EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 10077-1

July 2017

ICS 91.060.50; 91.120.10

Supersedes EN ISO 10077-1:2006

English Version

Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 1: General (ISO 10077-1:2017, Corrected version 2020-02)

Performance thermique des fenêtres, portes et fermetures - Calcul du coefficient de transmission thermique - Partie 1: Généralités (ISO 10077-1:2017, Version corrigée 2020-02)

Wärmetechnisches Verhalten von Fenstern, Türen und Abschlüssen - Berechnung des Wärmedurchgangskoeffizienten - Teil 1: Allgemeines (ISO 10077-1:2017, korrigierte Fassung 2020-02)

This European Standard was approved by CEN on 27 February 2017.

This European Standard was corrected and reissued by the CEN-CENELEC Management Centre on 18 March 2020.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Ref. No. EN ISO 10077-1:2017 E

European foreword

This document (EN ISO 10077-1:2017) 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of an identical text or by endorsement, at the latest by January 2018 and conflicting national standards shall be withdrawn at the latest by January 2018.

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

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This document is part of the set of standards on the energy performance of buildings (the set of EPB standards) and has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association (Mandate M/480, see reference [EF1] below), and supports essential requirements of EU Directive 2010/31/EC on the energy performance of buildings (EPBD, [EF2]).

In case this standard is used in the context of national or regional legal requirements, mandatory choices may be given at national or regional level for such specific applications, in particular for the application within the context of EU Directives transposed into national legal requirements.

Further target groups are users of the voluntary common European Union certification scheme for the energy performance of non-residential buildings (EPBD art.11.9) and any other regional (e.g. Pan European) parties wanting to motivate their assumptions by classifying the building energy performance for a dedicated building stock.

This document supersedes EN ISO 10077-1:2006.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

References:

[EF1] Mandate M480, Mandate to CEN, CENELEC and ETSI for the elaboration and adoption of standards for a methodology calculating the integrated energy performance of buildings and promoting the energy efficiency of buildings, in accordance with the terms set in the recast of the Directive on the energy performance of buildings (2010/31/EU) of 14th December 2010

[EF2] EPBD, Recast of the Directive on the energy performance of buildings (2010/31/EU) of 14th December 2010.

Endorsement notice

The text of ISO 10077-1:2017, Corrected version 2020-02 has been approved by CEN as EN ISO 10077-1:2017 without any modification.

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

ISO 10077-1 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 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 third edition cancels and replaces the second edition (ISO 10077-1:2006), of which it constitutes a minor revision. The necessary editorial revisions were made to comply with the requirements for the EPB set of standards.

In addition, the following clauses and subclauses of the previous version have been revised.

— In Clause 6 (previous edition), the boundary condition "determined with the glazing replaced with a material of thermal conductivity not exceeding 0,04 W/(m^2·K)" was deleted, because the rules are defined in EN 12412-2.

— In Clause 6 (previous edition), the measurement according to EN 12412-2 for the determination of Ψ_g and/or Ψ_p was deleted. It is not within the scope of EN 12412-2 to determine Ψ values.

— In Clause 6 (previous edition), the second paragraph was deleted. It is not necessary to give further possibilities. Determination of the input data in unambiguous is defined.

— In 5.2.2 (previous edition), the formula was deleted. Determination of U_g is according to ISO 10292.[1)]

— Formulae (1) and (2) were extended for the consideration of glazing bars.

— Tabulated values were added for the linear thermal transmittance of glazing bars.

— Status of Annex C (previous edition) was changed to normative; some values were revised to give the values to two significant figures.

1) See Table C.1 for alternative regional references in line with ISO Global Relevance Policy.

— Table C.2 (previous edition) was moved to ISO/TR 52022-2:2017.

— Annex E (previous edition) was moved to the main body of the document.

— Annex G and Annex H (previous edition) were moved to ISO/TR 52022-2:2017.

It also incorporates the Technical Corrigendum ISO 10077-1:2006/Cor. 1:2009.

A list of all parts in the ISO 10077 series can be found on the ISO website.

This corrected version of ISO 10077-1:2017 incorporates the following corrections:

— In the Introduction, the reference to Annex D was changed to Annex F;

— In the Introduction, the reference to Annex E was changed to Annex G;

— In 6.3.2.2, the reference to Annex G was changed to Annex H;

— In 6.3.2.3.2, Ug was changed to U_g;

— In the Note in 6.4.2.1.2, the reference to Annex F was changed to Annex E;

— In the header of Tables H.2, H.3 and H.4, the value was changed from 0,8 to 0,80;

— In Table H.3, in the thirteenth column and first row after the header, the value was changed from 51 to 5,1;

— In Table H.3, in the third column and twenty-ninth row after the header, the value was changed from 0,18 to 0,81.

Introduction

This document is part of a series of standards aiming at international harmonization of the methodology for the assessment of the energy performance of buildings, called "set of EPB standards."

All EPB standards follow specific rules to ensure overall consistency, unambiguity and transparency.

All EPB standards provide a certain flexibility with regard to the methods, the required input data and references to other EPB standards, by the introduction of a normative template in Annex A and Annex B with informative default choices.

For the correct use of this document, a normative template is given in Annex A to specify these choices. Informative default choices are provided in Annex B.

The main target groups of this document are manufacturers of windows.

Use by or for regulators: In case the document is used in the context of national or regional legal requirements, mandatory choices may be given at national or regional level for such specific applications. These choices (either the informative default choices from Annex B or choices adapted to national/regional needs, but in any case, following the template in Annex A) can be made available as national annex or as separate (e.g. legal) document (national data sheet).

NOTE 1 So in this case:

— the regulators will **specify** the choices;

— the individual user will apply the standard to assess the energy performance of a building, and thereby **use** the choices made by the regulators.

Topics addressed in this document can be subject to public regulation. Public regulation on the same topics can override the default values in Annex B. Public regulation on the same topics can even, for certain applications, override the use of this document. Legal requirements and choices are in general not published in standards but in legal documents. In order to avoid double publications and difficult updating of double documents, a national annex may refer to the legal texts where national choices have been made by public authorities. Different national annexes or national data sheets are possible, for different applications.

It is expected, if the default values, choices and references to other EPB standards in Annex B are not followed due to national regulations, policy or traditions, that

— national or regional authorities prepare data sheets containing the choices and national or regional values, according to the model in Annex A. In this case, a national annex (e.g. NA) is recommended, containing a reference to these data sheets;

— or, by default, the national standards body will consider the possibility to add or include a national annex in agreement with the template in Annex A, in accordance to the legal documents that give national or regional values and choices.

Further target groups are parties wanting to motivate their assumptions by classifying the building energy performance for a dedicated building stock.

More information is provided in the Technical Report accompanying this document (ISO/TR 52022-2).

The calculation method described in this document 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 calculation is testing of the complete window or door according to ISO 12567-1 or, for roof windows, according to ISO 12567-2.

The calculation is based on four component parts of the overall thermal transmittance:

— for elements containing glazing, the thermal transmittance of the glazing, calculated using EN 673 or measured according to EN 674 or EN 675;

— for elements containing opaque panels, the thermal transmittance of the opaque panels, calculated according to ISO 6946 and/or ISO 10211 (all parts) or measured according to ISO 8301 or ISO 8302;

— thermal transmittance of the frame, calculated using ISO 10077-2, measured according to EN 12412-2, or taken from Annex F;

— linear thermal transmittance of the frame/glazing junction, calculated according to ISO 10077-2 or taken from Annex G.

The thermal transmittance of curtain walling can be calculated using ISO 12631.

EN 13241-1 gives procedures applicable to doors intended to provide access for goods and vehicles.

Table 1 shows the relative position of this document within the set of EPB standards in the context of the modular structure as set out in ISO 52000-1.

NOTE 2 In ISO/TR 52000-2, the same table can be found, with, for each module, the numbers of the relevant EPB standards and accompanying technical reports that are published or in preparation.

NOTE 3 The modules represent EPB standards, although one EPB standard could cover more than one module and one module could be covered by more than one EPB standard, for instance, a simplified and a detailed method respectively.

Table 1 — Position of this document (in case M2–5) within the modular structure of the set of EPB standards

	Overarching		**Building (as such)**		**Technical Building Systems**									
Sub-module	**Descriptions**		**Descriptions**		**Descriptions**	**Heating**	**Cooling**	**Ventilation**	**Humidification**	**Dehumidification**	**Domestic hot water**	**Lighting**	**Building automation and control**	**PV, wind, ..**
sub1		**M1**		**M2**		**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**
1	General		General		General									
2	Common terms and definitions; symbols, units and subscripts		Building energy needs		Needs								a	
3	Applications		(Free) indoor conditions without systems		Maximum load and power									
4	Ways to express energy performance		Ways to express energy performance		Ways to express energy performance									
5	Building categories and building boundaries		Heat transfer by transmission	ISO 10077-1	Emission and control									
6	Building occupancy and operating conditions		Heat transfer by infiltration and ventilation		Distribution and control									

[a] The shaded modules are not applicable.

Table 1 *(continued)*

	Overarching		Building (as such)		Technical Building Systems									
Sub-module	**Descriptions**		**Descriptions**		**Descriptions**	**Heating**	**Cooling**	**Ventilation**	**Humidification**	**Dehumidification**	**Domestic hot water**	**Lighting**	**Building automation and control**	**PV, wind, ..**
sub1		**M1**		**M2**		**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**
7	Aggregation of energy services and energy carriers		Internal heat gains		Storage and control									
8	Building zoning		Solar heat gains		Generation and control									
9	Calculated energy performance		Building dynamics (thermal mass)		Load dispatching and operating conditions									
10	Measured energy performance		Measured energy performance		Measured Energy Performance									
11	Inspection		Inspection		Inspection									
12	Ways to express indoor comfort				BMS									
13	External environment conditions													
14	Economic calculation													

[a] The shaded modules are not applicable.

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

Part 1: General

1 Scope

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

This document allows for

— different types of glazing (glass or plastic; single or multiple glazing; with or without low emissivity coatings, and with spaces filled with air or other gases),

— opaque panels within the window or door,

— various types of frames (wood, plastic, metallic with and without thermal barrier, metallic with pinpoint metallic connections or any combination of materials), and

— where appropriate, the additional thermal resistance introduced by different types of closed shutter or external blind, depending on their air permeability.

The thermal transmittance of roof windows and other projecting windows can be calculated according to this document, provided that the thermal transmittance of their frame sections is determined by measurement or by numerical calculation.

Default values for glazing, frames and shutters are given in the 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 (see standards under M2-8),

— heat transfer caused by air leakage (see standards under M2-6),

— calculation of condensation,

— ventilation of air spaces in double and coupled windows, and

— surrounding parts of an oriel window.

The document is not applicable to

— curtain walls and other structural glazing (see other standards under M2-5), and

— industrial, commercial and garage doors.

