equation:

$$U_\mathrm{W} = \frac{1}{1/U_\mathrm{W1} - R_\mathrm{si} + R_\mathrm{s} - R_\mathrm{se} + 1/U_\mathrm{W2}} \qquad (3)$$

where

$U_\mathrm{W1}, U_\mathrm{W2}$ are the thermal transmittances of the external and internal window; respectively, calculated according to equation (1);

R_si is the internal surface resistance of the external window when used alone;

R_se is the external surface resistance of the internal window when used alone;

R_s is the thermal resistance of the space between the glazing in the two windows.

Typical values of R_si and R_se are given in normative annex A and of R_s in the informative annex C.

> NOTE If the gap exceeds 3 mm and measures have not been taken to prevent excessive air exchange with external air, the method does not apply.
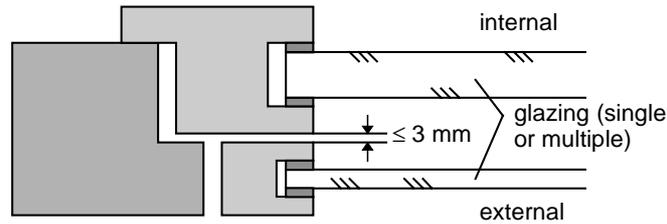
5.1.3 Coupled windows

Figure 6 - llustration of coupled windows

The thermal transmittance U_w of a system consisting of one frame and two separate sashes shall be calculated using equation (1). To determine the thermal transmittance U_g of the combined glazing equation (4) shall be used:

$$U_g = \frac{1}{1/U_{g1} - R_{si} + R_s - R_{se} + 1/U_{g2}} \qquad (4)$$

where

U_{g1}, U_{g2} are the thermal transmittances of the external and internal glazing; respectively, calculated according to equations (5) and (6);

R_{si} is the internal surface resistance of the external glazing when used alone;

R_{se} is the external surface resistance of the internal glazing when used alone;

R_s is the thermal resistance of the space between the internal and external glazing.

Typical values of R_{si} and R_{se} are given in normative annex A and of R_s in the informative annex C.

> NOTE   If the gap exceeds 3 mm and measures have not been taken to prevent excessive air exchange with external air, the method does not apply.

5.2   Glazing

5.2.1   Single glazing

The thermal transmittance of the single and laminated glazing, U_g, shall be calculated with the following equation:

$$U_g = \frac{1}{R_{se} + \sum_j \dfrac{d_j}{\lambda_j} + R_{si}} \qquad (5)$$

where

R_{se} is the external surface resistance;

λ_j is the thermal conductivity of glass or material layer j;

d_j is the thickness of the glass pane or material layer j;

R_{si} is the internal surface resistance.

5.2.2 Multiple glazing

The thermal transmittance of multiple glazing U_g can be calculated according to EN 673 or by means of the following equation:

$$U_g = \frac{1}{R_{se} + \sum_j \dfrac{d_j}{\lambda_j} + \sum_j R_{s,j} + R_{si}}$$ (6)

where

R_{se} is the external surface resistance;
λ_j is the thermal conductivity of glass or material layer j;
d_j is the thickness of the glass pane or material layers j;
R_{si} is the internal surface resistance;
$R_{s,j}$ is the thermal resistance of air space j.

NOTE   Typical values of R_s are given in informative annex C.

5.3   Windows with closed shutters

A shutter on the outside of a window introduces an additional thermal resistance, resulting from both the air layer enclosed between the shutter and the window, and the shutter itself (see figure 7). The thermal transmittance of a window with closed shutters, U_{ws}, is given by:

$$U_{WS} = \frac{1}{1/U_W + \Delta R}$$ (7)

where

U_w is the thermal transmittance of the window;
ΔR is the additional thermal resistance due to the air layer enclosed between the shutter and the window and the closed shutter itself (see figure 7).
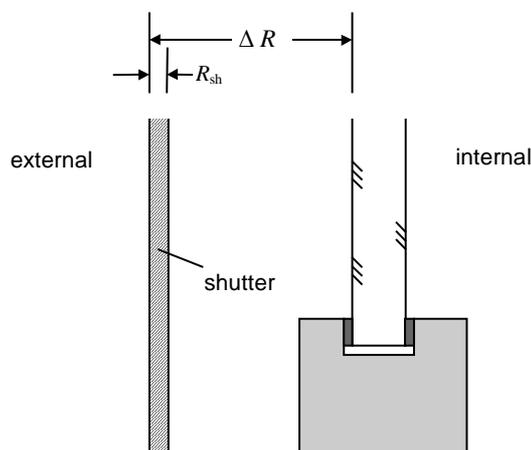

