TECHNICAL REPORT

ISO/TR 52022-2

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Energy performance of buildings — Thermal, solar and daylight properties of building components and elements —

Part 2:
Explanation and justification

Performance énergétique des bâtiments — Propriétés thermiques, solaires et lumineuses des composants et éléments du bâtiment —

Partie 2: Explication et justification

Reference number
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Contents

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 52022-2 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 89, *Thermal performance of buildings and building components*, in collaboration with ISO Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2 *Calculation methods*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all parts in the ISO 52022 series can be found on the ISO website.

Introduction

The set of EPB standards, technical reports and supporting tools

In order to facilitate the necessary overall consistency and coherence, in terminology, approach, input/output relations and formats, for the whole set of EPB-standards, the following documents and tools are available:

a) a document with basic principles to be followed in drafting EPB-standards: CEN/TS 16628:2014[1];

b) a document with detailed technical rules to be followed in drafting EPB-standards; CEN/TS 16629:2014[2].

The detailed technical rules are the basis for the following tools:

1) a common template for each EPB-standard, including specific drafting instructions for the relevant clauses;

2) a common template for each technical report that accompanies an EPB standard or a cluster of EPB standards, including specific drafting instructions for the relevant clauses;

3) a common template for the spreadsheet that accompanies each EPB (calculation) standard, to demonstrate the correctness of the EPB calculation procedures.

Each EPB-standards follows the basic principles and the detailed technical rules and relates to the overarching EPB-standard, ISO 52000-1 [3].

One of the main purposes of the revision of the EPB-standards is to enable that laws and regulations directly refer to the EPB-standards and make compliance with them compulsory. This requires that the set of EPB-standards consists of a systematic, clear, comprehensive and unambiguous set of energy performance procedures. The number of options provided is kept as low as possible, taking into account national and regional differences in climate, culture and building tradition, policy and legal frameworks (subsidiarity principle). For each option, an informative default option is provided (Annex B).

Rationale behind the EPB technical reports

There is a risk that the purpose and limitations of the EPB standards will be misunderstood, unless the background and context to their contents – and the thinking behind them - is explained in some detail to readers of the standards. Consequently, various types of informative contents are recorded and made available for users to properly understand, apply and nationally or regionally implement the EPB standards.

If this explanation would have been attempted in the standards themselves, the result is likely to be confusing and cumbersome, especially if the standards are implemented or referenced in national or regional building codes.

Therefore each EPB standard is accompanied by an informative technical report, like this one, where all informative content is collected to ensure a clear separation between normative and informative contents (see CEN/TS 16629[2]):

— to avoid flooding and confusing the actual normative part with informative content;

— to reduce the page count of the actual standard, and

— to facilitate understanding of the set of EPB standards..

This was also one of the main recommendations from the European CENSE project[5] that that laid the foundation for the preparation of the set of EPB standards.

This technical report

This technical report accompanies the suite of EPB standards on thermal transmission properties windows, doors and curtain wallings and the standards for solar and daylight characteristics for solar protection devices combined with glazing. It relates to ISO 10077-1 [6], ISO 10077-2 [7], ISO 12631 [8], ISO 52022-1 [9] and ISO 52022-3 [10] which form part of a set of standards related to the evaluation of the energy performance of buildings (EPB).

The role and the positioning of the accompanied standard(s) in the set of EPB standards is defined in the introductions to ISO 10077-1, ISO 10077-2, ISO 12631, ISO 52022-1 and ISO 52022-3.

Accompanying spreadsheets

Concerning ISO 10077-1, ISO 10077-2, ISO 12631, ISO 52022-1 and ISO 52022-3, spreadsheets were produced for:

— ISO 10077-1;

— ISO 12631;

— ISO 52022-1.

No accompanying calculation spreadsheets were prepared on:

— ISO 10077-2: The calculation method of ISO 10077-2 cannot be implemented in a spreadsheet.

— ISO 52022-3: The calculation method of ISO 52022-3 cannot be implemented in a spreadsheet.

These spreadsheets are available at www.epb.center.

Energy performance of buildings — Thermal, solar and daylight properties of building components and elements —

Part 2:
Explanation and justification

1 Scope

This document contains information to support the correct understanding and use of ISO 10077-1, ISO 10077-2, ISO 12631, ISO 52022-1 and ISO 52022-3.

This technical report does not contain any normative provision.

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 methods*

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

ISO 10077-1, *Thermal performance of windows, doors and shutters — Calculation of thermal transmittance — Part 1: General*

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

ISO 12631:2017, *Thermal performance of curtain walling — Calculation of thermal transmittance*

ISO 52022-1, *Energy performance of buildings— Thermal, solar and daylight properties of building components and elements Part 1: Simplified calculation method of the solar and daylight characteristics for solar protection devices combined with glazing*

ISO 52022-3, *Energy performance of buildings— Thermal, solar and daylight properties of building components and elements Part 3: Detailed calculation method of the solar and daylight characteristics for solar protection devices combined with glazing*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6946, ISO 7345, ISO 10077-1, ISO 10077-2, ISO 12631, ISO 52022-1 and ISO 52022-3 apply.

More information on some key EPB terms and definitions is given in ISO/TR 52000-2.

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

4   Symbols and subscripts

For the purposes of this document, the symbols and subscripts given in ISO 7345, ISO 6946, ISO 10077-1, ISO 10077-2, ISO 12631, ISO 52022-1 and ISO 52022-3 apply.

5   Brief description of the methods

5.1   Outputs of the method

The main outputs of these standards are:

— thermal transmittance of windows, doors, curtain walls, shutter boxes and frames;

— solar and daylight characteristics (solar energy transmittance, daylight transmittance) for solar protecting devices combined with glazing.

5.2   General description of the methods

ISO 10077-1, ISO 10077-2, ISO 12631, ISO 52022-1 and ISO 52022-3 provide the methodology to obtain the energy losses due to transmission and the energy gains due to solar radiation for windows, doors and curtain walls.

The calculation of the thermal transmittance of windows, doors according to ISO 10077-1 and curtain walls according to ISO 12631 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 of the thermal transmittance of frame profiles, shutter boxes and the linear thermal transmittance according to ISO 10077-2 is carried out using a two dimensional numerical method.

There are two separate standards for the calculation of the solar and daylight characteristics for solar protection devices combined with glazing. ISO 52022-1 defines a simplified method based on the thermal transmittance and total solar energy transmittance of the glazing and on the light transmittance and reflectance of the solar protection device to estimate the total solar energy transmittance of a solar protection device combined with glazing. The results generally tend to lie on the safe side for cooling load estimations. The results are not intended to be used for calculating beneficial solar gains or thermal comfort criteria. The calculations according to ISO 52022-1 can in principle be performed by a pocket calculator.

For cases not covered by ISO 52022-3 more exact calculations based on the optical properties (in general the spectral data) of glass and solar protection device can be carried out in accordance with ISO 52022-3. The total solar energy transmittance, the total solar direct transmittance and the total light transmittance is calculated as a function of the thermal resistance and spectral "optical" properties (transmittance, reflectance) of the individual layers. To solve the system of equations defined in ISO 52022-3 the use of an iterative procedure and therefore in general a software tool is necessary.

6   ISO 10077-1 Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 1: General

6.1   General

ISO 10077-1 provides a calculation method to obtain the thermal transmittance of windows and pedestrian doors consisting of glazed and/or or opaque panels fitted in a frame, with and without shutters.

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.

An alternative to calculation according to ISO 10077-1 is testing of the complete window or door according to ISO 12567-1 or, for roof windows, according to ISO 12567-2.

The following subclauses provide information in addition to that given in ISO 10077-1.

6.2 Thermal transmittance of the glazing

If measured or calculated data are not available, the values in Annex A may be used.

6.3 Additional thermal resistance of windows with closed shutters

A shutter or blind on the outside of a window introduces an additional thermal resistance ΔR, resulting from both the air layer enclosed between the shutter and the window, and the shutter itself. ΔR depends on the thermal transmission properties of the shutter/blind and on its air permeability and is evaluated according to ISO 10077-1.

Annex B of this document gives some typical values of shutter thermal resistance and the corresponding values of ΔR, which can be used in the absence of values of R_{sh} obtained from measurement or calculation.

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

7.1 General

ISO 10077-2 specifies a method and gives reference input data for the calculation of the thermal transmittance of frame profiles and of the linear thermal transmittance of their junction with glazing or opaque panels. The method can also be used to evaluate the thermal resistance of shutter profiles and the thermal characteristics of roller shutter boxes and similar components (e.g., blinds). ISO 10077-2 also gives criteria for the validation of numerical methods used for the calculation.

7.2 Calculation principle

The calculation is carried out using a two-dimensional numerical method conforming to ISO 10211. The elements are divided such that any further division does not change the calculated result significantly. ISO 10211 gives criteria for judging whether sufficient sub-divisions have been used.

Two different approaches for the calculation of the heat transfer through cavities are given:

1. the radiosity method and;

2. the single equivalent thermal conductivity method.

The radiosity method considers that the heat transfer through an air cavity occurs simultaneously through conduction/convection and through radiation. The two phenomena are happening in parallel so that the calculation of each contribution is done separately.

When using the single equivalent thermal conductivity method the heat flow rate in cavities is represented by a single equivalent thermal conductivity λ_{eq}. This equivalent thermal conductivity includes the heat flow by conduction, by convection and by radiation, and depends on the geometry of the cavity and on the adjacent materials.

The single equivalent thermal conductivity method is equal to the calculation method given in ISO 10077-2:2012.

8 ISO 12631 Thermal performance of curtain walling – Calculation of thermal transmittance

8.1 General

ISO 12631 provides a calculation method to obtain the thermal transmittance of curtain walls consisting of glazed and/or or opaque panels fitted in a frame.

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

Two methods of calculating the thermal transmittance of curtain wall systems are specified:

— the single assessment method; and

— the component assessment method.

The single assessment method is based on detailed computer calculations of the heat transfer through a complete construction including mullions, transoms, and filling elements (e.g., glazing unit, opaque panel). The heat flow rate (between two adiabatic lines) is calculated by modelling each thermal joint between two filling elements (opaque panel and/or glazing unit) using two-dimensional or three-dimensional finite element analysis software. By area weighting the U-values of thermal joints and filling elements, the overall façade U-value can be calculated. This method can be used for any curtain walling system (i.e. unitised systems, stick systems, patent glazing, structural sealant glazing, rain screens, structural glazing).

The component assessment method divides the representative element into areas of different thermal properties, e.g., glazing units, opaque panels and frames. By area weighting the U-values of these elements with additional correction terms describing the thermal interaction between these elements (Ψ-values), the overall façade U-value can be calculated. This method can be used for curtain walling systems such as unitised systems, stick systems and patent glazing. Structural silicone glazing, rain screens and structural glazing are excluded from the component assessment method.

Both methods result in the same value for the thermal transmittance of a curtain wall.

8.2 Calculation examples

Annex C gives an example for the calculation of a curtain walling module according to the component method.

Annex D gives an example for the calculation of a curtain walling module according to the single assessment method.

