INTERNATIONAL STANDARD

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

Part 2:
Numerical method for frames

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

Partie 2: Méthode numérique pour les encadrements

Reference number
ISO 10077-2:2003(E)

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 10077-2 was prepared by the European Committee for Standardization (CEN) in collaboration with Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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

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

— *Part 1: Simplified method*

— *Part 2: Numerical method for frames*

Contents

Page

Foreword

This document EN ISO 10077-2:2003 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of an identical text or by endorsement, at the latest by April 2004, and conflicting national standards shall be withdrawn at the latest by April 2004.

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

Annexes B, C, D and ZA are normative.

Annexes A and ZB are informative.

This document includes a Bibliography.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

The series of EN ISO 10077, *"Thermal performance of windows, doors and shutters – Calculation of thermal transmittance"*, consists of two parts. The method in Part 2: *"Numerical method for frames",* is intended to provide calculated values of the thermal characteristics of frame profiles, suitable to be used as input data in the simplified calculation method of the thermal transmittance of windows, doors and shutters given in Part 1: *"Simplified method*. It is an alternative to the test method specified in prEN 12412–2 (see Bibliography). In some cases, the hot box method can be preferred, especially if physical and geometrical data are not available or if the profile is of complicated geometrical shape.

Although the method in this Part 2 basically applies to vertical frame profiles, it is an acceptable approximation for horizontal frame profiles (e.g. sill and head sections) and for products used in sloped positions (e.g. roof windows). The heat flow pattern and the temperature field within the frame are useful by-products of this calculation.

1 Scope

This European Standard 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 glazings 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.

This European Standard also gives criteria for the validation of numerical methods used for the calculation.

This European Standard does not include effects of solar radiation, heat transfer caused by air leakage or three-dimensional heat transfer such as pin point metallic connections. Thermal bridge effects between the frame and the building structure are not included.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

prEN 12519:1996, *Windows and doors – Terminology.*

EN ISO 7345:1995, *Thermal insulation – Physical quantities and definitions (ISO 7345:1987).*

EN ISO 10211-1:1995, *Thermal bridges in building construction – Heat flows and surface temperatures – Part 1: General calculation methods (ISO 10211-1:1995).*

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

3 Terms, definitions, symbols and units

For the purposes of this European Standard, the terms and definitions given in EN ISO 7345:1995 and prEN 12519:1996 apply.

Symbol	Quantity	Unit
A	area	m^2
b	width, i.e. perpendicular to the direction of heat flow	m
d	depth, i.e. parallel to the direction of heat flow	m
E	intersurface emittance	–
F	view factor	–
h	heat transfer coefficient	$W/(m^2 \cdot K)$
L^{2D}	two-dimensional thermal conductance or thermal coupling coefficient	$W/(m \cdot K)$
l	length	m
q	density of heat flow rate	W/m^2
R	thermal resistance	$m^2 \cdot K/W$
T	thermodynamic temperature	K
U	thermal transmittance	$W/(m^2 \cdot K)$
σ	Stefan-Boltzmann constant	$W/(m^2 \cdot K^4)$
ε	emissivity	–
λ	thermal conductivity	$W/(m \cdot K)$
Ψ	linear thermal transmittance	$W/(m \cdot K)$

Subscripts

a	convective (surface to surface)
e	external (outdoor)
g	glazing
eq	equivalent
f	frame
i	internal (indoor)
p	panel
r	radiative
s	space (air or gas space)
sb	shutter box
se	external surface
si	internal surface

4 Calculation method

4.1 General principle

The calculation is carried out using a two-dimensional numerical method conforming to EN ISO 10211-1. The elements shall be divided such that any further division does not change the calculated result significantly. EN ISO 10211-1 gives criteria for judging whether sufficient sub-divisions have been used.

It is assumed that the principal heat flow in the section is perpendicular to a plane parallel to the external and internal surfaces. Vertical orientation of sections and air cavities is assumed. It is assumed that the emissivity of the surfaces adjoining the air cavities is 0,9 (it is assumed that the normal emissivity is 0,85). If other values are used they shall be clearly stated with references in the report.

4.2 Validation of the calculation program

To ensure the suitability of the calculation program used, calculations shall be carried out on the examples described in annex D. The calculated two-dimensional thermal conductance L^{2D} shall not differ from the corresponding values given in Table D.3 by more than ± 3 %. This will lead to an accuracy of the thermal transmittance, U, and the linear thermal transmittance Ψ, of about 5 %.