Figure 7 - Window with external shutter

The additional thermal resistance for five categories of shutter air permeability is given in the following expressions:

– shutters with very high air permeability:
$$\Delta R = 0{,}08 \text{ m}^2{\cdot}\text{K/W} \tag{8}$$

– shutters with high air permeability:
$$\Delta R = 0{,}25\,R_{\text{sh}} + 0{,}09 \text{ m}^2{\cdot}\text{K/W} \tag{9}$$

– shutters with an average air permeability (for example solid wing shutters, wooden venetian shutters with solid overlapping slats, roller shutters made of wood, plastic or metal, with connecting slats):

$$\Delta R = 0{,}55\,R_{\text{sh}} + 0{,}11 \text{ m}^2{\cdot}\text{K/W} \tag{10}$$

– shutters with low air permeability:
$$\Delta R = 0{,}80\,R_{\text{sh}} + 0{,}14 \text{ m}^2{\cdot}\text{K/W} \tag{11}$$

– tight shutters:
$$\Delta R = 0{,}95\,R_{\text{sh}} + 0{,}17 \text{ m}^2{\cdot}\text{K/W} \tag{12}$$

where R_{sh} is the thermal resistance of the shutter itself.

The above equations are valid for $R_{\text{sh}} < 0{,}3$ m$^2{\cdot}$K/W. If no measured or calculated values for R_{sh} are available, the typical values given in annexes G and H can be used. For external or internal blinds use equations (8) to (12) with $R_{\text{sh}} = 0$.

> NOTE 1   Annex H gives further information about the permeability of shutters.
> NOTE 2   The expression ΔR for tight shutters is the best current estimate, and future developments may lead to other values.
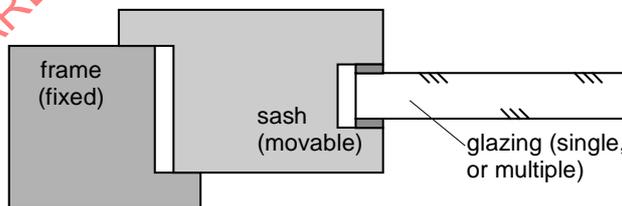
5.4   Doors

Figure 8 - Illustration of door with glazing

The thermal transmittance U_{D} of a doorset, which is of similar design to a window, is obtained using equation (13).

$$U_{\text{D}} = \frac{A_{\text{g}} U_{\text{g}} + A_{\text{f}} U_{\text{f}} + l_{\text{g}} \Psi_{\text{g}}}{A_{\text{g}} + A_{\text{f}}} \tag{13}$$

where

A_f , A_g and l_g are defined in clause 4;

U_g	is the thermal transmittance of the glazing;
U_f	is the thermal transmittance of the frame;
Ψ_g	is the linear thermal transmittance due to the combined thermal effects oglazing spacer and frame;

In the case of single glazing the last term of the numerator in equation (13) shall be taken as zero (no spacer effect) because any correction is negligible.
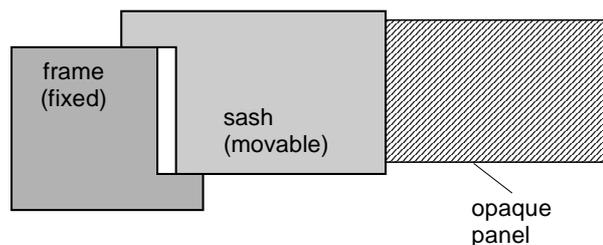

Figure 9 - Schematic illustration of door with opaque panel

If the door consists of frame, glazing and opaque panels, then the following equation shall be used:

$$U_D = \frac{A_g U_g + A_p U_p + A_f U_f + l_g \Psi_g + l_p \Psi_p}{A_g + A_p + A_f} \qquad (14)$$

where

A_p and l_p are defined in clause 4;

U_p	is the thermal transmittance of the opaque panel(s);
Ψ_p	is the linear thermal transmittance for opaque panels.

If the opaque panel is thermally bridged at the edge by a less insulating spacer, the effect of the bridging shall be taken into account in the same way as for glazing.