9 ISO 52022-1 Energy performance of buildings — Thermal, solar and daylight properties of building components and elements — Part 1: Simplified calculation method of the solar and daylight characteristics for solar protection devices combined with glazing

9.1 General

ISO 52022-1 defines a simplified method for the calculation of:

— the total solar energy transmittance;

— the total solar direct transmittance;

— the total light transmittance; and

— a glazing in combination with an external or internal or integrated solar protection device.

These characteristics are calculated as a function of the "optical" properties of the solar protection device and the glazing, the thermal transmittance of the glazing and the position of the solar protection device.

The formulae given in ISO 52022-1 are based on a simple physical model and the values of the notional parameters G are mathematically fitted to a more precise reference calculation, following the principles of ISO 52022-3.

The results generally tend to lie on the safe side for cooling load estimations. The results are not intended to be used for calculating beneficial solar gains during heating period or thermal comfort criteria.

9.2 Data for typical glazing and solar protection devices

Annex E gives some typical values for the characteristics of glazing and solar protection devices which can be used in the absence of values obtained from measurement or calculation.

9.3 Solar transmittance of solar protection devices

Figure 1 shows the principles of solar transmittance of solar protection devices.

The simplified equations in ISO 52022-1 for venetian blinds open to 45° to not take into account direct solar transmittance and diffuse radiation. The reflection of the slats is to be considered diffuse. If diffuse irradiation has to be considered the relevant properties of louvre or Venetians blinds should be calculated in accordance with ISO 52022-3.
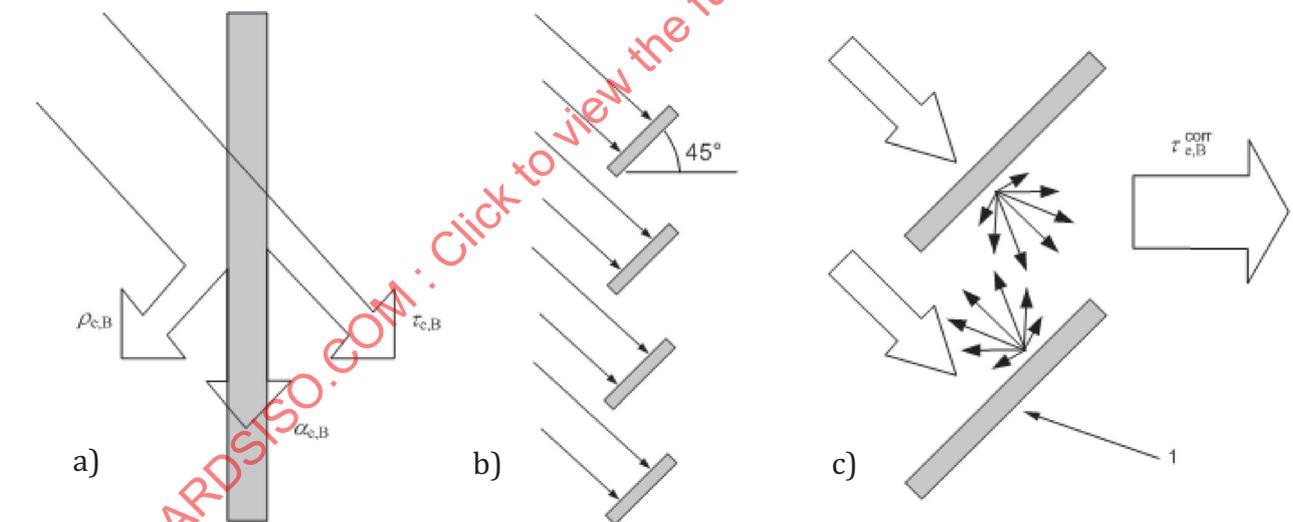
Key

1   blinds 45°

a)   transmittance, absorptance and reflectance of a solar protection device

b)   no direct penetration in the case of louvre or Venetian blinds open to 45°

c)   principle of the correction of the transmittance in the case of blinds open to 45°

Figure 1 — Principles of solar transmittance of solar protection devices

9.4 Calculation example

Annex F gives an example of calculation for the three positions of a solar protection device in combination with a double clear glazing.

10 ISO 52022-3 Energy performance of buildings — Thermal, solar and daylight properties of building components and elements — Part 3: Detailed calculation method of the solar and daylight characteristics for solar protection devices combined with glazing

10.1 General

ISO 52022-3 defines a procedure for a detailed calculation of the solar and daylight characteristics for solar protection devices combined with glazing.

The procedure is based on the spectral transmission and reflection data of the materials, comprising the solar protection devices and the glazing, to determine the total solar energy transmittance and other relevant solar-optical data of the combination. If spectral data are not available the methodology can be adapted to use integrated data.

In the physical model the glass panes and blinds are considered as parallel, solid layers. In general, the total solar energy transmittance, the total solar direct transmittance and the total light transmittance is calculated as a function of the thermal resistance and spectral "optical" properties (transmittance, reflectance) of the individual layers.

Two sets of boundary conditions are given for the vertical position of the glazing and the blind.

Reference conditions:

These boundary conditions are consistent with the general assumptions of EN 410 and ISO 10292 and to be used for product comparison and average solar gain calculations during the heating period.

Summer conditions:

These boundary conditions are representative of more extreme conditions and are used for comfort evaluations and cooling load calculations.

10.2 Equivalent solar and light optical characteristics for louvres or venetian blinds

ISO 52022-3:2017, Annex D defines a method for the determination of equivalent solar and light optical characteristics for louvres or venetian blinds. The method is restricted to the assumptions stated in ISO 52022-3:2017, Annex D.

Annex G report defines an extended method which may be applied as an alternative method.

10.3 Calculation example

Annex H gives an example of calculation for the three positions of a solar protection device in combination with a double clear glazing.

Annex A
(informative)

ISO 10077-1: Thermal transmittance of double and triple glazing

Table A.1 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 Table A.1 apply to the emissivities and gas concentration given.

Table A.1 — Thermal transmittance of double and triple glazing filled with different gases for vertical glazing

Glazing				Thermal transmittance for different types of gas space[a] U_g				
Type	Glass	Normal emissivity	Dimensions mm	Air	Argon	Krypton	SF$_6$[b]	Xenon
Double glazing	Uncoated glass (normal glass)	0,89	4–6-4	3,3	3,0	2,8	3,0	2,6
			4–8-4	3,1	2,9	2,7	3,1	2,6
			4–12–4	2,8	2,7	2,6	3,1	2,6
			4–16–4	2,7	2,6	2,6	3,1	2,6
			4–20–4	2,7	2,6	2,6	3,1	2,6
	One pane coated glass	≤ 0,2	4–6-4	2,7	2,3	1,9	2,3	1,6
			4–8-4	2,4	2,1	1,7	2,4	1,6
			4–12–4	2,0	1,8	1,6	2,4	1,6
			4–16–4	1,8	1,6	1,6	2,5	1,6
			4–20–4	1,8	1,7	1,6	2,5	1,7
	One pane coated glass	≤ 0,15	4–6-4	2,6	2,3	1,8	2,2	1,5
			4–8-4	2,3	2,0	1,6	2,3	1,4
			4–12–4	1,9	1,6	1,5	2,3	1,5
			4–16–4	1,7	1,5	1,5	2,4	1,5
			4–20–4	1,7	1,5	1,5	2,4	1,5
	One pane coated glass	≤ 0,1	4–6-4	2,6	2,2	1,7	2,1	1,4
			4–8-4	2,2	1,9	1,4	2,2	1,3
			4–12–4	1,8	1,5	1,3	2,3	1,3
			4–16–4	1,6	1,4	1,3	2,3	1,4
			4–20–4	1,6	1,4	1,4	2,3	1,4
	One pane coated glass	≤ 0,05	4–6-4	2,5	2,1	1,5	2,0	1,2
			4–8-4	2,1	1,7	1,3	2,1	1,1
			4–12–4	1,7	1,3	1,1	2,1	1,2
			4–16–4	1,4	1,2	1,2	2,2	1,2
			4–20–4	1,5	1,2	1,2	2,2	1,2

NOTE   The values of thermal transmittance in the table were calculated using EN 673. They apply to the emissivities and gas concentration given.

[a]   Gas concentration ≥ 90 %.

[b]   The use of SF$_6$ is prohibited in some jurisdictions.

Table A.1 *(continued)*

Glazing				Thermal transmittance for different types of gas space[a] U_g				
Type	Glass	Normal emissivity	Dimensions mm	Air	Argon	Krypton	SF$_6$[b]	Xenon
Triple glazing	Uncoated (normal) glass	0,89	4–6-4–6-4	2,3	2,1	1,8	1,9	1,7
			4-8-4-8-4	2,1	1,9	1,7	1,9	1,6
			4–12-4-12–4	1,9	1,8	1,6	2,0	1,6
	Two panes coated	≤ 0,2	4–6-4–6-4	1,8	1,5	1,1	1,3	0,9
			4-8-4-8-4	1,5	1,3	1,0	1,3	0,8
			4–12-4-12–4	1,2	1,0	0,8	1,3	0,8
	Two panes coated	≤ 0,15	4–6-4–6-4	1,7	1,4	1,1	1,2	0,9
			4-8-4-8-4	1,5	1,2	0,9	1,2	0,8
			4–12-4-12–4	1,2	1,0	0,7	1,3	0,7
	Two panes coated	≤ 0,1	4–6-4–6-4	1,7	1,3	1,0	1,1	0,8
			4-8-4-8-4	1,4	1,1	0,8	1,1	0,7
			4–12-4-12–4	1,1	0,9	0,6	1,2	0,6
	Two panes coated	≤ 0,05	4–6-4–6-4	1,6	1,2	0,9	1,1	0,7
			4-8-4-8-4	1,3	1,0	0,7	1,1	0,5
			4–12-4-12–4	1,0	0,8	0,5	1,1	0,5

NOTE   The values of thermal transmittance in the table were calculated using EN 673. They apply to the emissivities and gas concentration given.

[a]   Gas concentration ≥ 90 %.

[b]   The use of SF$_6$ is prohibited in some jurisdictions.

Annex B
(informative)

ISO 10077-1: Additional thermal resistance for windows with closed shutters

B.1 Additional thermal resistance

When the thermal resistance of the shutter itself, R_{sh}, is known (by calculation or by measurement), the additional thermal resistance, ΔR, can be obtained using the appropriate expression in Table B.1, depending on the air permeability of the shutter (see B.2).

Table B.1 — Additional thermal resistance for windows with closed shutters

Air permeability of shutter[a]	Additional thermal resistance ΔR m²·K/W
Very high	0,08
High	0,25 R_{sh} + 0,09
Average	0,55 R_{sh} + 0,11
Low	0,80 R_{sh} + 0,14
Tight	0,95 R_{sh} + 0,17
[a] The definition of the air permeability of shutters is given in B.2.	

Average air permeability applies typically to solid wing shutters, wooden Venetian shutters with solid overlapping slats, roller shutters with connecting slats made of wood, plastic or metal.

Table B.2 gives some typical values of shutter thermal resistance and the corresponding values of ΔR, which can be used in the absence of values of R_{sh} obtained from measurement or calculation.