NOTE Table 1 in the Introduction shows the relative position of this document within the set of EPB standards in the context of the modular structure as set out in ISO 52000-1.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 6946, *Building components and building elements — Thermal resistance and thermal transmittance — Calculation method*

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

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*

ISO 10077-2, *Thermal performance of windows, doors and shutters — Calculation of thermal transmittance — Part 2: Numerical method for frames*

ISO 10211, *Thermal bridges in building construction — Heat flows and surface temperatures — Detailed calculations*

ISO 10291, *Glass in building — Determination of steady-state U values (thermal transmittance) of multiple glazing — Guarded hot plate method*

ISO 10292, *Glass in building — Calculation of steady-state U values (thermal transmittance) of multiple glazing*

ISO 10293, *Glass in building — Determination of steady-state U values (thermal transmittance) of multiple glazing — Heat flow meter method*

ISO 10456, *Building materials and products — Hygrothermal properties — Tabulated design values and procedures for determining declared and design thermal values*

ISO 12567-2, *Thermal performance of windows and doors — Determination of thermal transmittance by hot box method — Part 2: Roof windows and other projecting windows*

ISO 52000-1:2017, *Energy performance of buildings — Overarching EPB assessment —– Part 1: General framework and procedures*

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*

EN 12412-2, *Thermal performance of windows, doors and shutters — Determination of thermal transmittance by hot box method — Frames*

EN 12664, *Thermal performance of building materials and products — Determination of thermal resistance by means of guarded hot plate and heat flow meter methods — Dry and moist products of medium and low thermal resistance*

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 13125, *Shutters and blinds — Additional thermal resistance — Allocation of a class of air permeability to a product*

EN 13561, *External blinds and awnings — Performance requirements including safety*

EN 13659, *Shutters and external venetian blinds — Performance requirements including safety*

NOTE Default references to EPB standards other than ISO 52000-1 are identified by the EPB module code number and given in Annex A (normative template in Table A.1) and Annex B (informative default choice in Table B.1).

EXAMPLE EPB module code number: M5–5, or M5–5.1 (if module M5–5 is subdivided), or M5–5/1 (if reference to a specific clause of the standard covering M5–5).

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10292, ISO 7345, ISO 52000-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

NOTE In Clause 6, descriptions are given of a number of geometrical characteristics of glazing and frame.

3.1
EPB standard
standard that complies with the requirements given in ISO 52000-1, CEN/TS 16628[3] and CEN/TS 16629[4]

Note 1 to entry: These three basic EPB documents were developed under a mandate given to CEN by the European Commission and the European Free Trade Association (Mandate M/480), and support essential requirements of EU Directive 2010/31/EU on the energy performance of buildings (EPBD). Several EPB standards and related documents are developed or revised under the same mandate.

[SOURCE: ISO 52000-1:2017, definition 3.5.14]

4 Symbols and subscripts

4.1 Symbols

For the purposes of this document, the symbols given in ISO 52000-1 and the following apply.

Symbol	Name of quantity	Unit
A	area	m^2
R	thermal resistance	$m^2 \cdot K/W$
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	$W/(m \cdot K)$

4.2 Subscripts

For the purposes of this document, the subscripts given in ISO 52000-1 and the following apply.

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

5 Description of the method

5.1 Output of the method

The output of this document is the thermal transmittance of windows and pedestrian doors consisting of glazed and/or opaque panels fitted in a frame, with and without shutters:

Depending on the type of product or assembly, it is one of the following:

— the thermal transmittance of a single window, U_W;

— the thermal transmittance, U_W, of a system consisting of two separate windows;

— the thermal transmittance, U_W, of a system consisting of one frame and two separate sashes or casements;

— the thermal transmittance of a window with closed shutters or external blinds, U_{WS};

— the thermal transmittance, U_D, of a door set of which the door leaf is fully glazed, or if the door consists of frame, glazing and opaque panels, or if the door has no glazing.

5.2 General description

In general, the thermal transmittance or U-value of the window or door product or assembly is calculated as a function of the thermal transmittance of the components and their geometrical characteristics, plus the thermal interactions between the components.

— The calculation procedures depend on the composition of the product or assembly.

— Components may include (where appropriate): glazings, opaque panels, frames, and closed shutters or external blinds.

— Thermal interactions are lateral heat flow (linear thermal bridge effect) between adjacent components and surface and cavity thermal resistances (thermal radiation and convection).

— The geometrical characteristics concern the sizes and positions of the components and the tilt angle of the window or door.

5.3 Other general topics

Results obtained for the purposes of comparison of products (declared values) shall be calculated or measured for horizontal heat flow.

If design values are taking into account the actual inclination of the window, they shall be determined for the actual inclination and boundary conditions, by including the effect of the inclination of the window in the determination of U_g. However, U_f and Ψ_g and/or Ψ_p as determined for the window in the vertical position are used for all inclinations of the window. The design value is to be calculated only if it is needed for the calculation of the energy demand of the building.

Throughout this document, where indicated in the text, Table C.1 shall be used to identify alternative regional references in line with ISO Global Relevance Policy.

6 Calculation of thermal transmittance

6.1 Output data

The outputs of this document are transmission heat transfer coefficients as shown in Table 2.

Table 2 — Output data

Description	Symbol	Unit	Destination module	Validity interval	Varying
Thermal transmittance of window	U_W	W/(m²·K)	M2-2, M2-3, M2-4	0 to ∞	No
Thermal transmittance of door	U_D	W/(m²·K)	M2-2, M2-3, M2-4	0 to ∞	No
Thermal transmittance of window with closed shutter or external blind	U_{WS}	W/(m²·K)	M2-2, M2-3, M2-4	0 to ∞	No

6.2 Calculation time intervals

The input, the method and the output data are for steady state conditions and assumed to be independent of actual conditions, such as indoor and outdoor temperature or effect of wind or solar radiation.

6.3 Input data

6.3.1 Geometrical characteristics

6.3.1.1 General

Table 3 shows the necessary geometrical characteristics.

Table 3 — Identifiers for geometric characteristics

Name	Symbol	Unit	Range	Origin module[a]	Varying
Geometrical data					
Window area	A_W	m^2	0 to ∞	Window or door product or assembly	No
Door area	A_D	m^2	0 to ∞	Window or door product or assembly	No
Glazed area	A_g	m^2	0 to ∞	Window or door product or assembly	No
Frame area	A_f	m^2	0 to ∞	Window or door product or assembly	No
Opaque panel area	A_p	m^2	0 to ∞	Window or door product or assembly	No
Total perimeter of the glazing	l_g	m	0 to ∞	Window or door product or assembly	No
Total perimeter of the panel	l_p	m	0 to ∞	Window or door product or assembly	No
Total length of the glazing bar	l_{gb}	m	0 to ∞	Window or door product or assembly	No

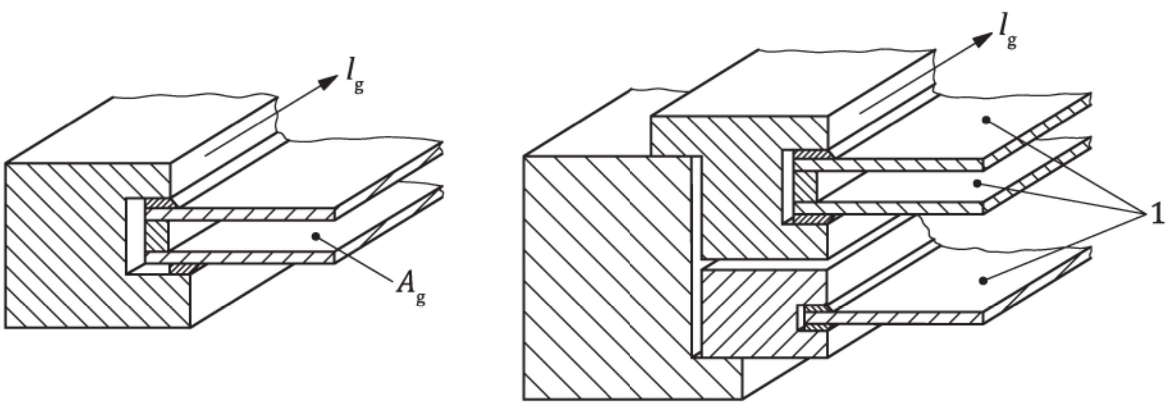
[a] According to specifications given in 6.3.1.2 to 6.3.1.5.

6.3.1.2 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.

6.3.1.3 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 1.



Key

1 glass

Figure 1 — Illustration of glazed area and perimeter

6.3.1.4 Frame areas

For the definition of the areas, see also Figure 2.

$A_{f,i}$ Internal projected frame area:

The internal projected frame area is the area of the projection of the internal frame, including sashes if present, 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, including sashes if present, on a plane parallel to the glazing panel.

A_f Frame area:

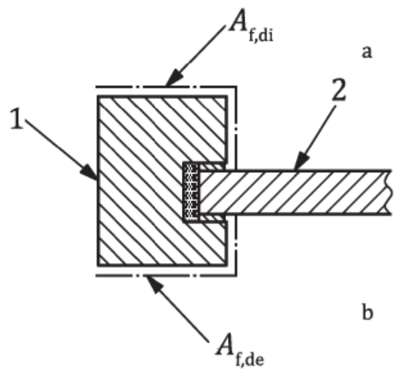
The frame area is the larger of the two projected areas seen from both sides.

$A_{f,di}$ Internal developed frame area:

The internal developed frame area is the area of the frame, including sashes if present, in contact with the internal air (see Figure 2).

$A_{f,de}$ External developed frame area:

The external developed frame area is the area of the frame, including sashes if present, in contact with the external air (see Figure 2).



Key

1 frame

2 glazing

a Internal.

b External.

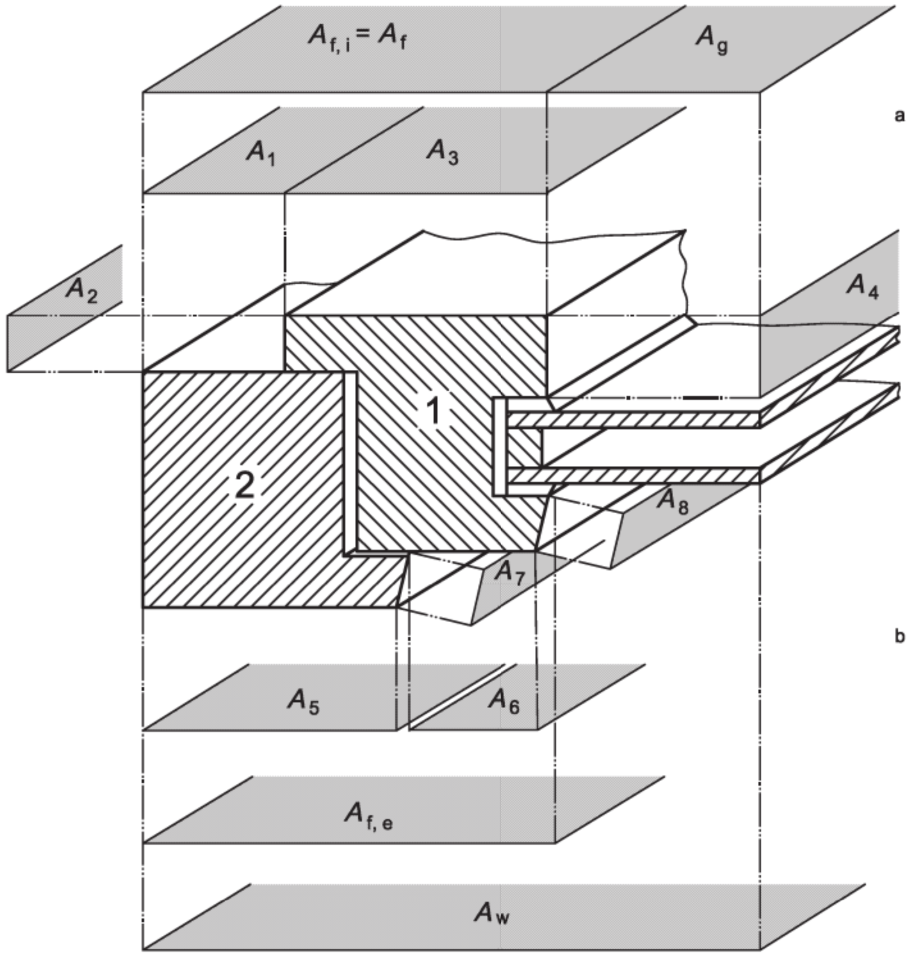
Figure 2 — Internal and external developed area

6.3.1.5 Window area and door area

The window area, A_w, or the door area, A_D; A is the sum of the frame area, A_f, and the glazing area, A_g, (or the panel area, A_p).