> NOTE 1   Annex D gives typical values of U_f for different types of frame.
> prEN ISO 10077-2 gives a method for calculating the linear thermal transmittance.
> NOTE 2   Typical values of Ψ are given in annex E.

The thermal transmittance of door leaves without a frame and without inhomogeneities (having different layers only perpendicular to the heat flow direction) can be measured in the guarded hot plate apparatus, in accordance with ISO 8302.

If the doorset does not have a design similar to a window system then the thermal transmittance of the door leaves can be calculated in accordance with EN ISO 6946 provided that the ratio of the thermal conductivities of any two different materials in the door does not exceed 1:5 (screws, nails, and so on are excluded); this method includes the calculation of the maximum relative error which should be less than 10 %.

If the maximum relative error is higher than 10 % or the ratio of the thermal conductivities of the different materials is greater than 1:5 a numerical calculation in accordance with prEN ISO 10077-2 and/or EN ISO 10211-2 should be carried out.

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6 Input data

The thermal transmittance of the frame, U_f, is to be determined with the glazing replaced with a material of thermal conductivity not exceeding 0,04 W/(m·K), by hot box measurement or numerical calculation in accordance with prEN ISO10077-2. The thermal transmittance of the glazing, U_g, is to be determined according to EN 673, EN 674 or EN 675. Both U_f and U_g thus exclude the thermal interaction between the frame and the glazing (or opaque panel), which is taken into account by the linear thermal transmittance, Ψ, either tabulated in this standard or obtained by numerical calculations in accordance with prEN ISO 10077-2 or by measurement in accordance with prEN 12412-2.

Other values to be used in the basic formulae can be obtained from annex A and EN 12524 or by means of prEN 1098, EN ISO 6946 and ISO 8302.

If measured or calculated data are not available, the values in informative annexes B to H may be used.

If the results are to be used for comparison of the performance of different windows, the sources of the numerical values of each parameter shall be identical for each door or window included in the comparison.

7 Report

The calculation report shall include the following.

7.1 Drawing of sections

A technical drawing (preferably scale 1:1) giving the sections of all the different frame parts permitting verification of:
– the thickness, height, position, type and number of thermal breaks (for metallic frames);
– the number and thickness of air chambers (for plastic frames only);
– the presence and position of metal stiffening (for plastic frames only);
– the thickness of wooden frames and the thickness of plastic and PUR–frame (polyurethane) material;
– the thickness of gas spaces, the identification of the gas and the percentage assured to be present;
– the type of glass and its thickness or its thermal properties and emissivity of its surfaces;
– the thickness and description of any opaque panels in the frame;
– the internal projected frame area $A_{f,i}$ and the external projected frame area $A_{f,e}$;
– the internal developed frame area $A_{d,i}$ and the external developed frame area $A_{d,e}$ (only for metallic frames);
– the position of the glass spacers or of the edge stiffening for opaque panels; description of any shutters.

In the case of metallic frames with pin-point connections the distance between the pinpoints shall be clearly indicated.

7.2 Drawing of the whole window or door

A drawing of the whole window or door (seen from inside) with the following information:
– glazed area A_g and/or opaque panel area A_p;
– frame area: A_f;
– perimeter length of the glazing l_g and/or of the opaque panels l_p.

7.3 Values used in the calculation

a) If the informative annexes are used this shall be clearly stated and reference shall be made to the tables in the annexes.

b) If other sources are used to determine one or more of the U_g, U_f and Ψ values, the sources shall be given. It shall be ascertained that these other sources use the same definitions of the areas A_g, A_f and of the perimeter length l_g and l_p.

c) If a glazing not covered by the table in the annex C is used, a detailed calculation following EN 673 shall be given.

d) If measured or calculated values are used for one of the three parameters the relevant standards shall be identified and it shall be confirmed that the values obtained correspond to the definitions of the areas given in this standard.

7.4 Presentation of results

The thermal transmittance of the window or door, calculated according to the standard shall be given with two significant figures.

Annex A (normative)

Internal and external surface thermal resistances

For typical normal emissivities ($\geq 0{,}8$) for the inside and outside surfaces of the glazing, the following values for the surface resistances R_{se} and R_{si} shall be used.