Table B.2 — Additional thermal resistance for windows with closed shutters

Shutter type	Typical thermal resistance of shutter R_{sh} m²·K/W	Additional thermal resistances at specific air permeability of the shutters[a] ΔR m²·K/W		
		High or very high air permeability	Average air permeability	Tight or low air permeability
Roller shutters of aluminium	0,01	0,09	0,12	0,15
Roller shutters of wood and plastic without foam filling	0,10	0,12	0,16	0,22
Roller shutters of plastic with foam filling	0,15	0,13	0,19	0,26
Shutters of wood, 25 mm to 30 mm thickness	0,20	0,14	0,22	0,30
[a] The definition of the air permeability of shutters is given in B.2.				

B.2 Permeability of shutters

For the different types of shutter, the permeability criterion can be expressed in terms of an effective total gap, b_{sh}, between the shutter and its surround as given in Formula (B.1):

$$b_{sh} = b_1 + b_2 + b_3 \tag{B.1}$$

where

b_1, b_2 and b_3 are the average edge gaps at the bottom, top and side on the shutter (see Figure B.1);

b_3 is included for one side only, since gaps at the side influence the permeability less than the gaps at the top and bottom.
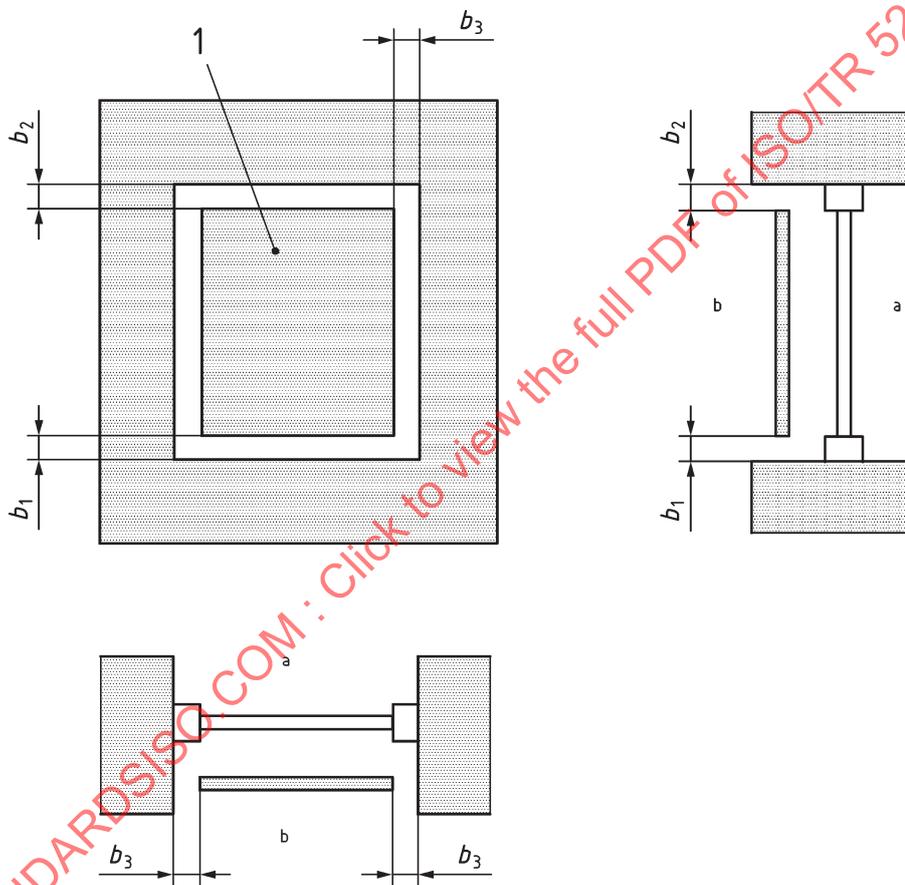
Key

1   shutter

a   internal

b   external

Figure B.1 — Definition of edge gaps

Table B.3 — Relationship between permeability and effective total edge gap between shutter and its surround

Class	Air permeability of shutter	b_{sh} mm
1	Very high	$b_{sh} \geq 35$
2	High	$15 \leq b_{sh} < 35$
3	Average	$8 \leq b_{sh} < 15$
4	Low	$b_{sh} \geq 8$
5	Tight	$b_{sh} \leq 3$ and ($b_1 + b_3 = 0$ or $b_2 + b_3 = 0$)

NOTE 1   For permeability classes 2 and above, there should be no openings within the shutter itself.

NOTE 2   For shutters of permeability class 5 the following criteria apply:

a   roller shutters:

   The edge gaps at the sides and the bottom are considered equal to 0 if strip gaskets are supplied in the guide rails and the final lath, respectively. The gap at the top is considered equal to 0 if the entrance to the roller shutter box is fitted with lips or brush-type joints on both sides of the shutter, or if the end of the shutter is pressed by a device (spring) against a sealing material at the inner surface of the outer side of the roller shutter box.

b   other shutters:

   Effective presence of strip gaskets on three sides and the gap at the fourth side less than 3 mm.

An alternative method to establish that a shutter is class 5 is to verify by measurement that the air flow through the shutter does not exceed 10 m³/(h·m²) under a pressure drop of 10 Pa.

Annex C
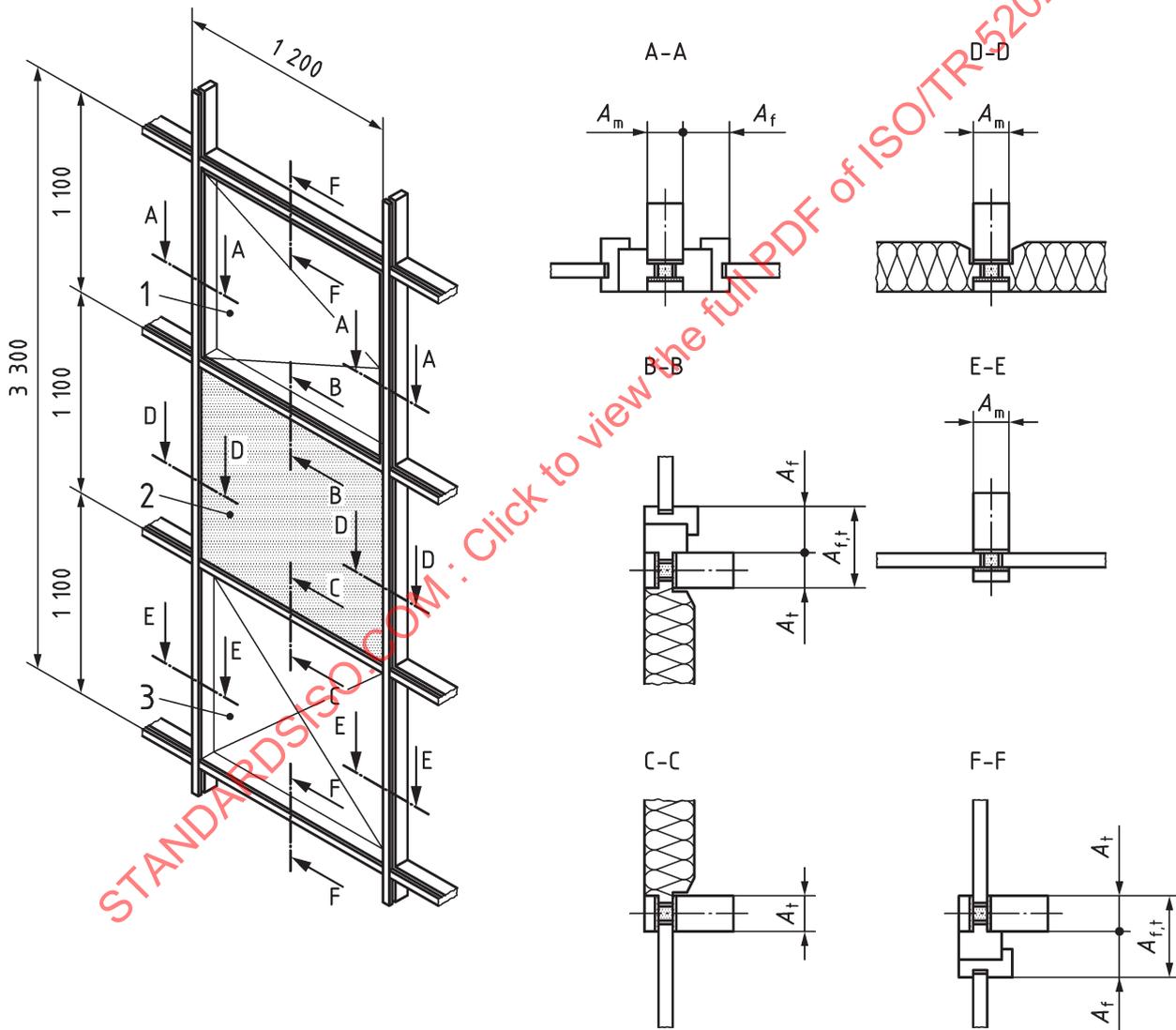## (informative)

ISO 12631: Component method: Calculation example

C.1 Data for examples

Annex C gives an example for the calculation of a curtain walling element according to the component method described in ISO 12631:2017, Clause 8.
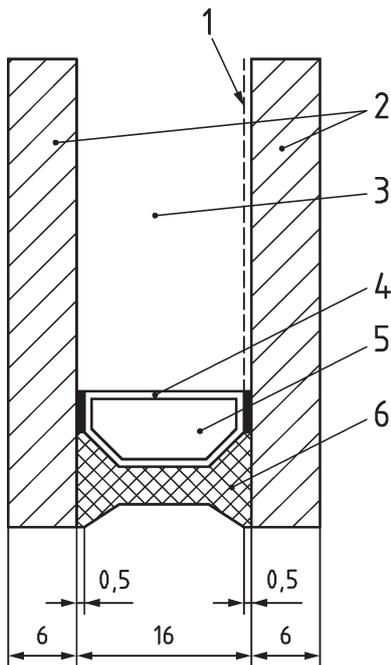
Dimensions in millimetres

Key

1   window
2   panel
3   fixed glazing unit

Figure C.1 — Element of a curtain wall seen from the exterior

Key

1   low E coating ε_n = 0,05

2   glass with λ = 1,0 W/(m·K)

3   argon 90 %

4   aluminium with a thickness of
    0,5 mm and λ = 160 W/(m·K)

5   molecular sieve with λ = 0,13 W/(m·K)

6   polysulfide with λ = 0,40 W/(m·K)

Key

1   steel

2   insulation with λ = 0,04 W/(m·K)

3   glass with λ = 1,0 W/(m·K)

4   spacer with λ = 0,4 W/(m·K)

Figure C.2 — Detail of glazing unit

Figure C.3 — Detail of panel

For the module illustrated in Figures C.1 to C.3, the calculation procedure is in accordance with C.2 to C.4.