4.3 Determination of the thermal transmittance

The thermal transmittance of a frame section and the linear thermal transmittance of the interaction of frame and glazing shall be determined with the glazing replaced by an insulating panel according to annex C, with the external and internal surface resistances taken from annex B.

5 Treatment of solid sections and boundaries

5.1 Solid materials

Design values of thermal conductivity for common materials are given in annex A. Design values derived from measurements may be used instead of those in annex A, but this shall be clearly stated in the report. Further values can be obtained from EN 12524.

NOTE Design values derived in accordance with ISO 10456 (see Bibliography) is an alternative.

5.2 Boundaries

The external and internal surface resistances depend on the convective and radiative heat transfer to the external and internal environment. If an external surface is not exposed to normal wind conditions the convective part may be reduced in edges or junctions between two surfaces (see EN ISO 10211-1:1995, annex E). The surface resistances for horizontal heat flow are given in annex B. The cutting plane of the infill and the cutting plane to neighbouring material shall be taken as adiabatic (see Figure 1).

For the calculation of condensation risk see EN ISO 10211-1.

6 Treatment of cavities

6.1 General

The heat flow rate in cavities shall be represented by an 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.

6.2 Cavities in glazing

The equivalent thermal conductivity of an unventilated space between glass panes in glazing shall be determined according to ISO 10292. The resulting equivalent conductivity shall be used in the whole cavity, up to the edge.

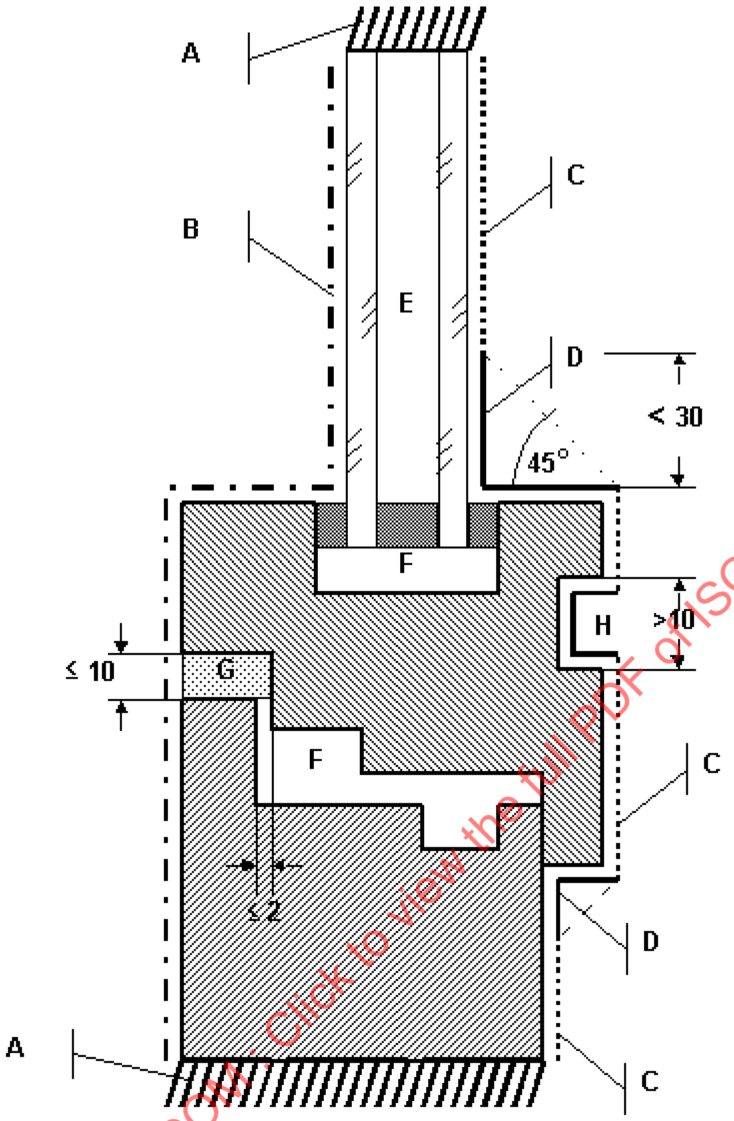
NOTE The correlations for high aspect ratio cavities used in EN 673 and ISO 10292 tend to give low values for the equivalent thermal conductivity. More accurate correlations are given in ISO 15099 (see Bibliography).