Table A.1 - Surface thermal resistances

Window position	Internal R_{si} m²·K/W	External R_{se} m²·K/W
Vertical or inclination α of the glazing to the horizontal such that $90° \geq \alpha > 60°$	0,13	0,04

R_{si} for special cases, for example a low emissivity coating on the outer surface of the interior pane, can be calculated according to EN 673.

Annex B (informative)

Thermal conductivity of glass

In the absence of specific information for the glass concerned the value $\lambda = 1{,}0$ W/(m·K) should be used.

Annex C (informative)

Thermal resistance of air spaces between glazing and thermal transmittance of coupled or double glazing

Table C.1 gives some values of the thermal resistance R_s of air spaces for double glazing, calculated according to EN 673. The data apply:

–   for vertical windows or an inclination α of the glazing to the horizontal such that 90 ° $\geq \alpha > 60°$;
–   for spaces filled with air;
–   with both sides uncoated or with one side coated with a low emissivity layer;
–   for a mean temperature of the glazing of 283 K and a temperature difference of 15 K between the two outer glazing surfaces.

For triple glazing the procedure in EN 673 should be used.

Table C.1 - Thermal resistance R_s of unventilated air spaces, in m²·K/W, for coupled and double windows

Thickness of air space	One side coated with a normal emissivity of:				Both sides uncoated
mm	0,1	0,2	0,4	0,8	
6	0,211	0,190	0,163	0,132	0,127
9	0,298	0,259	0,211	0,162	0,154
12	0,376	0,316	0,247	0,182	0,173
15	0,446	0,363	0,276	0,197	0,186
50	0,406	0,335	0,260	0,189	0,179
100	0,376	0,315	0,247	0,182	0,173
300	0,333	0,284	0,228	0,171	0,163

For wide air layers like in double windows or doors the calculation according to EN 673 does not lead to correct results. In such cases more sophisticated calculation methods or measurements should be used.

Table C.2 gives the thermal transmittance U_g of double and triple glazing filled with different gases, calculated in accordance with EN 673. The values of the thermal transmittance in the table apply to the emissivities and gas concentrations given. For individual glazing units the emissivity and/or gas concentration may change with time. Procedures for evaluating the effect of ageing on the thermal properties of glazed units are given in prEN 1279-1 and prEN 1279-3.

Table C.2 - Thermal transmittance U_g of double and triple glazing filled with different gases

Glazing				Type of gas space (gas concentration $\geq$ 90 %)			
Type	Glass	Normal emissivity	Dimensions mm	Air	Argon	Krypton	SF6
Double glazing	Uncoated glass (normal glass)	0,89	4-6-4	3,3	3,0	2,8	3,0
			4-9-4	3,0	2,8	2,6	3,1
			4-12-4	2,9	2,7	2,6	3,1
			4-15-4	2,7	2,6	2,6	3,1
			4-20-4	2,7	2,6	2,6	3,1
	One pane coated glass	$\leq$0,4	4-6-4	2,9	2,6	2,2	2,6
			4-9-4	2,6	2,3	2,0	2,7
			4-12-4	2,4	2,1	2,0	2,7
			4-15-4	2,2	2,0	2,0	2,7
			4-20-4	2,2	2,0	2,0	2,7
	One pane coated glass	$\leq$0,2	4-6-4	2,7	2,3	1,9	2,3
			4-9-4	2,3	2,0	1,6	2,4
			4-12-4	1,9	1,7	1,5	2,4
			4-15-4	1,8	1,6	1,6	2,5
			4-20-4	1,8	1,7	1,6	2,5
	One pane coated glass	$\leq$0,1	4-6-4	2,6	2,2	1,7	2,1
			4-9-4	2,1	1,7	1,3	2,2
			4-12-4	1,8	1,5	1,3	2,3
			4-15-4	1,6	1,4	1,3	2,3
			4-20-4	1,6	1,4	1,3	2,3
	One pane coated glass	$\leq$0,05	4-6-4	2,5	2,1	1,5	2,0
			4-9-4	2,0	1,6	1,3	2,1
			4-12-4	1,7	1,3	1,1	2,2
			4-15-4	1,5	1,2	1,1	2,2
			4-20-4	1,5	1,2	1,2	2,2
Triple glazing	Uncoated (normal) glass	0,89	4-6-4-6-4	2,3	2,1	1,8	2,0
			4-9-4-9-4	2,0	1,9	1,7	2,0
			4-12-4-12-4	1,9	1,8	1,6	2,0
	2 panes coated	$\leq$0,4	4-6-4-6-4	2,0	1,7	1,4	1,6
			4-9-4-9-4	1,7	1,5	1,2	1,6
			4-12-4-12-4	1,5	1,3	1,1	1,6
	2 panes coated	$\leq$0,2	4-6-4-6-4	1,8	1,5	1,1	1,3
			4-9-4-9-4	1,4	1,2	0,9	1,3
			4-12-4-12-4	1,2	1,0	0,8	1,4
	2 panes coated	$\leq$0,1	4-6-4-6-4	1,7	1,3	1,0	1,2
			4-9-4-9-4	1,3	1,0	0,8	1,2
			4-12-4-12-4	1,1	0,9	0,6	1,2
	2 panes coated	$\leq$0,05	4-6-4-6-4	1,6	1,3	0,9	1,1
			4-9-4-9-4	1,2	0,9	0,7	1,1
			4-12-4-12-4	1,0	0,8	0,5	1,1