C.2 Frames

C.2.1 Definition and evaluation of areas
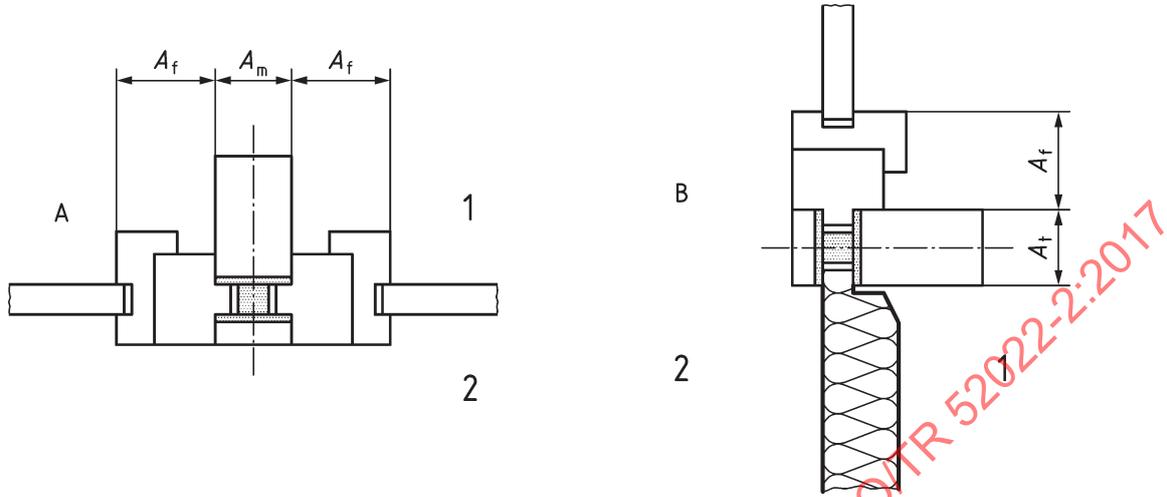
Key

A	mullion – frame	1	internal
B	transom – frame	2	external

Figure C.4 — Definition of areas

Mullion	$2 \times 3,3 \text{ m} \times 0,025 \text{ m}$	$= 0,165\,0 \text{ m}^2$
Area	A_m	$= 0,165\,0 \text{ m}^2$

Transom	$2 \times (1,20 \text{ m} - 2 \times 0,025 \text{ m}) \times 0,025 \text{ m}$	$= 0,057\,5 \text{ m}^2$
Area	$2 \times (1,20 \text{ m} - 2 \times 0,025 \text{m}) \times 0,050 \text{ m}$	$= 0,115\,0 \text{ m}^2$
	A_t	$= 0,172\,5 \text{ m}^2$

Frame	$2 \times (1,20 \text{ m} - 2 \times 0,025 \text{ m}) \times 0,080 \text{ m}$	$= 0,184\,0 \text{ m}^2$
Area	$2 \times (1,10 \text{ m} - 2 \times 0,025 \text{ m} - 2 \times 0,08 \text{ m}) \times 0,08 \text{ m}$	$= 0,142\,4 \text{ m}^2$
	A_f	$= 0,326\,4 \text{ m}^2$

A_m 50 mm width

A_t 50 mm width

A_f 80 mm width

C.2.2 Evaluation of U_f values

U_f values can be taken from measurement according to EN 12412-2 or can be calculated according to ISO 10077-2 (the effect of the screws is considered according to ISO 12631:2017, 8.3.2.2). For further calculations in this example it is assumed:

mullion	U_m	$2,2 \text{ W/(m}^2\text{·K)}$[a]
transom	U_t	$1,9 \text{ W/(m}^2\text{·K)}$[a]
frame	U_f	$2,4 \text{ W/(m}^2\text{·K)}$

[a] Measured value according to EN 12412–2.

C.3   Glazing units

C.3.1   Definition and evaluation of areas

Movable part	width	1,20 m – 2 × 0,025 m – 2 × 0,08 m	= 0,99 m
	height	1,10 m – 2 × 0,025 m – 2 × 0,08 m	= 0,89 m
	A_g	0,99 m × 0,89 m	= 0,881 1 m^2
Fixed part	width	1,20 m – 2 × 0,025 m	= 1,15 m
	height	1,10 m – 2 × 0,025 m	= 1,05 m
	A_g	1,15 m × 1,05 m	= 1,207 5 m^2

C.3.2   Evaluation of U_g values

For further calculations, it is assumed:

   U_g = 1,2 W/(m^2·K)

C.3.3   Definition of l_g and evaluation of Ψ_g, $\Psi_{m,f}$ and $\Psi_{t,f}$

Perimeter

| movable part | $l_{f,g}$ | 2 × 0,99 m + 2 × 0,89 m | = 3,76 m |
| fixed part | $l_{t,g} + l_{m,g}$ | 2 × 1,15 m + 2 × 1,05 m | = 4,40 m |

Ψ-values can be taken from ISO 12631:2017, Annex D or can be calculated according to ISO 10077-2 (see ISO 12631:2017, Tables D.1, D.3 and D.5).

$\Psi_{f,g}$	movable part	0,11 W/(m·K)
$\Psi_{m,g}$ $\Psi_{t,g}$	fixed part	0,17 W/(m·K)
$\Psi_{m,f}$	Type D2	0,07 W/(m·K)
$\Psi_{t,f}$	Type D2	0,07 W/(m·K)

C.4   Panels

C.4.1   Definition and evaluation of areas

width	1,20 m – 2 × 0,025 m	= 1,15 m
height	1,10 m – 2 × 0,025 m	= 1,05 m
area, A_p	1,15 m × 1,05 m	= 1,207 5 m^2

C.4.2   Evaluation of U_p values

The U-value of a panel can be evaluated according to ISO 6946. The panel shown in Figure C.2 gives:

   U_p 0,46 W/(m^2·K).

C.4.3   Definition of l_p and evaluation of the Ψ_p values

perimeter	l_p	$2 \times 1{,}15$ m $+ 2 \times 1{,}05$ m	$= 4{,}40$ m

Ψ_p values can be taken from ISO 12631:2017, Table D.5 or can be calculated according to ISO 10077-2. A panel shown in Figure C.3 gives:

	Ψ_p	0,18 W/(m·K).

C.4.4   Calculation of a complete element

Table C.1 — Presentation of values of calculation example

		A m^2		U W/(m^2·K)		L m		Ψ W/(m·K)	$A{\cdot}U$ W/K	$\Psi{\cdot}l$ W/K
mullion	A_m	0,165 0	U_m	2,2					0,363	
transom	A_t	0,172 5	U_t	1,9					0,328	
frame	A_f	0,326 4	U_f	2,4					0,783	
mullion – frame					$l_{m,f}$	2,1	$\Psi_{m,f}$	0,07		0,154
transom – frame					$l_{t,f}$	2,3	$\Psi_{t,f}$	0,07		0,154
glazing										
– movable part	A_g	0,881 1	U_g	1,2	$l_{f,g}$	3,76	Ψ_g	0,11	1,057	0,414
– fixed part	A_g	1,207 5	U_g	1,2	$l_{m,g}$ $l_{t,g}$	4,40	Ψ_g	0,17	1,449	0,748
panel	A_p	1,207 5	U_p	0,46	l_p	4,40	Ψ_p	0,18	0,556	0,792
total	A_{CW}	3,96							4,536	2,262

$$A_{cw}{\cdot}U_{cw} = \sum A{\cdot}U + \sum \Psi{\cdot}l = \quad 6{,}80$$

$$U_{cw} = \frac{\sum A{\cdot}U + \sum \Psi{\cdot}l}{A_{cw}} = 6{,}80/3{,}96 = \quad \begin{matrix}1{,}7\\(1{,}72)\end{matrix}$$

Annex D
(informative)

ISO 12631: Single assessment method: Calculation example

D.1 General description of examples

Annex D gives an example for the calculation of a curtain walling module according to the single assessment method described in ISO 12631:2017, Clause 7. For this example a structural silicone glazing is used.

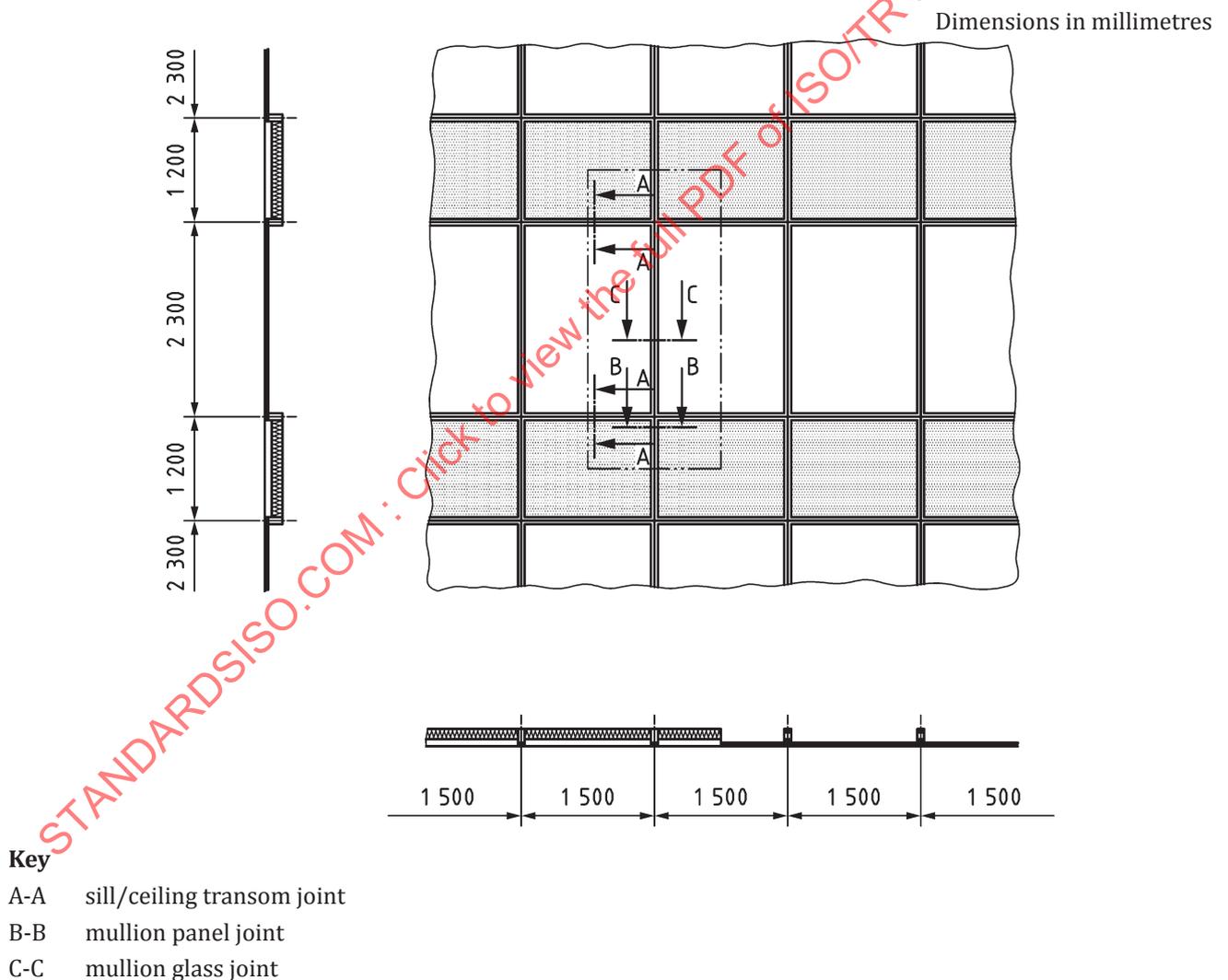The calculations are based on the given panel dimensions.