6.3 Unventilated air cavities in frames

6.3.1 Definition

Air cavities are unventilated if they are completely closed or connected either to the exterior or to the interior by a slit with a width not exceeding 2 mm (see Figure 1). Otherwise the cavity shall be treated as ventilated.

Dimensions in millimetres



Key

Boundaries (see annex B):

A Adiabatic boundary
B External surface resistance
C Internal surface resistance
D Increased surface resistance

Cavities and grooves:

E Glazing (see 6.2)
F Unventilated cavity (see 6.3)
G Slightly ventilated cavity or groove (see 6.4.1)
H Well ventilated cavity or groove (see 6.4.2)

Figure 1 — Schematic example for the treatment of cavities and grooves of a frame section and the treatment of the boundaries

6.3.2 Unventilated rectangular cavities

6.3.2.1 Equivalent thermal conductivity

The equivalent thermal conductivity of the cavity is given by Equation (1):

$$\lambda_{eq} = \frac{d}{R_s} \tag{1}$$

where

d is the dimension of the cavity in the direction of the heat flow, see Figure 2;

R_s is the thermal resistance of the cavity, given by Equation (2):

$$R_s = \frac{1}{h_a + h_r} \tag{2}$$

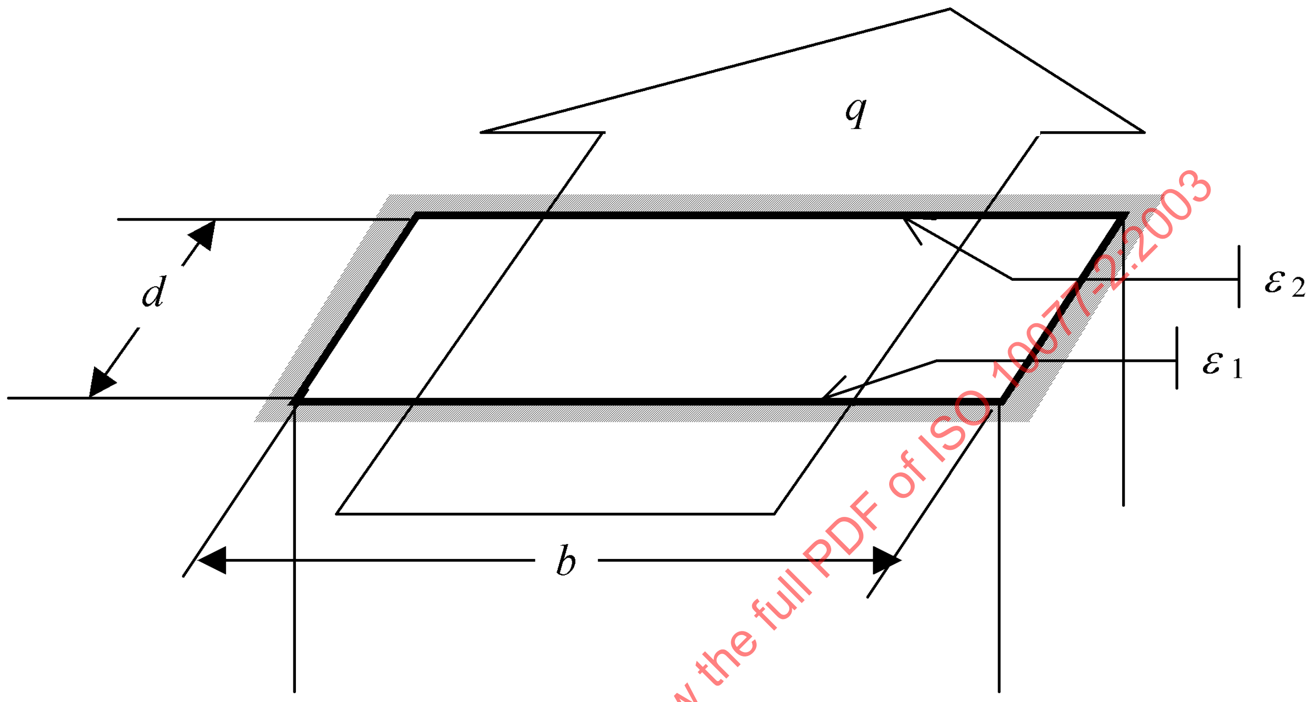


Figure 2 — Rectangular cavity and direction of heat flow

6.3.2.2 Convective heat transfer coefficient

The convective heat transfer coefficient, h_a, is:

In case of $b < 5$ mm

$$h_a = C_1 / d \tag{3}$$

where $C_1 = 0{,}025\ \text{W/(m} \cdot \text{K)}$

otherwise

$$h_a = \max\left\{C_1 / d; \quad C_2\, \Delta T^{1/3}\right\} \tag{4}$$

where $C_1 = 0{,}025\ \text{W/(m} \cdot \text{K)}$; $C_2 = 0{,}73\ \text{W/(m}^2 \cdot \text{K}^{4/3})$

and ΔT is the maximum surface temperature difference in the cavity.