NOTE   The values of thermal transmittance in the table were calculated using EN 673. They apply to the emissivities and gas concentration given. For individual glazing units the emissivity and/or gas concentrations may change with time. Procedures for evaluating the effect of ageing on the thermal properties of glazed units are given in prEN 1279-1 and prEN 1279-3.

Annex D (informative)

Thermal transmittance of frames

Values of U_f evaluated by numerical calculation methods (finite element, finite difference) in accordance with prEN ISO10077-2 can be used as input data for calculations, as can values of U_f obtained by direct measurements using hot box methods in accordance with prEN 12412-2.

If no other information is available, the values derived from the following tables and graphs can be used in the calculations for the corresponding frame types.

All values given in this annex refer to the vertical position only. Typical values for common types of frames are given in table D.1, figure D.2 and figure D.4, which can be used in the absence of specific measured or calculated information for the frame concerned.

All the values shown in table D.1, figure D.2 and figure D.4 are based on a large number of measured values as well as mathematically evaluated values determined using numerical calculation methods. They include the effect of the developed areas.

Future development should not be impeded by tabulated U_f values. Values for frames which are not described in the tables should be determined by measurements or calculations.

Especially in the case of aluminium profiles with thermal breaks[1] there is the problem that the thermal transmittance of the frame is influenced by different construction characteristics, such as:
– the distance *a* between the aluminium sections;
– the width *b* of the material of the thermal break zones;
– the conductivity of the thermal break material;
– the ratio of the width of the thermal break to the frame projection width.

A thermal break can be considered as such only if it completely separates the metal sections on the cold side from the metal sections on the warm side.

The values in this annex are based on R_{si} = 0,13 m²·K/W and R_{se} = 0,04 m²·K/W.
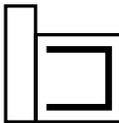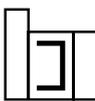
It is common practice to produce "Profile Systems" comprising a large number of different frames, having a wide range of geometric shapes but having similar thermal properties. This is because in these groups of frames, the important parameters such as the size, material and design of the thermal break, are the same. A document specifying practical procedures for evaluating the thermal properties of such "profile systems" is under preparation.

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[1] The values of U_f in table D.1, figure D.2 and figure D.4 cannot be used for sliding windows but the principle of equation (1) can be used.

Plastic frames

If no other data are available, the values in table D.1 can be used for frames without metal reinforcements.

Table D.1 - Thermal transmittances for plastic frames with metal reinforcements

Frame material	Frame type	U_f W/(m²·K)
Polyurethane	with metal core thickness of PUR ≥ 5 mm	2,8
PVC-hollow profiles[1]	external · · internal two hollow chambers	2,2
	external · · internal three hollow chambers	2,0
[1] With a distance between wall surfaces of hollow chambers of at least 5 mm (refer to figure D.1).		

Dimensions in millimetres

≥ 5
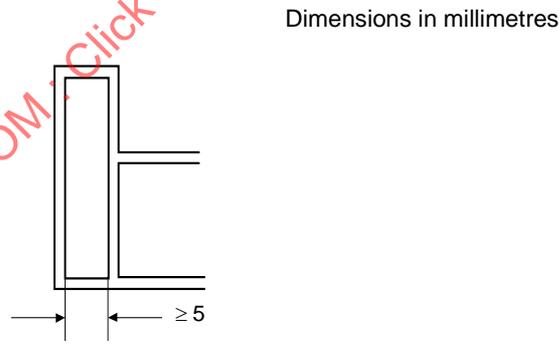
Figure D.1 - Hollow chamber in plastic frame

Other plastic profile sections should be measured or calculated.