Dimensions in millimetres

Key

A-A   sill/ceiling transom joint

B-B   mullion panel joint

C-C   mullion glass joint

Figure D.1 — Façade module geometry

Table D.1 — Panel dimensions

Panel	Dimensions mm
Façade module height	3 500
Façade module width	1 500
Spandrel panel height	1 200

D.2   Centre *U*-value of the glazing unit

The glazing unit chosen for this calculation is the following:

Outer-light: 8 mm Low E glass (ε_n = 0,04);

Cavity: 16 mm air filled;

Inner-light: 5 mm clear glass.

One-dimensional centre *U*-value calculation has been performed for this glazing unit in accordance with EN 673. The one-dimensional thermal transmittance of this glazing unit is found to be:

U_g = 1,4 W/(m^2·K)

D.3   Centre *U*-value of the spandrel panel

The one-dimensional panel thermal transmittance is U_p = 0,37 W/(m^2·K), in accordance with ISO 6946.

D.4   *U*-values of thermal joints

The thermal joints have been modelled by means of 2-dimensional FEA analysis. Material properties have been taken from ISO 10077-2:2017, Annex D.

The glazing unit has been modelled with aluminium spacers.

The assessed joint *U*-value U_{TJ} represents the heat flow rate through the frame plus all thermal effects due to the thermal interaction between the glass, frame and panel. The projected width of the joint (perpendicular to the filling element direction) excluding the glazing gaskets is measured between the two filling elements. For each of the models, the area of the joints is stated along with the joint *U*-value.

Table D.2 — *U*-values of thermal joints

Component	Ceiling transom joint (equal to sill transom joint in this example)	Mullion panel joint	Mullion glass joint
U_{TJ}	U_{TJ} = 9,97 W/(m^2·K)	U_{TJ} = 9,66 W/(m^2·K)	U_{TJ} = 9,71 W/(m^2·K)
A_{TJ}	A_{TJ} = 0,13 m^2	A_{TJ} = 0,11 m^2	A_{TJ} = 0,21 m^2
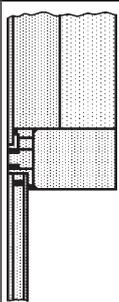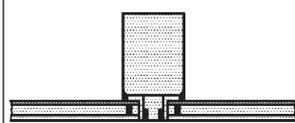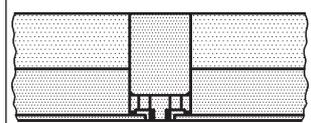
D.5 Overall *U*-value of the curtain wall

Area weighting of the *U*-values of all frames, glass and panels is used to calculate the overall *U*-value.

$$U_{\text{cw}} = \frac{\sum A_g U_g + \sum A_p U_p + \sum A_{TJ} U_{TJ}}{\sum A_g + \sum A_p + \sum A_{TJ}}$$

(D.1)

Table D.3 — Overall *U*-value of the curtain wall

Components	*U*-value W/(m²·K)	*A* m²	*U*·*A* W/K
Ceiling transom joint	9,97	0,13	1,29
Sill transom joint	9,97	0,13	1,29
Mullion glass joint	9,71	0,21	2,05
Mullion panel joint	9,66	0,11	1,07
Spandrel panel centre	0,37	1,56	0,58
Glazing centre	1,40	3,11	4,35
	TOTAL	5,25	10,63
Overall *U*-value curtain wall: U_{cw} = 2,0 W/(m²·K).			

Annex E
(informative)

ISO 52022-1: Data for typical glazing and solar protection devices

Table E.1 — Indicative data for typical glazing

Product	Thermal transmittance U_g W/(m²·K)	Total solar energy transmittance g	Light transmittance τ_v	Light reflectance $\rho_v = \rho_v$
Single clear glass	5,8	0,85	0,90	0,08
Double clear glass with air filling	2,9	0,76	0,82	0,15
Double clear glass with low emissivity coating and Argon filling	1,2	0,59	0,80	0,13
Triple clear glass with low emissivity coating and Argon filling	0,8	0,55	0,73	0,16

Table E.2 — Indicative data for typical solar protection devices

Transmittance $\tau_{e,B}$		Reflectance $\rho_{e,B}$			
		white	pastel	dark	black
Opaque (e.g., closed roller shutter)	0,0	0,7	0,5	0,3	0,1
Closed venetian blind with opaque slats	0,1	0,7	0,5	0,3	0,1
Medium translucent	0,2	0,6	0,4	0,2	0,1
High translucent	0,4	0,4	0,3	0,2	0,1

In case of uncertainty between two categories in Table E.2, the category with the highest transmittance and lowest reflectance should be selected.

These are typical values for transmittance and reflectance of solar protection device materials. The absorptance, $\alpha_{e,B}$, is given by $\alpha_{e,B} = 1 - \tau_{e,B} - \rho_{e,B}$. It is assumed that the transmittance and the reflectance for light are equal to the corresponding values for solar energy.

Annex F
(informative)

ISO 52022-1: Example of calculation of a solar protection device in combination with glazing

Annex F gives an example of calculation for the three positions of a medium translucent pastel solar protection device in combination with a double clear glazing.

The following data are taken from Tables E.1 and E.2. It is assumed, that the solar protection device is not selective and therefore the light transmittance and reflectance values are the same as for the solar direct transmittance and reflectance.

glazing:

solar protection device:

$\tau_v = 0,82$ $\tau_{e,B} = \tau_{v,B} = 0,2$

$g = 0,75$ $\rho_{e,B} = \rho_{v,B} = 0,4$

$U = 3,0\ \mathrm{W/(m^2 \cdot K)}$ $\alpha_{e,B} = 1 - 0,2 - 0,4 = 0,4$

$\rho_v = \rho'_v = 0,15$

a) External solar protection device

$$G_{\mathrm{ext}} = \frac{1}{\dfrac{1}{3,0} + \dfrac{1}{5} + \dfrac{1}{10}} = 1,6\,\mathrm{W}/\left(\mathrm{m}^2 \cdot \mathrm{K}\right)$$

$$g_{\mathrm{tot}} = 0,2 \times 0,75 + 0,4 \times \frac{1,6}{18} + 0,2 \times (1 - 0,75) \times \frac{1,6}{5} = 0,23$$

$$\tau_{v,\mathrm{tot}} = \frac{0,82 \times 0,2}{1 - 0,15 \times 0,4} = 0,17$$

b) Internal solar protection device

$$G_{\mathrm{int}} = \frac{1}{\dfrac{1}{3,0} + \dfrac{1}{30}} = 2,7\,\mathrm{W}/\left(\mathrm{m}^2 \cdot \mathrm{K}\right)$$

$$g_{\mathrm{tot}} = 0,75 \times \left(1 - 0,75 \times 0,4 - 0,4 \times \frac{2,7}{18}\right) = 0,50$$

$$\tau_{v,\mathrm{tot}} = \frac{0,82 \times 0,2}{1 - 0,15 \times 0,4} = 0,17$$

c) Solar protection device between panes

$$G_{\text{integr}} = \cfrac{1}{\cfrac{1}{3,0} + \cfrac{1}{3}} = 1,5\,\text{W}/\left(\text{m}^2\cdot\text{K}\right)$$

$$g_{\text{tot}} = 0,75 \times 0,2 + 0,75\left(0,4 + \left(1-0,75\right)\times\frac{1,5}{3,0}\right) = 0,34$$

$\tau_{\text{v,tot}}$ no simplified calculation provided.

Annex G
(informative)

Extended methodology for the determination of equivalent solar and light optical characteristics for louvres or venetian blinds

G.1 General

The extended calculation method of solar factors and light transmission is based on the method defined in ISO 52022-3. ISO 52022-3 considers mobile protection devices with tilted slats as a homogeneous layer with equivalent energy and light properties denoted τ_S, $\tau_{S'}$, ρ_S and $\rho_{S'}$, where (see Figure G.1):

— τ_S is transmittance of the side facing the incident radiation;

— $\tau_{S'}$ is the transmittance of the side facing away from the incident radiation;

— ρ_S is reflectance of the side facing the incident radiation;

— $\rho_{S'}$ is the reflectance of the side facing away from the incident radiation.
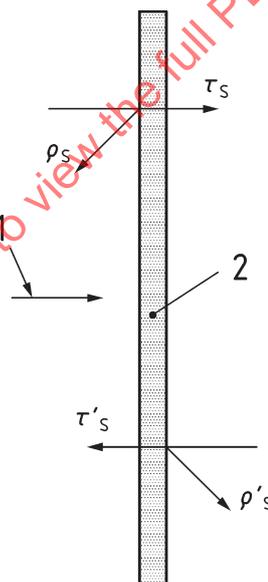
Key
1   incident radiation
2   mobile protection device

Figure G.1 — Equivalent properties according to ISO 52022-3

These equivalent energy and light properties are the following, depending on the profile angle η (as defined in G.1.2) and the slat pitch angle α of the venetian blind:

$$\tau_{S,e}(\alpha,\eta) = r_{dir} \cdot \left(\tau_{dir\text{-}dir}(\alpha,\eta) + \tau_{e,dir\text{-}dif}(\alpha,\eta) \right) + r_{dif\text{-}h} \cdot \tau_{e,dif\text{-}h}(\alpha)$$

$$\tau_{S,v}(\alpha,\eta) = r_{dir} \cdot \left(\tau_{dir\text{-}dir(\alpha,\eta)} + \tau_{v,dir\text{-}dif(\alpha,\eta)} \right) + r_{dif\text{-}h} \cdot \tau_{v,dif\text{-}h(\alpha)}$$

$$\tau_{S,th}(\alpha,\eta) = \tau_{th,dif\text{-}h}(\alpha)$$

$$\rho_{S,e}(\alpha,\eta) = r_{dir} \cdot \rho_{e,dir\text{-}dif}(\alpha,\eta) + r_{dif\text{-}h} \cdot \rho_{e,dif\text{-}h}(\alpha)$$

$$\rho_{S,v}(\alpha,\eta) = r_{dir} \cdot \rho_{v,dir\text{-}dif}(\alpha,\eta) + r_{dif\text{-}h} \cdot \rho_{v,dif\text{-}h}(\alpha)$$

$$\varepsilon_{S,th}(\alpha) = 1 - \tau_{th,dif\text{-}h}(\alpha) - \rho_{th,dif\text{-}h}(\alpha)$$

$$\tau'_{S,e}(\alpha) = \tau'_{e,dif\text{-}h}(\alpha)$$

$$\tau'_{S,v}(\alpha) = \tau'_{v,dif\text{-}h}(\alpha)$$

$$\tau'_{S,th}(\alpha,\eta) = \tau'_{th,dif\text{-}h}(\alpha)$$

$$\rho'_{S,e}(\alpha) = \rho'_{e,dif\text{-}h}(\alpha)$$

$$\rho'_{S,v}(\alpha) = \rho'_{v,dif\text{-}h}(\alpha)$$

$$\varepsilon'_{S,th}(\alpha,\eta) = 1 - \tau'_{th,dif\text{-}h}(\alpha) - \rho'_{th,dif\text{-}h}(\alpha)$$

Where r_{dir} and $r_{dif\text{-}h}$ are the average direct and diffuse part of incident radiation during the considering period, given in G.1.1.