The frame area and the glazed area are defined by the edge of the frame, i.e. sealing gaskets are ignored for the purposes of determination of the areas.

Window or door dimensions (height, width, frame width and frame thickness) shall be determined to the nearest millimetre.



Key

1	sash (moveable)	$A_f = \max(A_{f,i}; A_{f,e})$
2	frame (fixed)	$A_w = A_f + A_g$
a	Internal	$A_{f,di} = A_1 + A_2 + A_3 + A_4$.
b	External	$A_{f,de} = A_5 + A_6 + A_7 + A_8$.

NOTE 1 The frame area, A_f, includes the area of the fixed frame together with that of any moveable sash or casement.

NOTE 2 Drip trays and similar protuberances are not considered part of the developed area.

Figure 3 — Illustration of the various areas

6.3.2 Thermal characteristics

6.3.2.1 General

Table 4 identifies the thermal characteristics of the window/door components necessary for the calculation of the thermal transmittance of the window or door.

Table 4 — Identifiers for thermal characteristics of the window/door component

Name	Symbol	Unit	Range	Origin	Varying
Thermal transmittance of frame	U_f	W/(m²·K)	0 to ∞	ISO 10077-2 or EN 12412-2 or Annex F	No
Thermal transmittance of glazing	U_g	W/(m²·K)	0 to ∞	ISO 10291 for measured value (GHP), ISO 10292 for calculated value or ISO 10293 for measured value (HFM) (or see Subject 1, 2 or 3 in Table C.1)	No
Linear thermal transmittance due to combined effect of glazing, spacer and frame	Ψ_g	W/(m·K)	0 to ∞	Annex G or ISO 10077-2	No
Thermal transmittance of opaque panel	U_p	W/(m²·K)	0 to ∞	ISO 6946 or ISO 10211 or EN 12664/EN 12667	No
Linear thermal transmittance due to combined effect of panel, spacer and frame	Ψ_p	W/(m·K)	0 to ∞	ISO 10077-2	No
Linear thermal transmittance due to combined effect of glazing bar and glazing	Ψ_{gb}	W/(m·K)	0 to ∞	Annex G or ISO 10077-2	No

6.3.2.2 Frame

The thermal transmittance of the frame, U_f, shall be by hot box measurement in accordance with EN 12412-2 or numerical calculation in accordance with ISO 10077-2.

U_f for roof windows shall be either

— calculated in accordance with ISO 10077-2, or

— measured in accordance with EN 12412-2 with specimens mounted within the aperture in the surround panel flush with the cold side, in accordance with in ISO 12567-2.

For other windows, U_f shall be

— calculated in accordance with ISO 10077-2,

— measured in accordance with EN 12412-2, or

— obtained from Annex H.

6.3.2.3 Glazing

6.3.2.3.1 Single glazing

The thermal transmittance of a single or a single laminated glazing, U_g, shall be calculated using Formula (1):

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

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.

In the absence of specific information for the glass concerned, the value λ = 1,0 W/(m·K) shall be used.

6.3.2.3.2 Multiple glazing

The thermal transmittance of multiple glazing, U_g, shall be determined in accordance with ISO 10291 for measured value (GHP), ISO 10292 for calculated value or ISO 10293 for measured value (HFM) (or see Subject 1, 2 or 3 in Table C.1).

6.3.2.4 Panel/door leaves

The thermal transmittance of panels or opaque door leaves excluding the frame and without inhomogeneities (having different layers only perpendicular to the heat flow direction) can be measured in the heat-flow meter apparatus in accordance with ISO 8301 or in the guarded hot-plate apparatus, in accordance with ISO 8302. Alternatively, EN 12664 or EN 12667 may be used. Formula (8) is used to calculate the thermal transmittance of the door set, with A_g = 0.

Alternatively, the thermal transmittance of door leaves can be calculated in accordance with 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 ISO 10077-2 and/or ISO 10211 shall be carried out.

6.3.2.5 Linear thermal transmittance

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_g and/or Ψ_p, either tabulated in this document or obtained by numerical calculations in accordance with ISO 10077-2.

U_g excludes the linear thermal transmittance, Ψ_{gb} due to the combined effect of the glazing and a glazing bar (see 6.4.2).

In the case of single glazing, the linear thermal transmittance of the glazing, Ψ_g, shall be taken as zero (no spacer effect) because any correction is negligible.

Ψ_p may be taken as zero if

— the internal and external facings of the panel are of material with thermal conductivity less than 0,5 W/(m·K), and

— the thermal conductivity of any bridging material at the edges of the panel is less than 0,5 W/(m·K).

In other cases, Ψ_p shall be calculated in accordance with ISO 10077-2.

6.3.2.6 Other topics

If measured or calculated data are not available, the values in Annexes D 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.

6.4 Calculation procedure

6.4.1 Applicable time interval

The thermal transmittance of a windows or door determined according to this document is a steady state property which can also be used as input for dynamic (e.g. hourly) building calculations, because the time constant of these types of building elements is negligible compared to many opaque elements.

However, depending on the type of product or assembly, some properties and consequently the calculated thermal transmittance may be affected by the boundary conditions. The procedure whether and how this has to be taken into account is given in the standards that use the output from this document as input.

Also, some products or assemblies may be used in different modes of operation: parts that are opened, moved or removed as function of time or conditions. The output may be different per mode of operation.

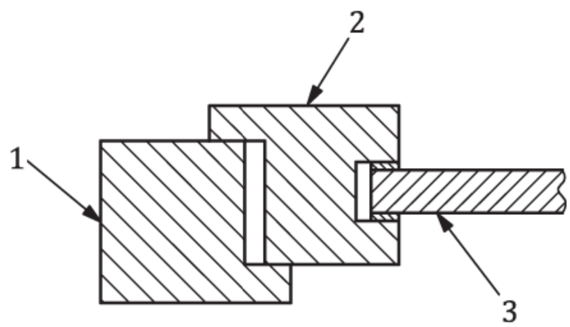
NOTE ISO 52016-1 contains procedures for the handling of building elements with different modes of operation (dynamic transparent building elements) in the calculation of the energy needs for heating and cooling and the internal temperature in a building.

6.4.2 Calculation of thermal transmittance

6.4.2.1 Windows

6.4.2.1.1 Single windows

An illustration of a single window is given in Figure 4.



Key

1 frame (fixed)

2 sash (moveable)

3 glazing (single or multiple)

Figure 4 — Illustration of single window

The thermal transmittance of a single window, U_W, shall be calculated using Formula (2):

$$U_W = \frac{\sum A_g U_g + \sum A_f U_f + \sum l_g \Psi_g + \sum l_{gb} \Psi_{gb}}{A_f + A_g} \quad (2)$$

where

U_g is the thermal transmittance of the glazing, obtained in accordance with ISO 10291 for measured value (GHP), ISO 10292 for calculated value or ISO 10293 for measured value (HFM) (or see Subject 1, 2 or 3 in Table C.1);

U_f is the thermal transmittance of the frame, obtained in accordance with 6.3.2;

Ψ_g is the linear thermal transmittance due to the combined thermal effects of glazing, spacer and frame, obtained in accordance with 6.3.2;

Ψ_{gb} is the linear thermal transmittance due to the combined thermal effects of glazing and glazing bar, obtained in accordance with 6.3.2;

and the other symbols are defined in 6.3. The summations included in Formula (2) are used to allow for different parts of the glazing or frame, e.g. several values of A_f are needed when different values of U_f apply to the sill, head, jambs and dividers.

When there are both opaque panels and glazed panes, U_W, is calculated using Formula (3):

$$U_W = \frac{\sum A_g U_g + \sum A_f U_f + \sum A_p U_p + \sum l_g \Psi_g + \sum l_p \Psi_p + \sum l_{gb} \Psi_{gb}}{A_f + A_g + A_p} \quad (3)$$

where

U_g is the thermal transmittance of the glazing, obtained in accordance with ISO 10291 for measured value (GHP), ISO 10292 for calculated value or ISO 10293 for measured value (HFM) (or see Subject 1, 2 or 3 in Table C.1);

U_f is the thermal transmittance of the frame, obtained in accordance with 6.3.2;

U_p is the thermal transmittance of the panel, obtained in accordance with 6.3.2;

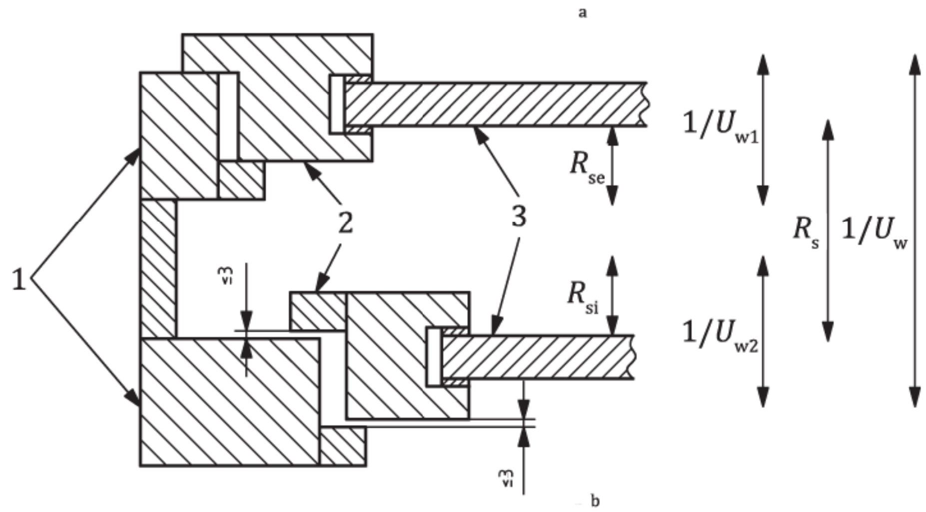
Ψ_g is the linear thermal transmittance due to the combined thermal effects of glazing, spacer and frame, obtained in accordance with 6.3.2;

Ψ_p is the linear thermal transmittance due to the combined thermal effects of panel, spacer and frame, obtained in accordance with 6.3.2;

Ψ_{gb} is the linear thermal transmittance due to the combined thermal effects of glazing and glazing bar, obtained in accordance with 6.3.2.

6.4.2.1.2 Double windows

Dimensions in millimetres



Key

1 frame (fixed)

2 sash (moveable)

3 glazing (single or multiple)

[a] Internal.

[b] External.

Figure 5 — Illustration of double window

The thermal transmittance, U_W, of a system consisting of two separate windows shall be calculated using Formula (4):

$$U_W = \frac{1}{1/U_{W1} - R_{si} + R_s - R_{se} + 1/U_{W2}} \quad (4)$$

where

U_{W1}, U_{W2} are the thermal transmittances of the external and internal window, respectively, calculated according to Formula (2);

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;

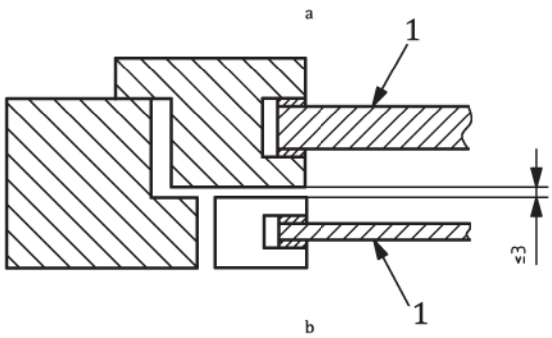
R_s is the thermal resistance of the space between the glazing in the two windows.