If no other information is available, use ΔT = 10 K for which

$$h_a = \max\left\{C_1 / d; \quad C_3\right\} \tag{5}$$

where

$$C_1 = 0{,}025\ \text{W/(m} \cdot \text{K)}$$

$$C_3 = 1{,}57\ \mathrm{W/(m^2 \cdot K)}$$

6.3.2.3 Radiative heat transfer coefficient

$$h_\mathrm{r} = 4\sigma T_\mathrm{m}^3 EF \tag{6}$$

where

σ = 5,67×10^{-8} W/(m^2·K^4) is the Stefan–Boltzmann constant;

$E = \left(\dfrac{1}{\varepsilon_1} + \dfrac{1}{\varepsilon_2} - 1\right)^{-1}$ is the intersurface emittance;

$F = \dfrac{1}{2}\left(1 + \sqrt{1 + (d/b)^2} - d/b\right)$ is the view factor for a rectangular section;

ε_1 and ε_2 are the emissivities of the surfaces indicated in Figure 2.

The values of the emissivities should be given down to the second decimal place.

If no other information is available, use $\varepsilon_1 = \varepsilon_2 = 0{,}9$ and $T_\mathrm{m} = 283\ \mathrm{K}$ for which

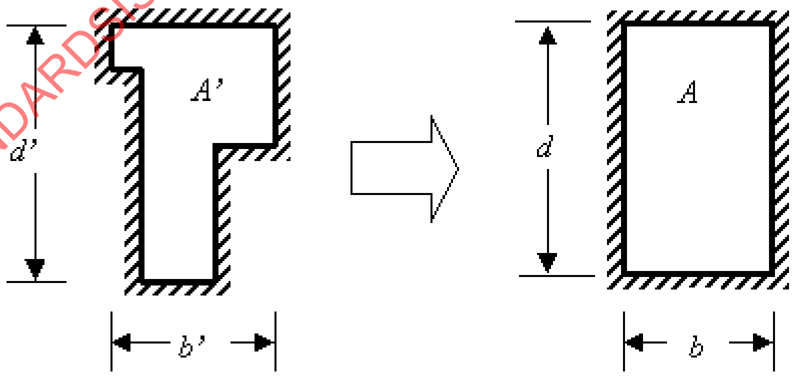
$$h_\mathrm{r} = C_4 \cdot \left(1 + \sqrt{1 + (d/b)^2} - d/b\right) \tag{7}$$

where $C_4 = 2{,}11\ \mathrm{W/(m^2 \cdot K)}$.

6.3.3 Unventilated non-rectangular air cavities

Non-rectangular air cavities (T-shape, L-shape etc.) are transformed into rectangular air cavities with the same area ($A = A'$) and aspect ratio ($d/b = d'/b'$), see Figure 3 and after which 6.3.2 is applied.

Cavities with one dimension not exceeding 2 mm or cavities with an interconnection not exceeding 2 mm shall be considered as separate.



Key

A area of the equivalent rectangular air cavity
d, b depth and width of the equivalent air cavity
A' area of the true cavity
d' b' depth and width of the smallest circumscribing rectangle

Figure 3 — Transformation of non-rectangular air cavities

The transformation is given by

$$b = \sqrt{A'b'/d'} \tag{8}$$

$$d = \sqrt{A'd'/b'} \tag{9}$$

6.4 Ventilated air cavities and grooves

6.4.1 Slightly ventilated cavities and grooves with small cross section

Grooves with small cross sections (see Figure 4) at the external or internal surfaces of profiles and cavities connected to the external or internal air by a slit greater than 2 mm but not exceeding 10 mm shall be considered as slightly ventilated air cavities. The equivalent conductivity is twice that of an unventilated air cavity of the same size according to 6.3.