For the direct transmission of direct incident radiation, the distinction between the visible spectrum and the solar spectrum is not necessary, as the factor $\tau_{dir\text{-}dir}$ is solely related to the geometry of the mobile protection device.

In the rest of Annex G, where the subscripts "e" and "v" and "th" are not indicated in the formulae, the calculation is carried out for the entire solar radiation (solar transmittance calculation), for the visible part of the spectrum (light transmittance calculation) and for the longwave infrared radiation (for the diffuse transmission and reflection only, needed for the solar transmittance calculation).

Transmittance and reflectance of the side facing away from the incident radiation are given in G.2.

Transmittance and reflectance of the side facing the incident radiation are given in G.3, G.4 and G.5 for mobile protection devices with horizontal and vertical slats.

G.1.1 Direct and diffuse parts of incident radiation

Strictly speaking, the temperature field varies from one instant to the next depending on the profile angle, the total intensity of the radiation and also the distribution between the direct, sky-diffuse or ground-reflected components of the incident flux, specific to the location of the building (climate zone, ground albedo, etc.).

However, in the context of product characterization and for the sake of simplification, assumptions on the average distributions of the type of incident radiation can be used for the calculation of all components of solar transmittance.

The conventional distribution considered is as follows:

— for vertical elements:

  direct part (r_{dir}): 45 %;

  diffuse part (r_{dif-h}): 55 %;

— for other pitched elements:

  direct part (r_{dir}): 55 %;

  diffuse part (r_{dif-h}): 45 %.

G.1.2   Profile angles η

By convention, profile angles are measured in relation to the normal to the plane of the mobile protection device (horizontal plane for a vertical element) in the clockwise direction.

G.1.2.1   Calculation of profile angles depending on the type of mobile protection device

Any incident radiation from a point in the sky or on the ground is expressed in terms of solar altitude γ (relative to the horizontal plane of the ground) and azimuth ψ.

The orientation of the plane of the mobile protection device is expressed by the azimuth ψ_{ws} of the normal to this plane and its pitch i_{ws} relative to a vertical plane.

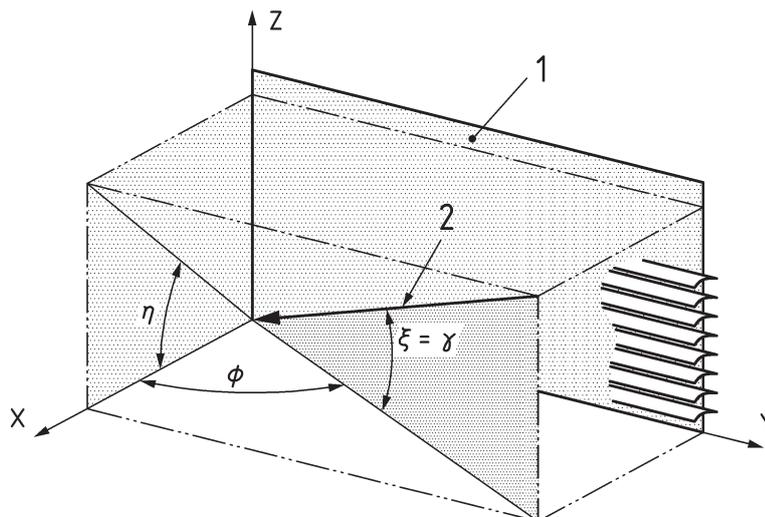#### G.1.2.2   Vertical mobile protection devices with horizontal slats

For vertical mobile protection devices with horizontal slats (see Figure G.2):

— the altitude angle is equal to the solar altitude: $\zeta = \gamma$; and

— the azimuth angle is given by the equation: $\varphi = \psi - \psi_{ws}$.

According to EN 14500, the profile angle η is given by:

  $\tan \eta = \tan \gamma \, / \cos (\Phi)$.

Key

1 plane of the mobile protection device
2 incident radiation
η profile angle
Φ azimuth angle
ξ altitude angle
γ solar altitude

Figure G.2 — Illustration of profile angle η for a vertical mobile protection device with horizontal slats

G.1.2.3   Pitched mobile protection devices with horizontal slats

For pitched mobile protection devices with horizontal slats, the reference plane is tilted at an angle i_{ws} such that the plane of the mobile protection device remains vertical (see Figure G.3).

According to EN 14500, the profile angle η is given by:

$$\tan (\eta + i_{ws}) = \tan \gamma / \cos (\psi - \psi_{ws})$$

Key
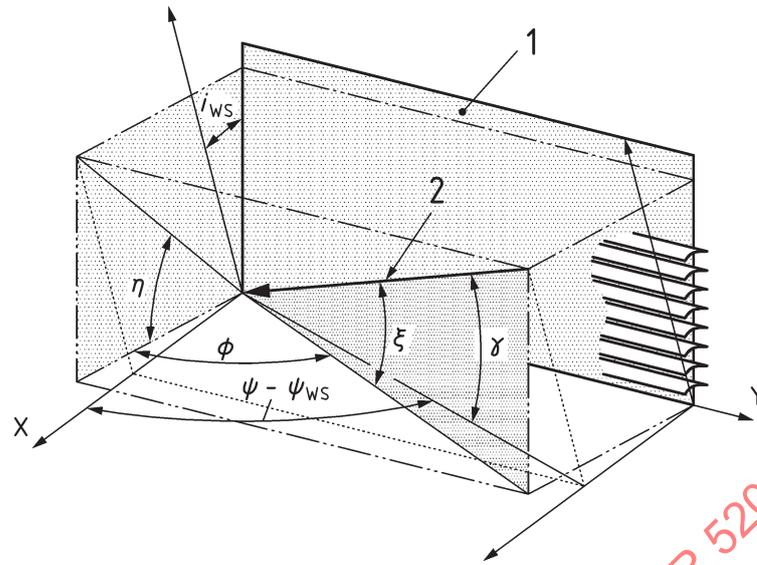
1	plane of the mobile protection device
2	incident radiation
η	profile angle
i_{ws}	pitch of the plane of the mobile protection device relative to the vertical
Φ	azimuth angle in the horizontal plane
ψ	azimuth angle in the plane normal to the mobile protection device
ξ	altitude angle
γ	solar altitude

Figure G.3 — Illustration of profile angle η for a pitched mobile protection device with horizontal slats

G.1.2.4 Vertical mobile protection devices with vertical slats

For vertical mobile protection devices with vertical slats, the same configuration as in G.1.2.2 is used, with a 90° rotation. The profile angle is then given directly by the azimuth angle:

$$\eta = \psi - \psi_{ws}$$

G.2 Transmission τ'_s and reflection ρ'_s rates of radiation from the interior

By convention, radiation from the interior is considered as diffuse and hemispherically transmitted.

The equivalent transmission and reflection rates of the mobile protection device for radiation from the interior are therefore equal to:

$$\tau'_s = \tau'_{dif\text{-}h} = \tau'_{S,d};$$

$$\rho'_s = \rho'_{dif\text{-}h} = \rho'_{S,d}$$

where $\tau'_{S,d}$ and $\rho'_{S,d}$ correspond to the diffuse transmission and reflection of diffuse incident radiation from the interior and are determined according to G.6.

G.3 Transmission and reflection rates of direct incident radiation $\tau_{\text{dir-dir}}$, $\tau_{\text{dir-dif}}$ and $\rho_{\text{dir-dif}}$

G.3.1 General

For a vertical mobile protection device, profile angles for direct radiation are always positive.

If a mobile protection device is pitched or has vertical slats, profile angles for direct radiation can be either positive or negative. An example of such a negative profile angle is given in Figure G.7.b).

The critical profile angle calculation is independent of the pitch of the slats.

G.3.2 Critical profile angles

G.3.2.1 General

Critical profile angle calculations are independent of the pitch of the slats.

G.3.2.2 Positive critical profile angle

For a slat pitch of the mobile protection device α, measured relative to the normal to the plane of the mobile protection device, a positive critical profile angle η_{crit} is defined as the minimum angle in Formula (G.1) which the radiation can penetrate directly (see Figure G.4):

$$\eta_{\text{crit}} = \left| \left(\frac{\frac{d}{l} - \sin(\alpha)}{\cos(\alpha)} \right) \right| \tag{G.1}$$

a) Vertical element   b) Pitched element

Key
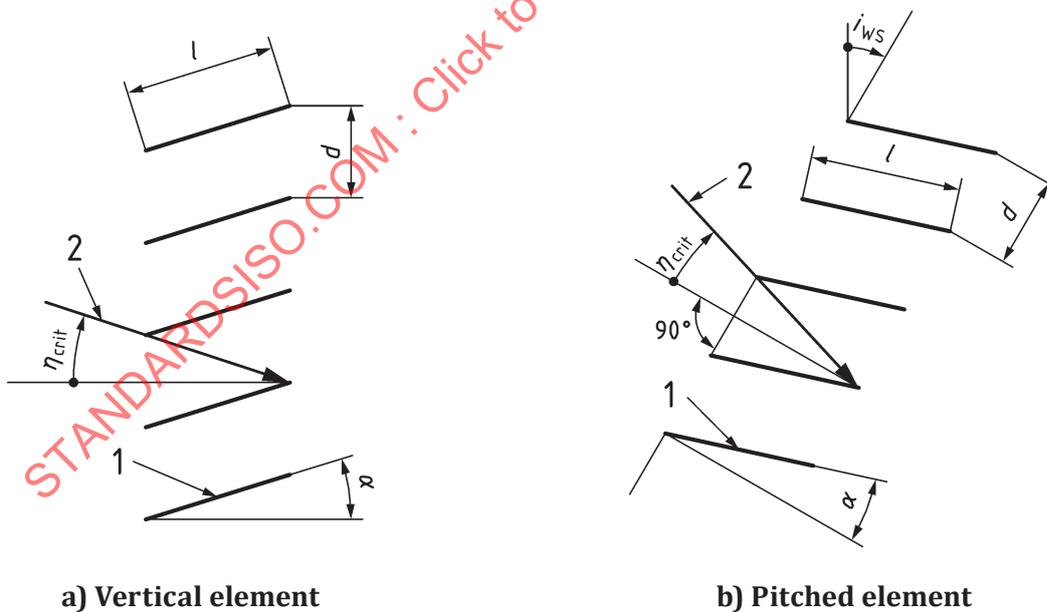
1   mobile protection device with adjustable slats

2   incident radiation

Figure G.4 — Illustration of positive critical profile angle η_{crit}

G.3.2.3 Negative critical profile angle for pitched element

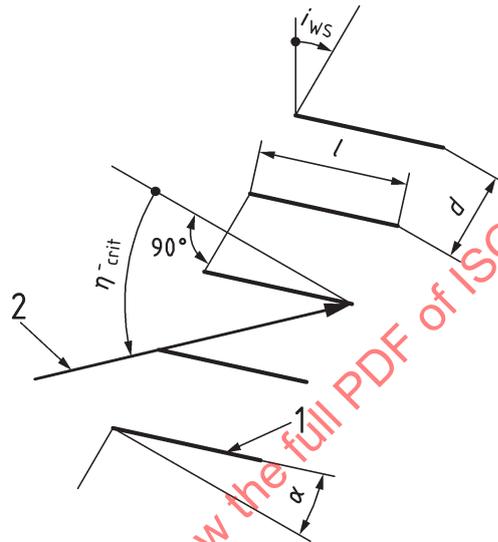For a slat pitch of the mobile protection device α, measured relative to the normal to the plane of the mobile protection device, a negative critical profile angle η^-_{crit} is defined as the minimum angle in Formula (G.2) which the radiation can penetrate directly (see Figure G.5):

$$\eta^-_{crit} = -\arctan\left(\frac{\dfrac{d}{l}+\sin(\alpha)}{\cos(\alpha)}\right) \tag{G.2}$$

Key

1   mobile protection device with adjustable slats

2   incident radiation for pitched element

Figure G.5 — Illustration of critical angle η^-_{crit} (η^-_{crit} < 0)

G.3.3 Calculation formulae according to geometry

G.3.3.1   Profile angle η greater than the critical angle ($\eta > \eta_{crit}$): no direct penetration.