NOTE Typical values of R_{si} and R_{se} are given in Annex D and of R_s in Annex E.

If either of the gaps shown in Figure 5 exceeds 3 mm and measures have not been taken to prevent excessive air exchange with external air, the method does not apply.

6.4.2.1.3 Coupled windows

Dimensions in millimetres



Key

1 glazing (single or multiple)

a Internal.

b External.

Figure 6 — Illustration of coupled window

The thermal transmittance, U_W, of a system consisting of one frame and two separate sashes or casements shall be calculated using Formula (1). To determine the thermal transmittance, U_g, of the combined glazing, Formula (5) shall be used:

$$U_g = \frac{1}{1/U_{g1} - R_{si} + R_s - R_{se} + 1/U_{g2}} \quad (5)$$

where

U_{g1}, U_{g2} are the thermal transmittances of the external and internal glazing; respectively, obtained in accordance with ISO 10291 for measured value (GHP), ISO 10292 for calculated value or ISO 10293 for measured value (HFM) (or see Subject 1, 2 or 3 in Table C.1);

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.

NOTE Values of R_{si} and R_{se} are given in Annex D and of R_s in Annex E.

If the gap shown in Figure 6 exceeds 3 mm and measures have not been taken to prevent excessive air exchange with external air, the method does not apply.

6.4.2.2 Windows with closed shutters or blinds

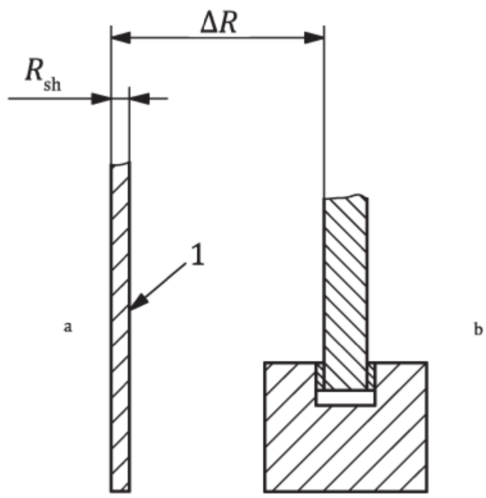
A shutter or blind on the outside of a window introduces an additional thermal resistance, resulting from both the air layer enclosed between the shutter or external blind and the window, and the shutter or external blind itself (see Figure 7). The thermal transmittance of a window with closed shutters or external blinds, U_{WS}, is given by Formula (6):

$$U_{WS} = \frac{1}{1/U_W + \Delta R} \tag{6}$$

where

U_W is the thermal transmittance of the window, obtained according to Formulae (2), (3) or (4)... etc.;

ΔR is the additional thermal resistance due to the air layer enclosed between the shutter/external blind and the window and the closed shutter/external blind itself (see Figure 7).



Key

1 Shutter/blind

a External.

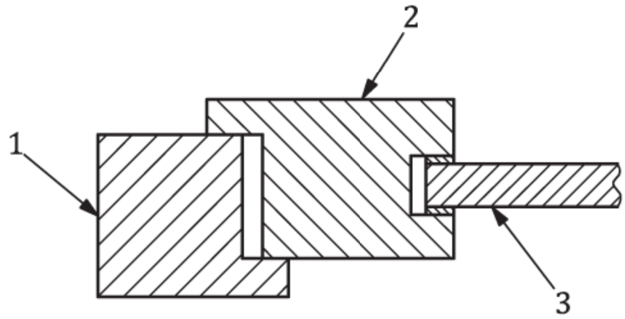
b Internal.

Figure 7 — Window with shutter or external blind

ΔR depends on the thermal transmission properties of the shutter/external blind and on its air permeability and shall be evaluated in accordance with Subject 4, 5 or 6 in Table C.1.

6.4.2.3 Doors

6.4.2.3.1 Fully glazed doors



Key

1 frame (fixed)

2 sash (moveable)

3 glazing (single or multiple)

Figure 8 — Illustration of door with glazing

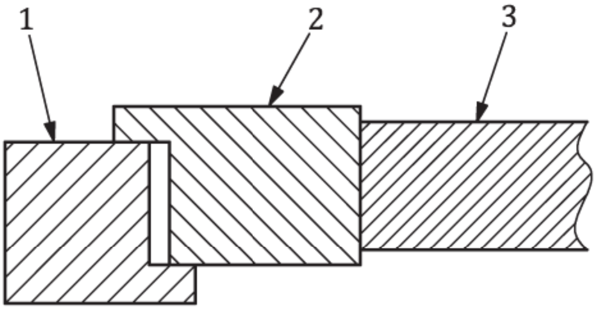
The thermal transmittance, U_D, of a door set of which the door leaf is fully glazed is obtained using Formula (7):

$$U_D = \frac{\sum A_g U_g + \sum A_f U_f + \sum l_g \Psi_g + \sum l_{gb} \Psi_{gb}}{A_f + A_g} \tag{7}$$

where

A_f, A_g, l_g and l_{gb}	are defined in 6.3.1;
U_g	is the thermal transmittance of the glazing, obtained in accordance with Subject 4, 5 or 6 in Table C.1,
U_f	is the thermal transmittance of the frame, obtained in accordance with 6.3.2;.
Ψ_g	is the linear thermal transmittance due to the combined thermal effects of glazing spacer and frame, obtained in accordance with 6.3.2;
Ψ_{gb}	is the linear thermal transmittance due to the combined thermal effects of glazing and glazing bar, obtained in accordance with 6.3.2.

6.4.2.3.2 Doors containing glazing and opaque panels



Key

1 frame (fixed)

2 sash (moveable)

3 opaque panel

Figure 9 — Schematic illustration of door with opaque panel

If the door consists of frame, glazing and opaque panels, then Formula (8) shall be used:

$$U_D = \frac{\sum A_g U_g + \sum A_f U_f + \sum A_p U_p + \sum l_g \Psi_g + \sum l_p \Psi_p + \sum l_{gb} \Psi_{gb}}{A_f + A_g + A_p} \quad (8)$$

where

A_f, A_g, A_p, l_g, l_p and l_{gb}	are defined in 6.3.1;
U_g	is the thermal transmittance of the glazing, obtained in accordance with Subject 4, 5 or 6 in Table C.1;
U_f	is the thermal transmittance of the frame; obtained in accordance with 6.3.2;
U_p	is the thermal transmittance of the opaque panel(s) obtained in accordance with 6.3.2;
Ψ_g	is the linear thermal transmittance due to the combined thermal effects of glazing spacer and frame, obtained in accordance with 6.3.2;
Ψ_p	is the linear thermal transmittance due to the combined thermal effects of panel, spacer and frame, obtained in accordance with 6.3.2;
Ψ_{gb}	is the linear thermal transmittance due to the combined thermal effects of glazing and glazing bar, obtained in accordance with 6.3.2.

7 Test report

7.1 Contents of test report

The calculation test report shall include the following:

— a reference to this document, i.e. ISO 10077-1;

— an identification of the organization making the calculation;

— the date of calculation;

— the items listed in 7.2, 7.2.1 and 7.2.2.

7.2 Drawing of sections

A technical drawing (preferably on a scale of 1:1) giving the sections of all the different frame parts permitting verification of relevant details such as the following:

— thickness, height, position, type and number of thermal breaks (for metallic frames);

— number and thickness of air chambers (for plastic frames and metal frames where air cavities are associated with a thermal break);

— presence and position of metal stiffening (for plastic frames only);

— thickness of wooden frames and the thickness of plastic and PUR-frame (polyurethane) material;

— thickness of gas spaces, the identification of the gas and the percentage assured to be present;

— type of glass and its thickness or its thermal properties and emissivity of its surfaces;

— thickness and description of any opaque panels in the frame;

— internal projected frame area, $A_{f,i}$, and the external projected frame area, $A_{f,e}$;

— internal developed frame area, $A_{d,i}$, and the external developed frame area, $A_{d,e}$, (only for metallic frames);

— position of the glazing spacers or of the edge stiffening for opaque panels;

— description of any shutters or external blinds.

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

7.2.1 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, l_g, of the glazing and/or l_p of the opaque panels.

7.2.2 Values used in the calculation

The origin of the values used in the calculations shall be indicated.

a) If the 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 or Ψ values, the sources shall be given. It shall be ascertained that these other sources use the same definitions of the areas, A_g and A_f, and of the perimeter lengths, l_g and l_p.

7.2.3 Presentation of results

The thermal transmittance of the window or door calculated according to this document shall be given to two significant figures.

Annex A
(normative)

Input and method selection data sheet — Template

A.1 General

The template in Annex A of this document shall be used to specify the choices between methods, the required input data and references to other documents.

NOTE 1 Following this template is not enough to guarantee consistency of data.

NOTE 2 Informative default choices are provided in Annex B. Alternative values and choices can be imposed by national/regional regulations. If the default values and choices of Annex B are not adopted because of the national/regional regulations, policies or national traditions, it is expected that:

— national or regional authorities prepare data sheets containing the national or regional values and choices, in line with the template in Annex A; or

— by default, the national standards body will add or include a national annex (Annex NA) to this document, in line with the template in Annex A, giving national or regional values and choices in accordance with their legal documents.

NOTE 3 The template in Annex A is applicable to different applications (e.g., the design of a new building, certification of a new building, renovation of an existing building and certification of an existing building) and for different types of buildings (e.g., small or simple buildings and large or complex buildings). A distinction in values and choices for different applications or building types could be made:

— by adding columns or rows (one for each application), if the template allows;

— by including more than one version of a table (one for each application), numbered consecutively as a, b, c, ... For example: Table NA.3a, Table NA.3b;

— by developing different national/regional data sheets for the same standard. In case of a national annex to the standard these will be consecutively numbered (Annex NA, Annex NB, Annex NC, ...).

NOTE 4 In the section "Introduction" of a national/regional data sheet information can be added, for example about the applicable national/regional regulations.

NOTE 5 For certain input values to be acquired by the user, a data sheet following the template of Annex A, could contain a reference to national procedures for assessing the needed input data. For instance, reference to a national assessment protocol comprising decision trees, tables and pre-calculations.

The shaded fields in the tables are part of the template and consequently not open for input.

A.2 References

The references, identified by the EPB module code number, are given in Table A.1 (template).

Table A.1 — References

Reference	Reference document	
	Number	Title
Mx-y[a]	...	...
[a] In this document there are no choices in references to other EPB standards. The Table is kept to maintain uniformity between all EPB standards		

Table A.1 *(continued)*

Reference	Reference document	
	Number	**Title**
	...	...
[a] In this document there are no choices in references to other EPB standards. The Table is kept to maintain uniformity between all EPB standards		

A.3 Calculation of thermal transmittance of window or door

NOTE Currently, in this document, there are no choices between methods and the required input data foreseen that are to be kept open for completion as explained in A.1. To satisfy the need for congruence with all other EPB standards and to make explicitly clear that in this document there are no choices kept open, Annex A and Annex B are kept.

Annex B
(informative)

Input and method selection data sheet — Default choices

B.1 General

The template in Annex A of this document shall be used to specify the choices between methods, the required input data and references to other documents.

NOTE 1 Following this template is not enough to guarantee consistency of data.

NOTE 2 Informative default choices are provided in Annex B. Alternative values and choices can be imposed by national/regional regulations. If the default values and choices of Annex B are not adopted because of the national/regional regulations, policies or national traditions, it is expected that:

— national or regional authorities prepare data sheets containing the national or regional values and choices, in line with the template in Annex A; or

— by default, the national standards body will add or include a national annex (Annex NA) to this document, in line with the template in Annex A, giving national or regional values and choices in accordance with their legal documents.