Dimensions in millimetres

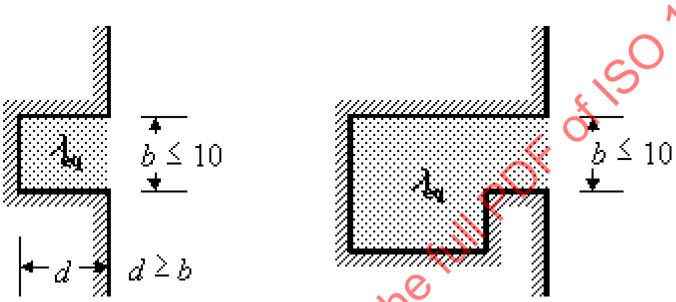


Figure 4 — Examples for slightly ventilated cavities and grooves with small cross section

6.4.2 Well ventilated cavities and grooves with large cross section

In cases not covered by 6.3 and 6.4.1, in particular when the width b of a groove or of a slit connecting a cavity to the environment exceeds 10 mm, it is assumed that the whole surface is exposed to the environment. Therefore, the surface resistance R_{si} or R_{se} according to 5.2 shall be used at the developed surface.

In the case of a large cavity connected by a single slit and a developed surface exceeding the width of the slit by a factor of 10 the surface resistance with reduced radiation shall be used (see annex B).

Dimensions in millimetres

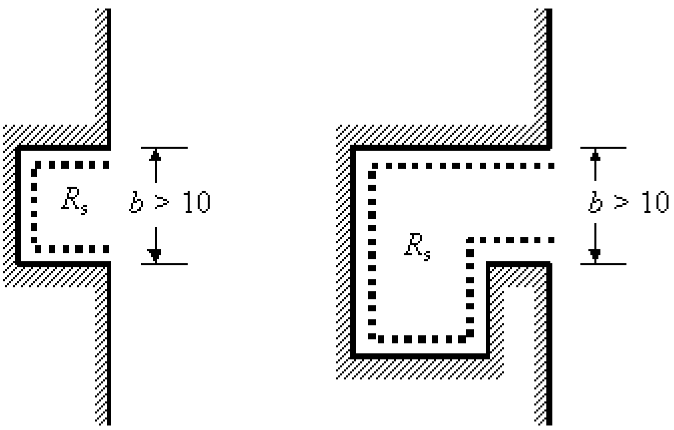


Figure 5 — Examples for well ventilated cavities and grooves

7 Report

7.1 General

The calculation report shall include all information necessary to allow the calculation to be repeated. The sources of all data not taken from this standard shall be given in the report.

7.2 Geometrical data

A scale drawing of the sections (preferably using 1:1 scale) shall be included in the report. The drawing shall give the dimensions and a description of the materials used. The minimum information to be given is:

— for metallic frames, the thickness, position, type and number of thermal breaks;

— for plastic frames, the presence and position of metal stiffening (reinforcements);

— the thickness of wooden or plastic frames;

— the internal and external projected frame areas as well as the corresponding developed areas.

The division of the section for the numerical calculation or at least the number of nodes in both directions shall be stated.

7.3 Thermal data

7.3.1 Thermal conductivity

All materials of the frame section shall be listed together with their design thermal conductivity. The data given in annex A should preferably be used. If other sources are used, this shall be clearly stated and reference made to the source.

7.3.2 Emissivity

For cavities the emissivity of the surrounding surfaces shall be stated, and supporting evidence, including references, shall be provided if values below 0,9 are used.

7.3.3 Boundary conditions

The internal and external surface resistances and the adiabatic boundaries, together with the internal and external air temperature, shall be indicated on the drawing.

7.4 Results

The total heat flow rate or the density of heat flow rate, the thermal transmittance of the frame section and the linear thermal transmittance according to annex C shall be given to two significant figures.

Annex A
(informative)

Design thermal conductivity of selected materials

Table A.1 includes the thermal conductivities of the materials used for the given groups. With few exceptions the values were taken from EN 12524 which also includes other materials.