This configuration is illustrated in Figure G.6.

a) Vertical element   **b) Pitched element**

Key
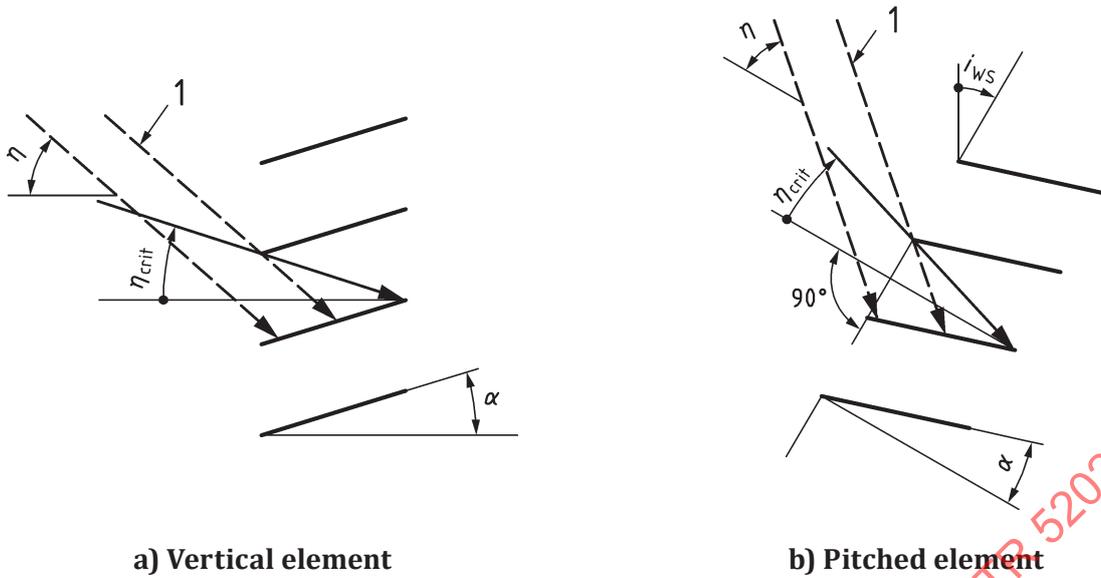
1   incident radiation

Figure G.6 — Illustration of $\eta > \eta_{crit}$

The calculation is performed using:

$\tau_{\text{dir-dir}} = 0$

$\tau_{\text{dir-dif}} = \tau_{S,D}$

$\rho_{\text{dir-dif}} = \rho_{S,D}$

$\tau_{S,D}$ and $\rho_{S,D}$ correspond to the diffuse transmission and reflection of direct incident radiation from the exterior and are determined according to G.6.

G.3.3.2   Profile angle η between the slat pitch angle and the critical angle ($-\alpha < \eta < \eta_{\text{crit}}$) or profile angle η less than the slat pitch angle ($-\eta < \alpha$: direct penetration).

This configuration is illustrated in Figure G.7 for cases in which η is less than α, with positive η, and in Figure G.8 for cases in which $-\eta$ is less than α, with negative η.

a) Vertical element

b) Pitched element

Key

1   incident radiation
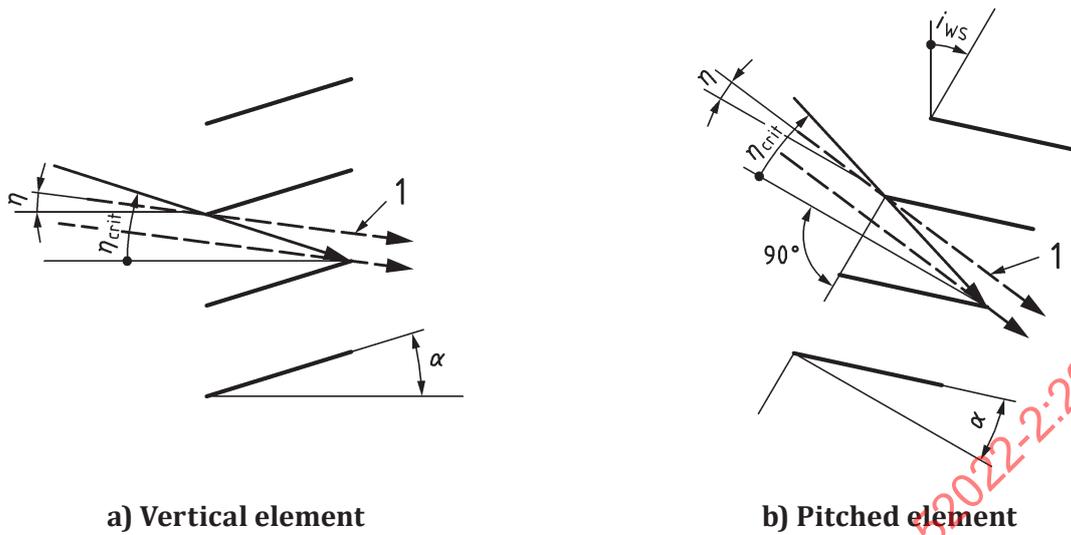
Figure G.7 — Illustration of $\eta < \eta_{\text{crit}}$ with $\eta > 0$

Key
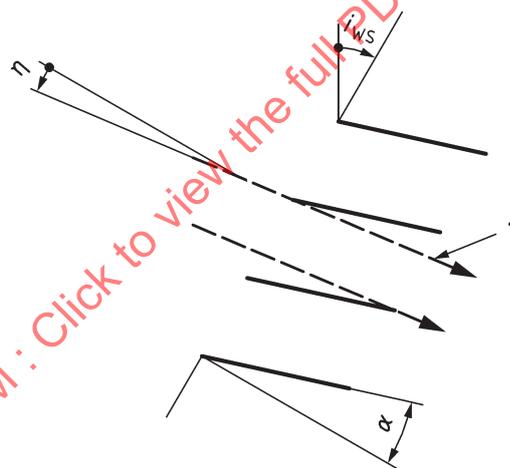
1   incident radiation for pitched or vertical slats elements

Figure G.8 — Illustration of $-\eta < \alpha$

The calculation is performed using:

$$\tau_{\text{dir-dir}} = 1 - \frac{l}{d}\frac{sin(\alpha + \eta)}{cos(\eta)}$$

$$\tau_{\text{dir-dif}} = (1 - \tau_{\text{dir-dir}}) \cdot \tau_{\text{S,D}}$$

$$\rho_{\text{dir-dif}} = (1 - \tau_{\text{dir-dir}}) \cdot \rho_{\text{S,D}}$$

The η_{crit} value to be considered is the one set out in G.3.2.2.

$\tau_{\text{S,D}}$ and $\boldsymbol{\rho}_{\text{S,D}}$ correspond to the diffuse transmission and reflection of direct incident radiation from the exterior and are determined according to G.6.

G.3.3.3 Profile angle $_\eta$ between the slat pitch angle and the critical reflection angle ($\alpha < {}^-\eta < {}^-\eta^-_{crit}$) for pitched elements or vertical slats: direct penetration.

The incident ray with an angle within this range can partly penetrate the interior directly, the other part being diffused with a first reflection on the underside of the slats. This configuration is illustrated in Figure G.9.

Key
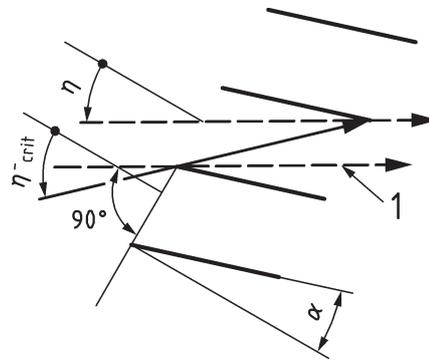
1   incident radiation for pitched or vertical slats element

Figure G.9 — Illustration of $\alpha < {}^-\eta < {}^-\eta_{crit}$

The calculation is performed using:

$$\tau^*{}_{\text{dir-dir}} = 1 + \frac{l \cdot \left(sin(\alpha + \eta) \right)}{d \cdot cos(\eta)}$$

$$\tau^*{}_{\text{dir-dif}} = (1 - \tau^*{}_{\text{dir-dir}}) \cdot \tau^*{}_{S,D}$$

$$\rho^*{}_{\text{dir-dif}} = (1 - \tau^*{}_{\text{dir-dir}}) \cdot \rho^*{}_{S,D}$$

The η_{crit} value to be considered is η^-_{crit} as set out in G.3.2.3.

$\tau^*{}_{SjD}$ and $\rho^*{}_{SD}$ correspond to the diffuse transmission and reflection of direct incident radiation from the exterior after a first reflection on the underside of the slats, and are determined according to G.6.

G.3.3.4 Profile angle η greater than the critical reflection angle (${}^-\eta > {}^-\eta^-_{crit}$) for pitched elements or vertical slats: no direct penetration.

The incident ray with an angle greater than the critical reflection angle cannot penetrate the interior directly and is entirely diffused with a first reflection on the underside of the slats. This configuration is illustrated in Figure G.10.
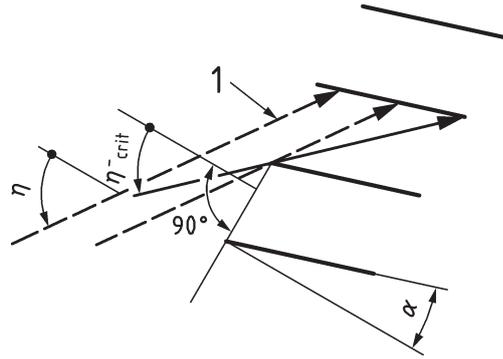
1   incident radiation for pitched or vertical slats element

Figure G.10 — Illustration of $^-\eta > {}^-\eta^-_{crit}$

The calculation is performed using:

$\tau^*_{dir\text{-}dir} = 0$

$\tau^*_{dir\text{-}dif} = \tau^*_{S,D}$

$\rho^*_{dir\text{-}dif} = \rho^*_{S,D}$

The η_{crit} value to be considered is η^-_{crit} as set out in G.3.2.3.

τ^*_{SjD} and ρ^*_{SD} correspond to the diffuse transmission and reflection of direct incident radiation from the exterior after a first reflection on the underside of the slats, and are determined according to G.6.