NOTE 3 The template in Annex A is applicable to different applications (e.g., the design of a new building, certification of a new building, renovation of an existing building and certification of an existing building) and for different types of buildings (e.g., small or simple buildings and large or complex buildings). A distinction in values and choices for different applications or building types could be made:

— by adding columns or rows (one for each application), if the template allows;

— by including more than one version of a table (one for each application), numbered consecutively as a, b, c, ... For example: Table NA.3a, Table NA.3b;

— by developing different national/regional data sheets for the same standard. In case of a national annex to the standard these will be consecutively numbered (Annex NA, Annex NB, Annex NC, ...).

NOTE 4 In the section "Introduction" of a national/regional data sheet information can be added, for example about the applicable national/regional regulations.

NOTE 5 For certain input values to be acquired by the user, a data sheet following the template of Annex A, could contain a reference to national procedures for assessing the needed input data. For instance, reference to a national assessment protocol comprising decision trees, tables and pre-calculations.

The shaded fields in the tables are part of the template and consequently not open for input.

B.2 References

The references, identified by the EPB module code number, are given in Table B.1.

Table B.1 — References

Reference	Reference document	
	Number	Title
Mx-y[a]	...	...

[a] In this document there are no choices in references to other EPB standards. The Table is kept to maintain uniformity between all EPB standards.

Table B.1 *(continued)*

Reference	Reference document	
	Number	**Title**
	...	...
[a] In this document there are no choices in references to other EPB standards. The Table is kept to maintain uniformity between all EPB standards.		

B.3 Calculation of thermal transmittance of window or door

NOTE Currently, in this document, there are no choices between methods and the required input data foreseen that are to be kept open for completion as explained in B.1. To satisfy the need for congruence with all other EPB standards and to make explicitly clear that in this document there are no choices kept open, Annex A and Annex B are kept.

Annex C
(normative)

Regional references in line with ISO Global Relevance Policy

This document contains specific parallel routes in referencing other standards, in order to take into account existing national and/or regional regulations and/or legal environments while maintaining global relevance.

The standards that shall be used as called for in the successive clauses are given in Table C.1.

Table C.1 — Regional references in line with ISO Global Relevance Policy

Subject		Global	CEN area[a]
Thermal transmission: glazing			
1	Calculated value	ISO 10292	EN 673
2	Measured value (GHP apparatus)	ISO 10291	EN 674
3	Measured value (HFM apparatus)	ISO 10293	EN 675
Additional thermal resistance ΔR			
4	Air permeability	EN 13125	EN 13125
5	Thermal resistance of shutters and blinds depending on type of product	EN 13659 (depending on product)	EN 13659 (depending on product)
6	Thermal resistance of shutters and blinds depending on type of product	EN 13561 (depending on product)	EN 13561 (depending on product)

[a] CEN area = Countries whose national standards body is a member of CEN. Attention is drawn to the need for observance of EU Directives transposed into national legal requirements.

Annex D
(normative)

Internal and external surface thermal resistances

For typical normal emissivities (≥ 0,8) for the inside and outside surfaces of the glazing, the values in Table D.1 for the surface resistances R_{se} and R_{si} shall be used.

Table D.1 — Surface thermal resistances

Window position	Internal R_{si} $m^2 \cdot K/W$	External R_{se} $m^2 \cdot K/W$
Vertical, or inclination, α, of the glazing to the horizontal such that $90° \geq \alpha \geq 60°$ (heat flow direction ±30° from the horizontal plane)	0,13	0,04
Horizontal, or inclination α of the glazing to the horizontal such that $60° > \alpha \geq 0°$ (heat flow direction more than 30° from the horizontal plane)	0,10	0,04

R_{si} for special cases, for example a low-emissivity coating on the outer surface of the interior pane, can be calculated in accordance with ISO 10292 (or see Subject 1 in Table C.1), using the convective coefficient from ISO 6946 for horizontal heat flow if $\alpha > 60°$ and for upwards heat flow if $\alpha < 60°$.

Annex E
(normative)

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

Table E.1 gives some values of the thermal resistance, R_s, of air spaces for double glazing, calculated in accordance with ISO 10292 (or see Subject 1 in Table C.1). The data apply:

— for vertical windows;

— 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, or for inclination other than vertical, the procedure in ISO 10292 (or see Subject 1 in Table C.1) shall be used.

Table E.1 — Thermal resistance of unventilated air spaces for coupled and double vertical windows

Thickness of air space	Thermal resistance R_s m²·K/W				
	One side coated with a normal emissivity of				Both sides uncoated
mm	0,1	0,2	0,4	0,8	
6	0,211	0,191	0,163	0,132	0,127
9	0,299	0,259	0,211	0,162	0,154
12	0,377	0,316	0,247	0,182	0,173
15	0,447	0,364	0,276	0,197	0,186
50	0,406	0,336	0,260	0,189	0,179

For wider air layers like in double windows or doors, the calculation according to ISO 10292 (or Subject 1 in Table C.1) does not lead to correct results. For such cases, more detailed formulae are given in ISO 15099, or numerical calculation methods or measurements can be used.

Annex F
(normative)

Thermal transmittance of frames

F.1 General

The preferred methods of establishing values of thermal transmittance of frames are numerical calculation methods (e.g. finite element, finite difference, boundary element) in accordance with ISO 10077-2 and direct measurements using hot-box methods in accordance with EN 12412-2. If no other information is available, the values derived from the tables and graphs in this annex can be used for vertical windows 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 F.1 and Figures F.2 and F.4, which can be used in the absence of specific measured or calculated information for the frame concerned.

NOTE The values are based on a large number of measured values as well as mathematically evaluated values determined using numerical calculation methods.

The data in Table F.1 and Figure F.2 include the effect of the developed areas; the data in Figure F.4 are derived from surface temperature measurements and a correction is required for the effect of developed areas.

The values of U_f in Table F.1 and Figures F.2 and F.4 cannot be used for sliding windows but the principle of Formula (G.1) can be used.

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

Especially in the case of aluminium profiles with thermal breaks, there is the problem that the thermal transmittance of the frame is influenced by different construction characteristics, such as

— distance, d, between the aluminium sections,

— width, b, of the material of the thermal break zones,

— conductivity of the thermal break material,

— ratio of the width of the thermal break to the projected frame 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. The thermal transmittance of a profile or profile combination of a “profile system” can be evaluated by

— using the highest value of U_f of the profiles or profile combinations within the profile system, or

— using trend lines that show the relationship between U_f and defined geometrical characteristics.

In the latter case, the data points for the trend line are evaluated on selected profile cross-sections, taken from the profile system in question. Detailed procedures are described in References [5],[6] and[7].

F.2 Plastic frames

Table F.1 gives approximate values for plastic frames with metal reinforcements. If no other data are available, the values in Table F.1 can also be used for frames without metal reinforcements.

Table F.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[a]	two hollow chambers external  internal	2,2
	three hollow chambers external  internal	2,0

[a] With a distance between wall surfaces of each hollow chamber of at least 5 mm (refer to Figure F.1).

Dimensions in millimetres

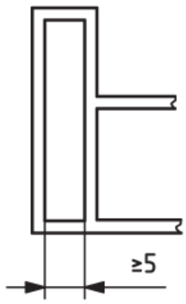
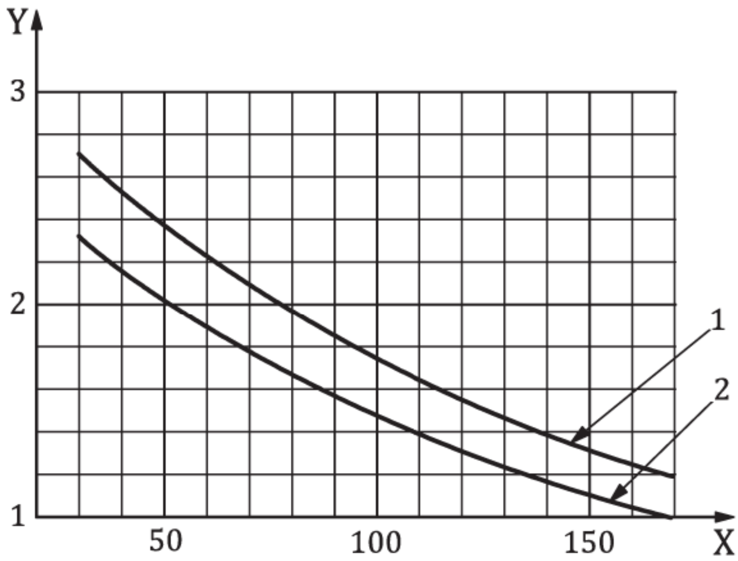


Figure F.1 — Hollow chamber in plastic frame

Other plastic profile sections should be measured or calculated.

F.3 Wood frames

Values for wood frames can be taken from Figure F.2. For U_f, the values correspond to a moisture content of 12 %. For definition of the thickness of the frame, see Figure F.3.



Key

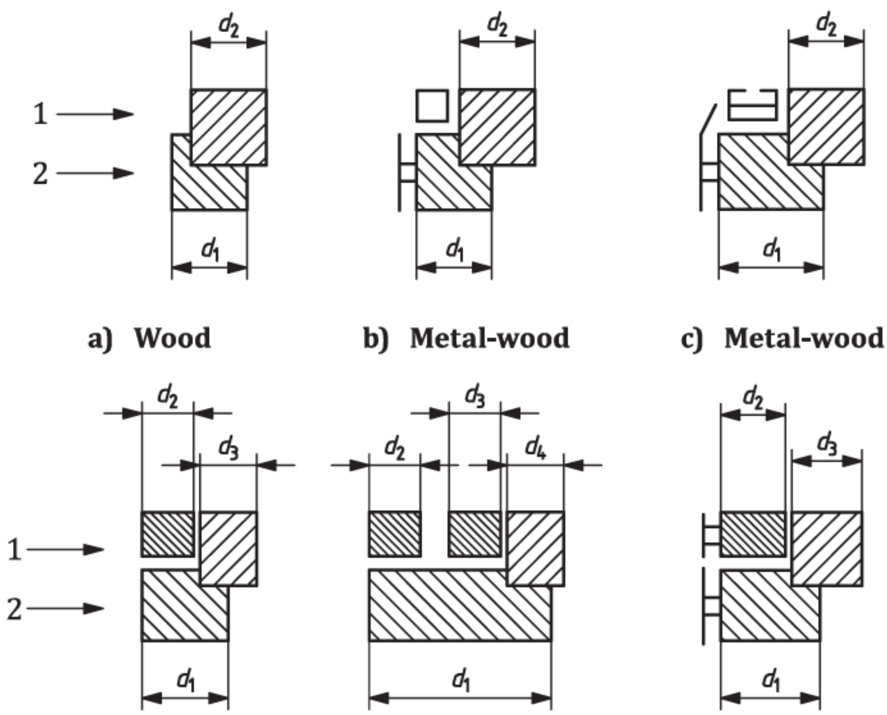
X thickness of frame, d_f, expressed in millimetres

Y thermal transmittance of frame, U_f, in W/(m²·K)

1 hardwood (density 700 kg/m³), λ = 0,18 W/(m·K)

2 softwood (density 500 kg/m³), λ = 0,13 W/(m·K)

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



a) **Wood** b) **Metal-wood** c) **Metal-wood**

internal: right-hand side of frame section

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

d) **Wood** e) **Wood** f) **Metal-wood**

external: left-hand side of frame section

$$d_f = \frac{d_1 + \sum_{j\,W2} d_j}{2}$$

Key

1 sash

2 frame

Figure F.3 — Definition of the thickness, d_f, of the frame for various window systems