Wood frames

Values for wood frames can be taken from figure D.2. For U_f, the values correspond to a moisture content of 12 %. For definition of the thickness of the frame see figure D.3.
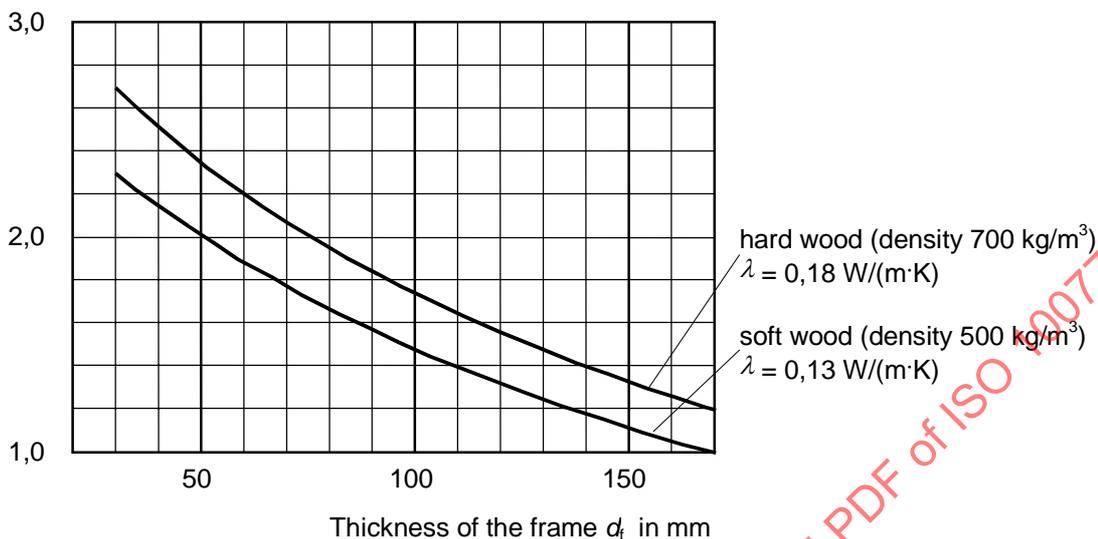
U_f in (W/m²·K)

hard wood (density 700 kg/m³)
$\lambda = 0,18$ W/(m·K)

soft wood (density 500 kg/m³)
$\lambda = 0,13$ W/(m·K)

Thickness of the frame d_f in mm

Figure D.2 - Thermal transmittances for wooden frames and metal-wood frames (see figure D.3) depending on the frame thickness d_f