G.3.4 Application by type of mobile protection device

G.3.4.1 Vertical mobile protection devices with horizontal slats (Venetian blinds, for example)

G.3.3.1 (Figure G.6a) and G.3.3.2 (Figure G.7a) apply.

G.3.4.2 Adjustable mobile protection devices with horizontal slats (Venetian blinds, for example)

The different cases in G.3.3 apply according to the values of α and η calculated based on γ, ψ, ψ_{ws} and i_{ws} according to G.1.2.3.

G.3.4.3 Vertical mobile protection devices with vertical slats (vertical blinds, for example)

The different cases in G.3.3 apply according to the values of α and η calculated based on ψ and ψ_{ws} according to G.1.2.4.

G.4 General overview

G.4.1 General

Clause G.4 sets out in a generic manner the general formulae summarizing all the cases applicable to mobile protection devices with horizontal or vertical adjustable slats, regardless of the position of the mobile protection device (vertical or pitched). Only profile angle η should be adjusted according to G.1.2, depending on the case (vertical or pitched mobile protection devices with horizontal slats or vertical mobile protection devices with vertical adjustable slats).

G.4.2 General formula for the direct transmission of direct radiation [Formulae (G.3) and (G.4)]

$$\tau_{dir-dir} = 1 - \frac{l}{d}\frac{\sin(\alpha+\eta)}{\cos(\eta)}; \quad \text{if } \eta > -\alpha \tag{G.3}$$

$$\tau *_{dir-dir} = 1 + \frac{l}{d}\frac{\sin(\alpha+\eta)}{\cos(\eta)} \quad \text{else} \tag{G.4}$$

G.4.3 General formula for the diffuse transmission and reflection of direct radiation [Formulae (G.5) and (G.6)]

$$\tau_{\text{dir-dif}}(\eta) = \begin{cases} (1-\tau_{dir-dir})\cdot\tau_{S,D}; & \text{if } \eta > -\alpha \\ (1-\tau *_{dir-dir})\cdot\tau *_{S,D} & \text{else} \end{cases} \tag{G.5}$$

$$\rho_{\text{dir-dif}}(\eta) = \begin{cases} (1-\tau_{dir-dir})\cdot\rho_{S,D}; & \text{if } \eta > -\alpha \\ (1-\tau *_{dir-dir})\cdot\rho *_{S,D} & \text{else} \end{cases} \tag{G.6}$$

G.5 Transmission and reflection of diffuse (hemispherical) radiation

The equivalent transmission and reflection rates of the mobile protection device for diffuse (hemispherical) radiation from the exterior are therefore equal to:

$$\tau_{\text{dif-h}} = \tau_{S,d}$$

$$\rho_{\text{dif-h}} = \rho_{S,d}$$

where $\tau_{S,d}$ and $\rho_{S,d}$ correspond to the diffuse transmission and reflection of diffuse incident radiation from the exterior and are determined according to G.6.

G.6 Determination of $\tau_{S,D}$, $\rho_{S,D}$, $\tau^*_{S,D}$, $\rho^*_{S,D}$, $\tau'_{S,d}$, $\rho'_{S,d}$

G.6.1 General

The view factors to be used for the calculations depend on the slat spacing ratio d/l, the slat pitch α and the profile angle η. Tabulated values are given in Annex H. In the following formulae, τ, ρ and ρ' correspond to the transmission, the upper and lower reflection of the slats composing the venetian blind. As longwave radiation is diffuse, only s G.6.4 and G.6.5 are applicable to calculate $\tau_{\text{th,dif-h}}$, $\rho_{\text{th,dif-h}}$, $\tau'_{\text{th,dif-h}}$ and $\rho'_{\text{th,dif-h}}$.

Z and Z' parameters are obtained by Formulae (G.7) and (G.8):

$$Z = \frac{\Phi_{34}\rho}{1-\Phi_{34}\tau} \tag{G.7}$$

$$Z' = \frac{\Phi_{34}\rho'}{1-\Phi_{34}\tau} \tag{G.8}$$

G.6.2 Diffuse transmission and reflection of direct radiation from the exterior after a first reflection on the upper side of the slats

When the first reflection occurs on the upper side of the slats, the diffuse transmission of direct radiation from the exterior is given by Formula (G.9):

$$\tau_{S,D} = \Phi_{51}\rho + \Phi_{61}\tau + \frac{\left(Z\Phi_{54}\rho' + \Phi_{63}\tau\right)\left(\Phi_{31}\rho + \Phi_{41}\tau\right) + \left(Z\Phi_{63}\tau + \Phi_{54}\rho\right)\left(\Phi_{41}\rho' + \Phi_{31}\tau\right)}{\Phi_{34}\rho\left(1 - ZZ'\right)} \cdot Z \tag{G.9}$$

The diffuse reflection of direct radiation from the exterior is given by Formula (G.10):

$$\rho_{S,D} = \Phi_{52}\rho + \Phi_{62}\tau + \frac{\left(Z\Phi_{54}\rho' + \Phi_{63}\tau\right)\left(\Phi_{32}\rho + \Phi_{42}\tau\right) + \left(Z\Phi_{63}\tau + \Phi_{54}\rho\right)\left(\Phi_{42}\rho' + \Phi_{32}\tau\right)}{\Phi_{34}\rho\left(1 - ZZ'\right)} \cdot Z \tag{G.10}$$

G.6.3 Diffuse transmission and reflection of direct radiation from the exterior after a first reflection on the lower side of the slats

When the first reflection occurs on the lower side of the slats, the diffuse transmission of direct radiation from the exterior is given by Formula (G.11):

$$\tau^*_{S,D} = \Phi_{61}\rho' + \Phi_{51}\tau + \frac{\left(Z'\Phi_{54}\tau + \Phi_{63}\rho'\right)\left(\Phi_{31}\rho + \Phi_{41}\tau\right) + \left(Z'\Phi_{63}\rho + \Phi_{54}\tau\right)\left(\Phi_{41}\rho' + \Phi_{31}\tau\right)}{\Phi_{34}\rho'\left(1 - ZZ'\right)} \cdot Z' \tag{G.11}$$

The diffuse reflection of direct radiation from the exterior is given by Formula (G.12):

$$\rho^*_{S,D} = \Phi_{62}\rho' + \Phi_{52}\tau + \frac{\left(Z'\Phi_{54}\tau + \Phi_{63}\rho'\right)\left(\Phi_{32}\rho + \Phi_{42}\tau\right) + \left(Z'\Phi_{63}\rho + \Phi_{54}\tau\right)\left(\Phi_{42}\rho' + \Phi_{32}\tau\right)}{\Phi_{34}\rho'\left(1 - ZZ'\right)} \cdot Z' \tag{G.12}$$

G.6.4 Diffuse transmission and reflection of diffuse radiation from the exterior

The diffuse transmission of diffuse radiation from the exterior is given by Formula (G.13):

$$\tau_{S,d} = \Phi_{21} + \frac{\left(\Phi_{23}\rho + \Phi_{24}\tau\right)\left(\Phi_{31} + Z'\Phi_{41}\right) + \left(\Phi_{24}\rho' + \Phi_{23}\tau\right)\left(\Phi_{41} + Z\Phi_{31}\right)}{\Phi_{34}\rho\left(1 - ZZ'\right)} \cdot Z \tag{G.13}$$

The diffuse reflection of diffuse radiation from the exterior is given by Formula (G.14):

$$\rho_{S,d} = \frac{\left(\Phi_{23}\rho + \Phi_{24}\tau\right)\left(\Phi_{32} + Z'\Phi_{42}\right) + \left(\Phi_{24}\rho' + \Phi_{23}\tau\right)\left(\Phi_{42} + Z\Phi_{32}\right)}{\Phi_{34}\rho\left(1 - ZZ'\right)} \cdot Z \tag{G.14}$$

G.6.5 Diffuse transmission and reflection of diffuse radiation from the interior

The diffuse transmission of diffuse radiation from the interior is given by Formula (G.15):

$$\tau'_{S,d} = \Phi_{12} + \frac{\left(\Phi_{13}\rho + \Phi_{14}\tau\right)\left(\Phi_{32} + Z'\Phi_{42}\right) + \left(\Phi_{14}\rho' + \Phi_{13}\tau\right)\left(\Phi_{42} + Z\Phi_{32}\right)}{\Phi_{34}\rho\left(1 - ZZ'\right)} \cdot Z \tag{G.15}$$

The diffuse reflection of diffuse radiation from the interior is given by Formula (G.16):

$$\rho'_{S,d} = \frac{\left(\Phi_{13}\rho + \Phi_{14}\tau\right)\left(\Phi_{31} + Z'\Phi_{41}\right) + \left(\Phi_{14}\rho' + \Phi_{13}\tau\right)\left(\Phi_{41} + Z\Phi_{31}\right)}{\Phi_{34}\rho\left(1 - ZZ'\right)} \cdot Z \tag{G.16}$$

NOTE   These formulae are identical to those for flux from the exterior to the interior, with the subscripts 1 and 2 reversed.

G.7 Examples of view factors for the calculation of solar energy transmittance and light transmittance of mobile protection devices with adjustable slats

G.7.1 General

The view factors Φ_{ij} between the different zones defined (see Figure G.11) were calculated for a spacing ratio d/l = 0,87, according to the values considered in EN 14500 (d/l = 72/80 or 43/50 or 22/25 or 14/16). The indices i and j refer to the zones 1 to 6 defined in Figure G.11.

Key
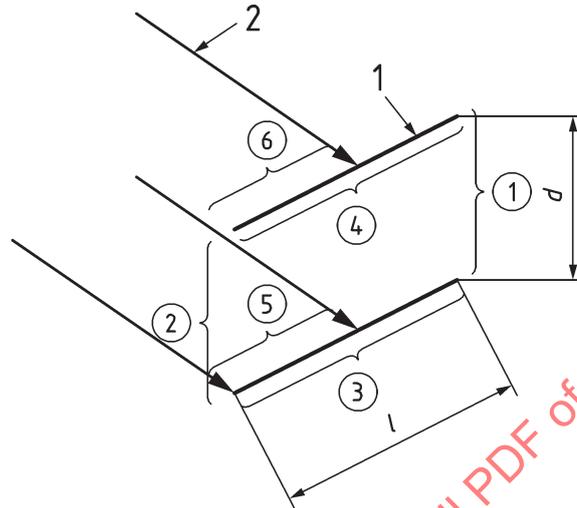
1   mobile protection device with adjustable slats
2   incident radiation

Figure G.11 — View factor zones

Table G.1 gives the critical profile angles η_{crit}, used to determine the presence or otherwise of direct penetration through the top of the slats for a positive slat pitch (see Annex G), depending on the slat pitch angle α and for a spacing ratio d/l = 0,87.

Table G.1 — Value of η_{crit} depending on slat pitch

Slat pitch α	Critical profile angles η_{crit}
0°	41°
15°	32°
30°	23°
45°	13°
60°	0°
75°	0°

Table G.2 gives the critical profile angles η^-_{crit}, used to determine the presence or otherwise of direct penetration through the bottom of the slats for a positive slat pitch, depending on the slat pitch angle α and for a spacing ratio d/l = 0,87.