F.4 Metal frames

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

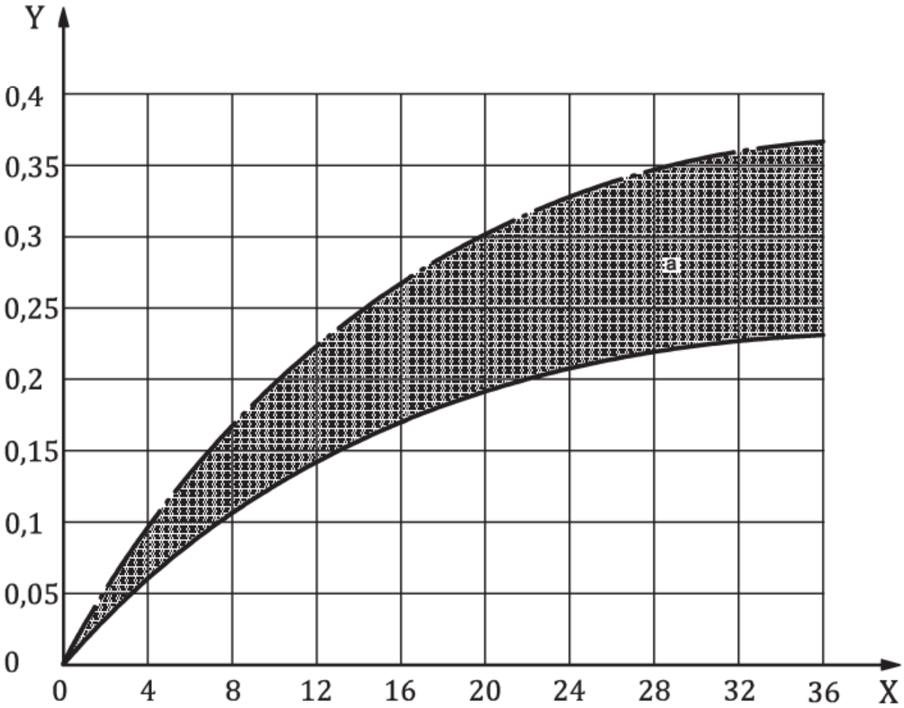
If such data are not available, values of U_f can be obtained by the following procedure:

— metal frames without a thermal break;

— metal frames with thermal breaks corresponding to the sections illustrated in Figures F.5 and F.6, subject to restrictions on the thermal conductivity and widths of the thermal breaks.

For metal frames without a thermal break, $R_f = 0$.

For metal frames with thermal breaks, take R_f from the lower, solid line in Figure F.4.



Key

X smallest distance, d, between opposite metal sections, expressed in millimetres

Y thermal resistance, R_f, of frame, expressed in $m^2 \cdot K/W$

[a] 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.

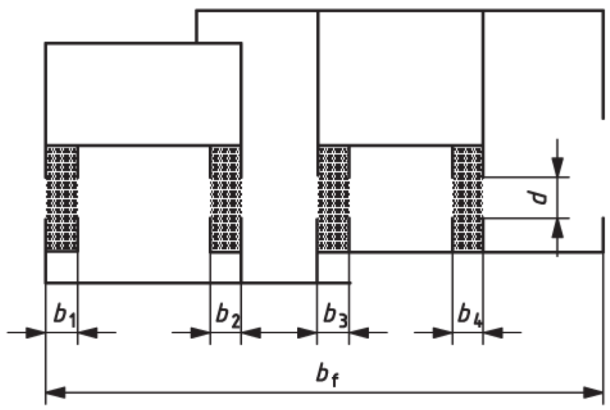
Figure F.4 — Values of R_f for metal frames with thermal break

The thermal transmittance, U_f, of the frame is given by Formula (F.1):

$$U_f = \frac{1}{R_{si}A_{f,i} / A_{f,di} + R_f + R_{se}A_{f,e} / A_{f,de}} \tag{F.1}$$

where

$A_{f,di}$, $A_{f,de}$, $A_{f,i}$, $A_{f,e}$	are the areas as defined in 6.3, 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 $m^2 \cdot K/W$.



Thermal conductivity, λ, of thermal break materials such that

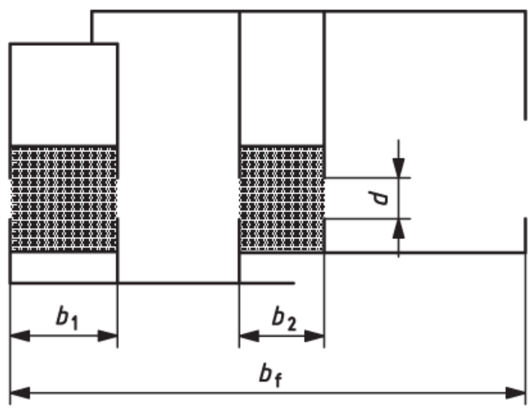
$0,2 < \lambda \leq 0,3$ W/(m·K)

where

- 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 F.5 — Section type 1 — Thermal break with a thermal conductivity less than 0,3 W/(m·K)



Thermal conductivity, λ, of thermal break materials such that

$0,1 < \lambda \leq 0,2$ W/(m·K)

where

- 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 F.6 — Section type 2 — Thermal break with a thermal conductivity less than 0,2 W/(m·K)

If the thermal conductivity of the thermal break material is less than 0,1 W/(m·K), there is no restriction according to the definition in Figure F.6.

Annex G
(normative)

Linear thermal transmittance of frame/glazing junction and glazing bars

G.1 General

The thermal transmittance of the glazing, U_g, is applicable to the central area of the glazing and does not include the effect of the glazing spacers at the edge of the glazing or glazing bars integrated in the glazing. The thermal transmittance of the frame, U_f, is applicable in the absence of the glazing. The linear thermal transmittance, Ψ_g, describes the additional heat conduction due to the interaction between the frame, glazing and spacer, and is affected by the thermal properties of each of these components.

The linear thermal transmittance Ψ_{gb} describes the additional heat conduction due to the interaction between glazing and glazing bar.

The preferred method of establishing values of linear thermal transmittance is by numerical calculation in accordance with ISO 10077-2.

Table G.1 and Table G.2 give default values of Ψ_g for typical combinations of frames, glazing and spacers that can be used when the results of a detailed calculation are not available.

For single glazing, $\Psi_g = 0$.

Table G.3 and Table G.4 give default values of Ψ_{gb} for typical glazing bars integrated in the IGU that can be used when the results of a detailed calculation are not available.

G.2 Aluminium and steel spacers

Table G.1 indicates values of Ψ_g for glazing spacers of aluminium or non-alloy steel for a specific range of types of frames and glazing.

Table G.1 — Values of linear thermal transmittance for common types of glazing spacer bars (e.g. aluminium or steel)

Frame type	Linear thermal transmittance for different types of glazing Ψ_g	
	Double or triple glazing uncoated glass air- or gas-filled	Double[a] or triple[b] glazing low-emissivity glass air- or gas-filled
Wood or PVC	0,06	0,08
Metal with a thermal break	0,08	0,11
Metal without a thermal break	0,02	0,05

[a] One pane coated for double glazed.

[b] Two panes coated for triple glazed.

G.3 Thermally improved spacers

For the purposes of this annex, a thermally improved spacer is defined by the following criterion in Formula (G.1):

$$\sum(d \cdot \lambda) \leq 0{,}007\text{W} / \text{K} \tag{G.1}$$

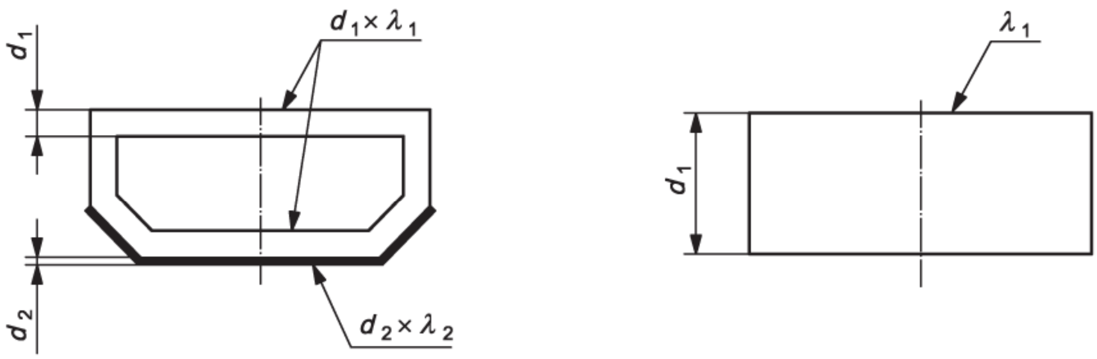
where

d is the thickness of the spacer wall, expressed in metres;

λ is the thermal conductivity of the spacer material, in W/(m·K).

The summation applies to all heat flow paths parallel to the principal heat flow direction, the thickness, d, being measured perpendicular to the principal heat flow direction; see Figure G.1. Values of thermal conductivity for spacer materials should be taken from ISO 10456 or ISO 10077-2.

Where the criterion in Formula (G.1) is not applicable because of the nature of the construction of the spacer, for example, where one or more of the heat flow paths comprises a combination of materials of different thermal conductivity, the linear thermal transmittance should be calculated in accordance with ISO 10077-2.



$\Sigma\ (d \times \lambda) = 2\ (d_1 \times \lambda_1) + (d_2\ \times \lambda_2)$ $\Sigma\ (d \times \lambda) = d_1 \times \lambda_1$

Figure G.1 — Examples of determination of criterion for thermally improved spacers

Table G.2 gives values for thermally improved spacers that conform to the criterion in Formula (G.1).

Table G.2 — Values of linear thermal transmittance for glazing spacer bars with improved thermal performance

Frame type	Linear thermal transmittance for different types of glazing with improved thermal performance Ψ_g	
	Double or triple glazing uncoated glass air- or gas-filled	Double[a] or triple[b] glazing low emissivity glass air- or gas-filled
Wood or PVC	0,05	0,06
Metal with a thermal break	0,06	0,08
Metal without a thermal break	0,01	0,04

[a] One pane coated for double glazed.

[b] Two panes coated for triple glazed.

G.4 Glazing bars

Table G.3 indicates values of Ψ_{gb} for glazing bars of metal (aluminium and steel) and Table G.4 indicates values of Ψ_{gb} for glazing bars of plastics, for specific types of glazing and for two distances d_{gb} between the glass panes and the glazing bar. The values given in Table G.3 and Table G.4 can be used for a maximum width of the glazing bar up to $l_{gb} \leq 30$ mm.