wood   metal-wood   metal-wood

internal:
right side of
frame section

$$d_f = \frac{d_1 + d_2}{2}$$

external:
left side of
frame section

wood   wood   metal-wood

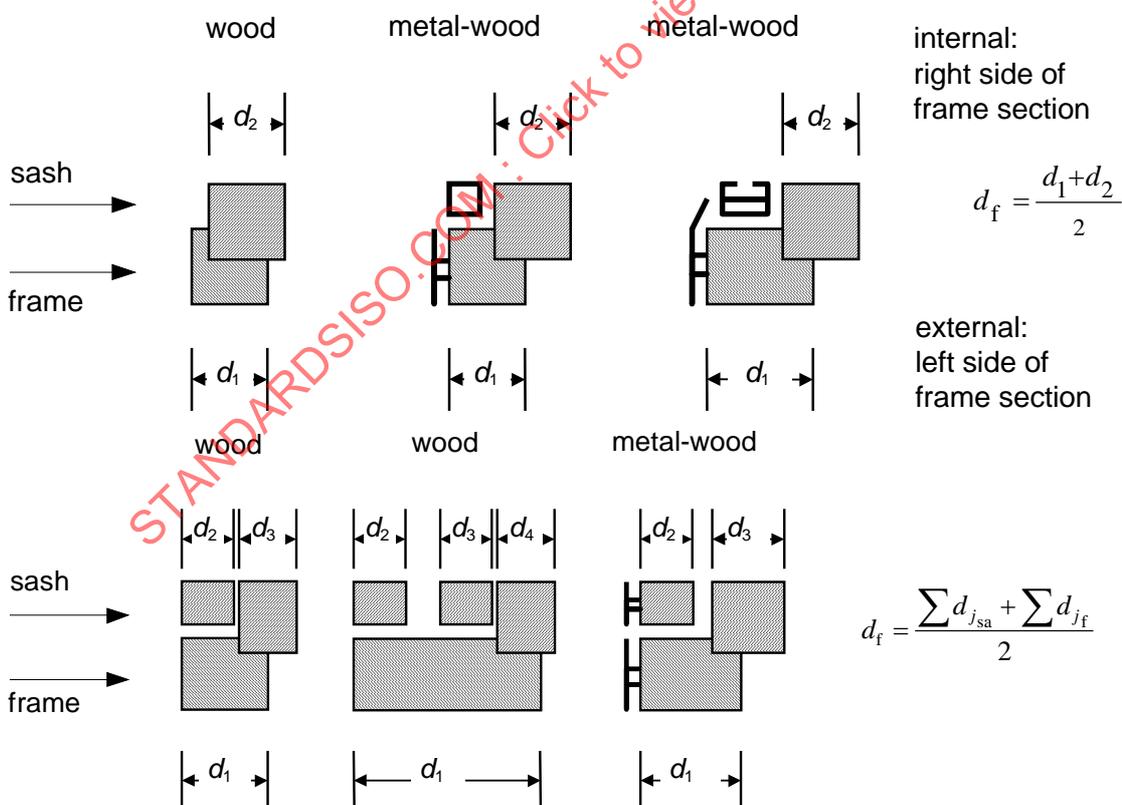$$d_f = \frac{\sum d_{j_{sa}} + \sum d_{j_f}}{2}$$

Figure D.3 - Definition of the thickness d_f of the frame for various window systems
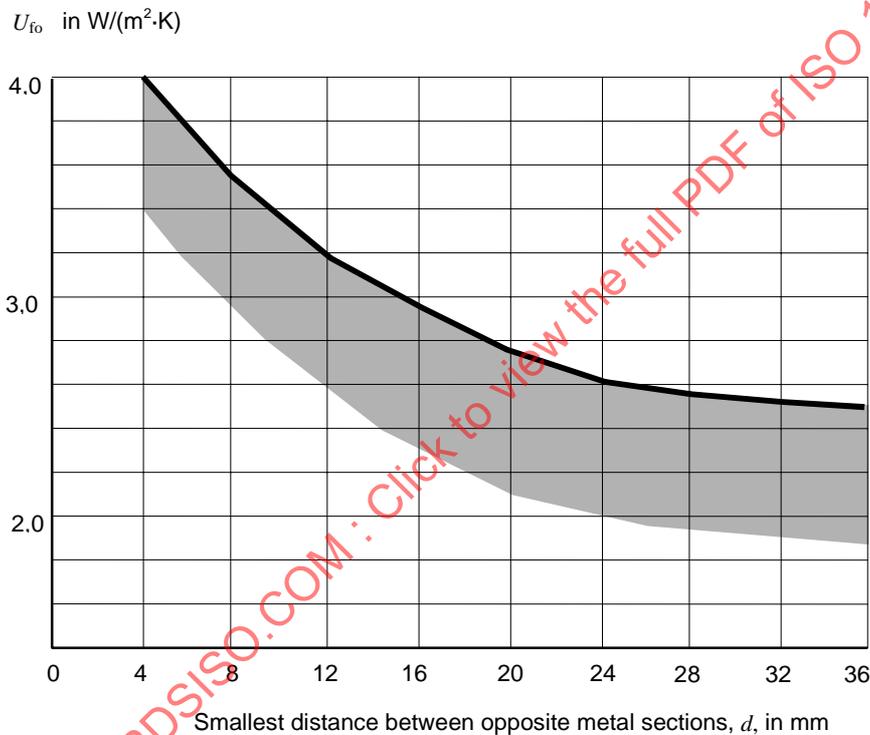
Metal frames

The thermal transmittance of metal frames can be determined by measurement using hot box methods in accordance with prEN 12412-2 or by numerical calculation in accordance with prEN ISO 10077-2. Values obtained by such methods should be used when available, in preference to the method given in this annex.