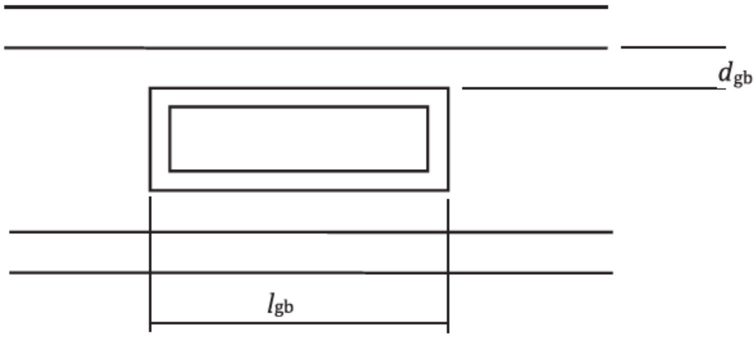
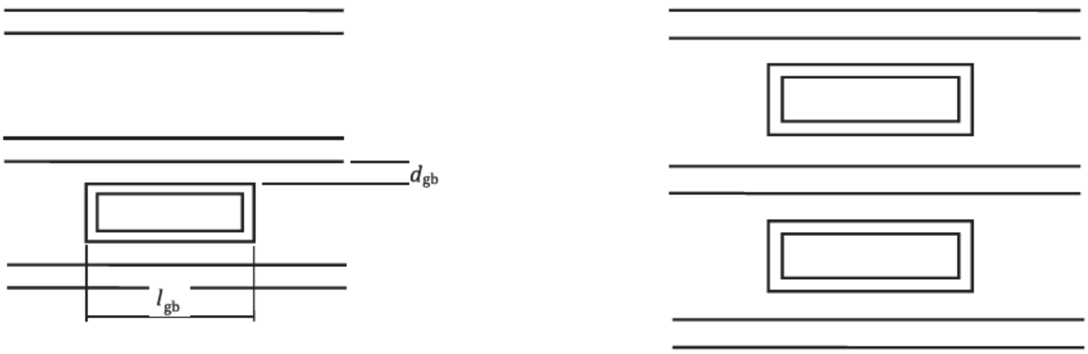


Figure G.2 — Schematic drawing of a glazing bar integrated in a double IGU



a) Left: Glazing bar in only one cavity **b) Right: Glazing bar in both cavities**

Figure G.3 — Schematic drawing of a glazing bar integrated in a triple IGU

Table G.3 — Values of linear thermal transmittance for glazing bars of metal [$\lambda \leq 160$ W/(m·K)] **integrated in the IGU**

Glazing type	**Distance between glass pane and glazing bar** d_{gb} in mm	**Linear thermal transmittance for different types of glazing** Ψ_{gb}	
		Double or triple glazing uncoated glass air- or gas-filled	**Double[a] or triple[b] glazing low-emissivity glass air- or gas-filled**
Double glazing	≥ 2	0,03	0,07
	≥ 4	0,01	0,04
Triple glazing with glazing bar in one cavity	≥ 2	—	0,03
	≥ 4	—	0,01

[a] One pane coated for double glazed.

[b] Two panes coated for triple glazed.

Table G.3 *(continued)*

Glazing type	Distance between glass pane and glazing bar d_{gb} in mm	Linear thermal transmittance for different types of glazing Ψ_{gb}	
		Double or triple glazing uncoated glass air- or gas-filled	**Double[a] or triple[b] glazing low-emissivity glass air- or gas-filled**
Triple glazing with glazing bar in both cavities	≥ 2	—	0,05
	≥ 4	—	0,02

[a] One pane coated for double glazed.

[b] Two panes coated for triple glazed.

Table G.4 — Values of linear thermal transmittance for glazing bars of plastic [$\lambda \leq 0,30$ W/(m·K)] **integrated in the IGU**

Glazing type	Distance between glass pane and glazing bar d_{gb} in mm	Linear thermal transmittance for different types of glazing Ψ_{gb}	
		Double or triple glazing uncoated glass air- or gas-filled	**Double[a] or triple[b] glazing low-emissivity glass air- or gas-filled**
Double glazing	≥ 2	0,00	0,04
	≥ 4	0,00	0,02
Triple glazing with glazing bar in one cavity	≥ 2	—	0,02
	≥ 4	—	0,01
Triple glazing with glazing bar in both cavities	≥ 2	—	0,03
	≥ 4	—	0,02

[a] One pane coated for double glazed.

[b] Two panes coated for triple glazed.

Annex H
(normative)

Thermal transmittance of windows

Tables H.1 and H.2 give values calculated by the method in this document using linear thermal transmittances from Annex G for normal types of glazing spacer bars (see Table G.1). Tables H.3 and H.4 give corresponding values for spacer bars with improved thermal performance (see Table G.2).

The data in Tables H.1 to H.4 are calculated for windows

— positioned vertically;

— of dimensions 1,23 m by 1,48 m;

— with frame area equal to 30 % and 20 % of the total window area;

— with glazing and frame types as follows:

  — glazing: $U_g \geq 2{,}1$ W/(m²·K): uncoated glass; $U_g \leq 2{,}0$ W/(m²·K): low emissivity glass;

  — frame: $U_f = 7{,}0$ W/(m²·K): metal without thermal break; 2,2 W/(m²·K) $\leq U_f \leq 3{,}8$ W/(m²·K): metal with thermal break; $U_f \leq 2{,}0$ W/(m²·K): wood or PVC;

— with a single light.

Values for windows of other sizes, positioned other than vertically, with other frame area fractions or with other frame/glazing permutations can be evaluated by means of the formulae in the main part of document.

Table H.1 — Thermal transmittances, U_w, for vertical windows with fraction of the frame area 30 % of the whole window area, common types of glazing spacer bars

Values in W/(m²·K)

Type of glazing	U_g	Thermal transmittances, U_w, for vertical windows with fraction of the frame area 30 % of the whole window area for common types of glazing spacer bars and following U_f values												
		0,80	1,0	1,2	1,4	1,6	1,8	2,0	2,2	2,6	3,0	3,4	3,8	7,0
Single	5,8	4,3	4,4	4,4	4,5	4,5	4,6	4,7	4,7	4,8	5,0	5,1	5,2	6,1
Double or triple	3,3	2,7	2,8	2,8	2,9	2,9	3,0	3,1	3,2	3,3	3,4	3,5	3,6	4,5
	3,2	2,6	2,7	2,7	2,8	2,9	2,9	3,0	3,1	3,2	3,3	3,5	3,6	4,4
	3,1	2,6	2,6	2,7	2,7	2,8	2,9	2,9	3,0	3,1	3,3	3,4	3,5	4,3
	3,0	2,5	2,5	2,6	2,7	2,7	2,8	2,8	3,0	3,1	3,2	3,3	3,4	4,2
	2,9	2,4	2,5	2,5	2,6	2,7	2,7	2,8	2,9	3,0	3,1	3,2	3,4	4,2
	2,8	2,3	2,4	2,5	2,5	2,6	2,6	2,7	2,8	2,9	3,1	3,2	3,3	4,1
	2,7	2,3	2,3	2,4	2,5	2,5	2,6	2,6	2,7	2,9	3,0	3,1	3,2	4,0
	2,6	2,2	2,3	2,3	2,4	2,4	2,5	2,6	2,7	2,6	2,9	3,0	3,2	4,0
	2,5	2,1	2,2	2,3	2,3	2,4	2,4	2,5	2,6	2,5	2,8	3,0	3,1	3,9
	2,4	2,1	2,1	2,2	2,2	2,3	2,4	2,4	2,5	2,5	2,8	2,9	3,0	3,8
	2,3	2,0	2,1	2,1	2,2	2,2	2,3	2,4	2,5	2,4	2,7	2,8	3,0	3,8
	2,2	1,9	2,0	2,0	2,1	2,2	2,2	2,3	2,4	2,3	2,6	2,8	2,9	3,7
	2,1	1,9	1,9	2,0	2,0	2,1	2,2	2,2	2,3	2,3	2,6	2,7	2,8	3,6
	2,0	1,8	1,9	2,0	2,0	2,1	2,1	2,2	2,3	2,5	2,6	2,7	2,8	3,6
	1,9	1,8	1,8	1,9	1,9	2,0	2,1	2,1	2,3	2,4	2,5	2,5	2,7	3,6
	1,8	1,7	1,8	1,8	1,9	1,9	2,0	2,1	2,2	2,3	2,4	2,6	2,7	3,5
	1,7	1,6	1,7	1,7	1,8	1,9	1,9	2,0	2,1	2,2	2,4	2,5	2,6	3,4
	1,6	1,6	1,6	1,7	1,7	1,8	1,9	1,9	2,1	2,2	2,3	2,4	2,5	3,3
	1,5	1,5	1,5	1,6	1,7	1,7	1,8	1,8	2,0	2,1	2,2	2,3	2,5	3,3
	1,4	1,4	1,5	1,5	1,6	1,7	1,7	1,8	1,9	2,0	2,2	2,3	2,4	3,2
	1,3	1,3	1,4	1,5	1,5	1,6	1,6	1,7	1,8	2,0	2,1	2,2	2,3	3,1
	1,2	1,3	1,3	1,4	1,5	1,5	1,6	1,6	1,8	1,9	2,0	2,1	2,3	3,1
	1,1	1,2	1,3	1,3	1,4	1,4	1,5	1,6	1,7	1,8	1,9	2,1	2,2	3,0
	1,0	1,1	1,2	1,3	1,3	1,4	1,4	1,5	1,6	1,8	1,9	2,0	2,1	2,9
	0,9	1,1	1,1	1,2	1,2	1,3	1,4	1,4	1,6	1,7	1,8	1,9	2,0	2,9
	0,8	1,0	1,1	1,1	1,2	1,2	1,3	1,4	1,5	1,6	1,7	1,9	2,0	2,8
	0,7	0,93	0,99	1,0	1,1	1,2	1,2	1,3	1,4	1,5	1,7	1,8	1,9	2,7
	0,6	0,86	0,92	0,98	1,0	1,1	1,2	1,2	1,4	1,5	1,6	1,7	1,8	2,7
	0,5	0,79	0,85	0,91	0,97	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,8	2,6

Table H.2 — Thermal transmittances, U_w, for vertical windows with fraction of the frame area 20 % of the whole window area, common types of glazing spacer bars

Values in W/(m²·K)

Type of glazing	U_g	Thermal transmittances, U_w, for vertical windows with fraction of the frame area 20 % of the whole window area for common types of glazing spacer bars and following U_f values												
		0,80	1,0	1,2	1,4	1,6	1,8	2,0	2,2	2,6	3,0	3,4	3,8	7,0
Single	5,8	4,8	4,8	4,9	4,9	5,0	5,0	5,0	5,1	5,2	5,2	5,3	5,4	6,0
Double or triple	3,3	3,0	3,0	3,0	3,1	3,1	3,2	3,2	3,3	3,4	3,5	3,5	3,6	4,1
	3,2	2,9	2,9	3,0	3,0	3,0	3,1	3,1	3,2	3,3	3,4	3,5	3,5	4,0
	3,1	2,8	2,8	2,9	2,9	3,0	3,0	3,0	3,1	3,2	3,3	3,4	3,5	3,9
	3,0	2,7	2,8	2,8	2,8	2,9	2,9	3,0	3,1	3,1	3,2	3,3	3,4	3,9
	2,9	2,6	2,7	2,7	2,8	2,8	2,8	2,9	3,0	3,1	3,1	3,2	3,3	3,8
	2,8	2,6	2,6	2,6	2,7	2,7	2,8	2,8	2,9	3,0	3,1	3,1	3,2	3,7
	2,7	2,5	2,5	2,6	2,6	2,6	2,7	2,7	2,8	2,9	3,0	3,1	3,1	3,6
	2,6	2,4	2,4	2,5	2,5	2,6	2,6	2,6	2,7	2,6	2,9	3,0	3,1	3,5
	2,5	2,3	2,4	2,4	2,4	2,5	2,5	2,6	2,7	2,5	2,8	2,9	3,0	3,5
	2,4	2,2	2,3	2,3	2,4	2,4	2,4	2,5	2,6	2,4	2,7	2,8	2,9	3,4
	2,3	2,2	2,2	2,2	2,3	2,3	2,4	2,4	2,5	2,4	2,7	2,7	2,8	3,3
	2,2	2,1	2,1	2,2	2,2	2,2	2,3	2,3	2,4	2,3	2,6	2,7	2,7	3,2
	2,1	2,0	2,0	2,1	2,1	2,2	2,2	2,2	2,3	2,2	2,5	2,6	2,7	3,1
	2,0	2,0	2,0	2,1	2,1	2,1	2,2	2,2	2,3	2,4	2,5	2,6	2,7	3,1
	1,9	1,9	1,9	2,0	2,0	2,1	2,1	2,1	2,3	2,3	2,4	2,5	2,6	3,1
	1,8	1,8	1,9	1,9	1,9	2,0	2,0	2,1	2,2	2,3	2,3	2,4	2,5	3,0
	1,7	1,7	1,8	1,8	1,9	1,9	1,9	2,0	2,1	2,2	2,3	2,3	2,4	2,9
	1,6	1,7	1,7	1,7	1,8	1,8	1,9	1,9	2,0	2,1	2,2	2,3	2,3	2,8
	1,5	1,6	1,6	1,7	1,7	1,7	1,8	1,8	1,9	2,0	2,1	2,2	2,3	2,7
	1,4	1,5	1,5	1,6	1,6	1,7	1,7	1,7	1,9	1,9	2,0	2,1	2,2	2,7
	1,3	1,4	1,5	1,5	1,5	1,6	1,6	1,7	1,8	1,9	1,9	2,0	2,1	2,6
	1,2	1,3	1,4	1,4	1,5	1,5	1,5	1,6	1,7	1,8	1,9	1,9	2,0	2,5
	1,1	1,3	1,3	1,3	1,4	1,4	1,5	1,5	1,6	1,7	1,8	1,9	1,9	2,4
	1,0	1,2	1,2	1,3	1,3	1,3	1,4	1,4	1,5	1,6	1,7	1,8	1,9	2,3
	0,9	1,1	1,1	1,2	1,2	1,3	1,3	1,3	1,5	1,5	1,6	1,7	1,8	2,3
	0,8	1,0	1,1	1,1	1,1	1,2	1,2	1,3	1,4	1,5	1,5	1,6	1,7	2,2
	0,7	0,93	0,97	1,0	1,1	1,1	1,1	1,2	1,3	1,4	1,5	1,5	1,6	2,1
	0,6	0,85	0,89	0,93	0,97	1,0	1,1	1,1	1,2	1,3	1,4	1,5	1,5	2,0
	0,5	0,77	0,81	0,85	0,89	0,93	0,97	1,0	1,1	1,2	1,3	1,4	1,5	1,9

Table H.3 — Thermal transmittances, U_w, for vertical windows with fraction of the frame area 30 % of the whole window area, glazing spacer bars with improved thermal performance

Values in W/(m²·K)

Type of glazing	U_g	Thermal transmittances, U_w, for vertical windows with fraction of the frame area 30 %, spacer bars with improved thermal performance, and following U_f values												
		0,80	1,0	1,2	1,4	1,6	1,8	2,0	2,2	2,6	3,0	3,4	3,8	7,0
Single	5,8	4,3	4,4	4,4	4,5	4,5	4,6	4,7	4,7	4,8	5,0	5,1	5,2	6,2
Double or triple	3,3	2,7	2,7	2,8	2,9	2,9	3,0	3,0	3,1	3,2	3,4	3,5	3,6	4,4
	3,2	2,6	2,7	2,7	2,8	2,8	2,9	3,0	3,0	3,2	3,3	3,4	3,5	4,4
	3,1	2,5	2,6	2,7	2,7	2,8	2,8	2,9	3,0	3,1	3,2	3,3	3,5	4,3
	3,0	2,5	2,5	2,6	2,6	2,7	2,8	2,8	2,9	3,0	3,1	3,3	3,4	4,2
	2,9	2,4	2,5	2,5	2,6	2,6	2,7	2,8	2,8	3,0	3,1	3,2	3,3	4,2
	2,8	2,3	2,4	2,4	2,5	2,6	2,6	2,7	2,8	2,9	3,0	3,1	3,2	4,1
	2,7	2,3	2,3	2,4	2,4	2,5	2,6	2,6	2,7	2,8	2,9	3,1	3,2	4,0
	2,6	2,2	2,2	2,3	2,4	2,4	2,5	2,5	2,6	2,6	2,9	3,0	3,1	3,9
	2,5	2,1	2,2	2,2	2,3	2,4	2,4	2,5	2,6	2,5	2,8	2,9	3,0	3,9
	2,4	2,0	2,1	2,2	2,2	2,3	2,3	2,4	2,5	2,5	2,7	2,8	3,0	3,8
	2,3	2,0	2,0	2,1	2,2	2,2	2,3	2,3	2,4	2,4	2,7	2,8	2,9	3,7
	2,2	1,9	2,0	2,0	2,1	2,1	2,2	2,3	2,3	2,3	2,6	2,7	2,8	3,7
	2,1	1,8	1,9	2,0	2,0	2,1	2,1	2,2	2,3	2,2	2,5	2,6	2,8	3,6
	2,0	1,8	1,8	1,9	2,0	2,0	2,1	2,1	2,3	2,4	2,5	2,6	2,7	3,6
	1,9	1,7	1,8	1,8	1,9	2,0	2,0	2,1	2,2	2,3	2,4	2,5	2,7	3,5
	1,8	1,6	1,7	1,8	1,8	1,9	1,9	2,0	2,1	2,2	2,4	2,5	2,6	3,5
	1,7	1,6	1,6	1,7	1,8	1,8	1,9	1,9	2,0	2,2	2,3	2,4	2,5	3,4
	1,6	1,5	1,6	1,6	1,7	1,7	1,8	1,9	2,0	2,1	2,2	2,3	2,5	3,3
	1,5	1,4	1,5	1,6	1,6	1,7	1,7	1,8	1,9	2,0	2,1	2,3	2,4	3,2
	1,4	1,4	1,4	1,5	1,5	1,6	1,7	1,7	1,8	2,0	2,1	2,2	2,3	3,2
	1,3	1,3	1,4	1,4	1,5	1,5	1,6	1,7	1,8	1,9	2,0	2,1	2,2	3,1
	1,2	1,2	1,3	1,3	1,4	1,5	1,5	1,6	1,7	1,8	1,9	2,1	2,2	3,0
	1,1	1,2	1,2	1,3	1,3	1,4	1,5	1,5	1,6	1,7	1,9	2,0	2,1	3,0
	1,0	1,1	1,1	1,2	1,3	1,3	1,4	1,4	1,6	1,7	1,8	1,9	2,0	2,9
	0,9	1,0	1,1	1,1	1,2	1,3	1,3	1,4	1,5	1,6	1,7	1,8	2,0	2,8
	0,8	0,95	1,0	1,1	1,1	1,2	1,2	1,3	1,4	1,5	1,7	1,8	1,9	2,8
	0,7	0,88	0,94	1,0	1,1	1,1	1,2	1,2	1,3	1,5	1,6	1,7	1,8	2,7
	0,6	0,81	0,87	0,93	0,99	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,8	2,6
	0,5	0,74	0,80	0,86	0,92	0,98	1,0	1,1	1,2	1,3	1,4	1,6	1,7	2,5

Table H.4 — Thermal transmittances, U_w, for vertical windows with fraction of the frame area 20 % of the whole window area, glazing spacer bars with improved thermal performance

Values in W/(m²·K)

Type of glazing	U_g	Thermal transmittances, U_w, for vertical windows with fraction of the frame area 20 %, spacer bars with improved thermal performance, and following U_f values												
		0,80	1,0	1,2	1,4	1,6	1,8	2,0	2,2	2,6	3,0	3,4	3,8	7,0
Single	5,8	4,8	4,8	4,9	4,9	5,0	5,0	5,0	5,1	5,2	5,2	5,3	5,4	6,0
Double or triple	3,3	2,9	3,0	3,0	3,1	3,1	3,1	3,2	3,2	3,3	3,4	3,5	3,6	4,1
	3,2	2,9	2,9	2,9	3,0	3,0	3,1	3,1	3,2	3,2	3,3	3,4	3,5	4,0
	3,1	2,8	2,8	2,9	2,9	2,9	3,0	3,0	3,1	3,2	3,2	3,3	3,4	3,9
	3,0	2,7	2,7	2,8	2,8	2,9	2,9	2,9	3,0	3,1	3,2	3,2	3,3	3,8
	2,9	2,6	2,7	2,7	2,7	2,8	2,8	2,9	2,9	3,0	3,1	3,2	3,2	3,7
	2,8	2,5	2,6	2,6	2,7	2,7	2,7	2,8	2,8	2,9	3,0	3,1	3,2	3,7
	2,7	2,5	2,5	2,5	2,6	2,6	2,7	2,7	2,8	2,8	2,9	3,0	3,1	3,6
	2,6	2,4	2,4	2,5	2,5	2,5	2,6	2,6	2,7	2,6	2,8	2,9	3,0	3,5
	2,5	2,3	2,3	2,4	2,4	2,5	2,5	2,5	2,6	2,5	2,8	2,8	2,9	3,4
	2,4	2,2	2,3	2,3	2,3	2,4	2,4	2,5	2,5	2,4	2,7	2,8	2,8	3,3
	2,3	2,1	2,2	2,2	2,3	2,3	2,3	2,4	2,4	2,4	2,6	2,7	2,8	3,3
	2,2	2,1	2,1	2,1	2,2	2,2	2,3	2,3	2,4	2,3	2,5	2,6	2,7	3,2
	2,1	2,0	2,0	2,1	2,1	2,1	2,2	2,2	2,3	2,2	2,4	2,5	2,6	3,1
	2,0	1,9	2,0	2,0	2,0	2,1	2,1	2,2	2,3	2,3	2,4	2,5	2,6	3,1
	1,9	1,8	1,9	1,9	2,0	2,0	2,0	2,1	2,2	2,3	2,3	2,5	2,5	3,0
	1,8	1,8	1,8	1,8	1,9	1,9	2,0	2,0	2,1	2,2	2,3	2,3	2,4	2,9
	1,7	1,7	1,7	1,8	1,8	1,8	1,9	1,9	2,0	2,1	2,2	2,3	2,3	2,9
	1,6	1,6	1,6	1,7	1,7	1,8	1,8	1,8	1,9	2,0	2,1	2,2	2,3	2,8
	1,5	1,5	1,6	1,6	1,6	1,7	1,7	1,8	1,9	1,9	2,0	2,1	2,2	2,7
	1,4	1,4	1,5	1,5	1,6	1,6	1,6	1,7	1,8	1,9	1,9	2,0	2,1	2,6
	1,3	1,4	1,4	1,4	1,5	1,5	1,6	1,6	1,7	1,8	1,9	1,9	2,0	2,5
	1,2	1,3	1,3	1,4	1,4	1,4	1,5	1,5	1,6	1,7	1,8	1,9	1,9	2,5
	1,1	1,2	1,2	1,3	1,3	1,4	1,4	1,4	1,5	1,6	1,7	1,8	1,9	2,4
	1,0	1,1	1,2	1,2	1,2	1,3	1,3	1,4	1,5	1,5	1,6	1,7	1,8	2,3
	0,9	1,0	1,1	1,1	1,2	1,2	1,2	1,3	1,4	1,5	1,5	1,6	1,7	2,2
	0,8	0,96	1,0	1,0	1,1	1,1	1,2	1,2	1,3	1,4	1,5	1,5	1,6	2,1
	0,7	0,88	0,92	0,96	1,0	1,0	1,1	1,1	1,2	1,3	1,4	1,5	1,5	2,1
	0,6	0,80	0,84	0,88	0,92	0,96	1,0	1,0	1,1	1,2	1,3	1,4	1,5	2,0
	0,5	0,72	0,76	0,80	0,84	0,88	0,92	0,96	1,1	1,1	1,2	1,3	1,4	1,9

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