If such data are not available, values of U_f can be obtained by the following procedure for:

- metal frames without a thermal break;
- metal frames with thermal breaks corresponding to the sections illustrated in figure D.5 and figure D.6, subject to restrictions on the thermal conductivity and widths of the thermal breaks.

For metal frames without a thermal break, use $U_{fo} = 5,9$ W/(m²·K).
For metal frames with thermal breaks, take U_{fo} from the solid line in figure D.4.

U_{fo} in W/(m²·K)

Smallest distance between opposite metal sections, d, in mm

NOTE   The shaded area indicates the range of values obtained from many measurements on frames carried out in several European countries, derived from the surface temperature difference across the frame.

Figure D.4 - U_{f0} -values for metal frames with thermal break

The thermal resistance of the frame, R_f, is given by

$$R_f = \frac{1}{U_{f0}} - 0,17 \tag{D.1}$$

and the thermal transmittance of the frame, U_f, from

$$U_f = \frac{1}{R_{si} A_{f,i} / A_{d,i} + R_f + R_{se} A_{f,e} / A_{d,e}} \tag{D.2}$$

where

$A_{d,i}$, $A_{d,e}$, $A_{f,i}$, $A_{f,e}$, are the areas as defined in clause 4, expressed in square metres;

R_{si} is the appropriate internal surface resistance of the frame, in $m^2 \cdot K/W$;

R_{se} is the appropriate external surface resistance of the frame, in $m^2 \cdot K/W$;

R_f is the thermal resistance of the frame section, in $m^2 \cdot K/W$, resulting from the thermal transmittance of the frame taking into account the appropriate surface resistance.

U_{f0} is the thermal transmittance, in $W/(m^2 \cdot K)$, calculated as if the developed area were equal to the projected area.
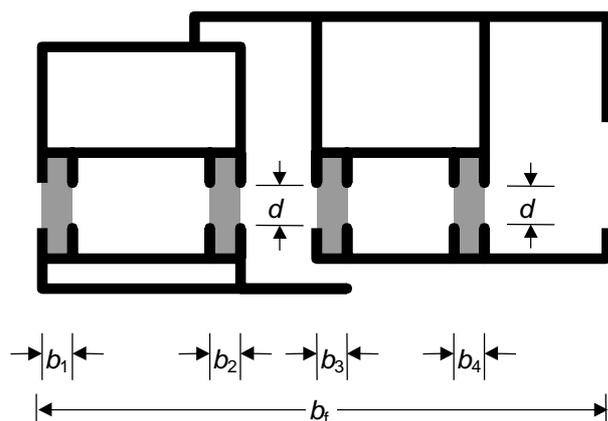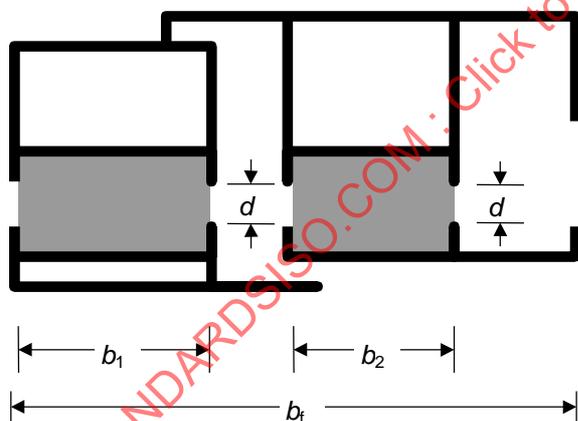

Thermal conductivity of thermal break materials
$0,2 < \lambda \leq 0,3$ W/(m·K)

d is the smallest distance between opposite aluminium sections of the thermal break;

b_j is the width of thermal break j;

b_f is the width of the frame.

$$\sum_j b_j \leq 0,2 b_f$$

Figure D.5 - Section Type 1: Thermal break with a thermal conductivity below 0,3 W/(m·K)

Thermal conductivity of thermal break materials
$0,1 < \lambda \leq 0,2$ W/(m·K)

d is the smallest distance between opposite aluminium sections of the thermal break;

b_j is the width of thermal break j;

b_f is the width of the frame.

$$\sum_j b_j \leq 0,3 b_f$$

Figure D.6 - Section Type 2: Thermal break with a thermal conductivity below 0,2 W/(m·K)

If the thermal conductivity of the termal break material is below 0,1 W/(m.K), the definition in figure D.6 is not valid.