Table A.1 — Design thermal conductivities of materials

Group	Material[a]	Density kg/m^3	Thermal conductivity W/(m·K)
Frame	Copper	8 900	380
	Aluminium (Si Alloys)	2 800	160
	Brass	8 400	120
	Steel	7 800	50
	Stainless steel	7 900	17
	PVC (polyvinylchloride), rigid	1 390	0,17
	Hardwood	700	0,18
	Softwood (typical construction timber)	500	0,13
	Fibreglass (UP-resin) *	1 900	0,40
Glass	Soda lime glass	2 500	1,00
	PMMA (polymethylmethacrylate)	1 180	0,18
	Polycarbonates	1 200	0,20
Thermal break	Polyamid (nylon)	1 150	0,25
	Polyamid 6.6 with 25 % glass fibre	1 450	0,30
	Polyethylene HD, high density	980	0,50
	Polyethylene LD, low density	920	0,33
	Polypropylene , solid	910	0,22
	Polypropylene with 25 % glass fibre	1 200	0,25
	PU (polyurethane), rigid	1 200	0,25
	PVC (polyvinylchloride), rigid	1 390	0,17
Weather stripping	PCP (polychloroprene), e.g. Neoprene	1 240	0,23
	EPDM (ethylene propylene diene monomer)	1 150	0,25
	Silicone, pure	1 200	0,35
	PVC, flexible (PVC-P) 40 % softener	1 200	0,14
	Mohair (polyester) sweep *		0,14
	Elastomeric foam, flexible	60 to 80	0,05
Sealant and glass edge material	PU (polyurethane), resin	1 200	0,25
	Butyl (isobutene) , solid/hot melt	1 200	0,24
	Polysulfide	1 700	0,40
	Silicone, pure	1 200	0,35
	Polyisobutylene	930	0,20

(*continued*)

Table A.1 (*continued*)

Group	**Material**[a]	**Density** kg/m^3	**Thermal conductivity** W/(m·K)
Sealant and glass edge material	Polyester resin	1 400	0,19
	Silica gel (desiccant)	720	0,13
	Molecular sieve(desiccant) *	650 to 750	0,10
	Silicone foam, low density	750	0,12
	Silicone foam, medium density *	820	0,17

a Most materials are taken from EN 12524 except those marked with *

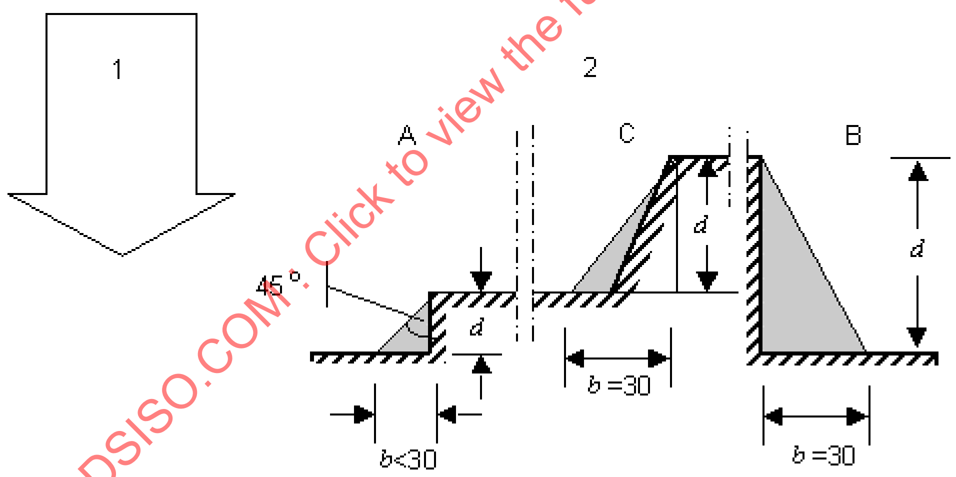
Annex B
(normative)

Surface resistances for horizontal heat flow

Table B.1 — Surface resistances for horizontal heat flow

Position	**External** R_{se} $m^2 \cdot K/W$	**Internal** R_{si} $m^2 \cdot K/W$
Normal (plane surface)	0,04	0,13
Reduced radiation/convection (in edges or junctions between two surfaces, see Figure B1)	0,04	0,20
NOTE These values correspond to the surface resistance values given in ISO 6946 (see Bibliography). ISO 6946 gives further information about the influence of convection and radiation on surface resistances.		

Dimensions in millimetres



Key

1 Direction of heat flow
2 Internal surface

Figure B.1 — Schematic representation of surfaces with an increased surface resistance due to a reduced radiation/convection heat transfer

In Figure B.1 the increased surface resistances apply over the distances b and d, where b is equal to the depth d, but not greater than 30 mm.

Example A: $b = d$ when $d \leq 30$ mm;
Example B: $b = 30$ mm when $d > 30$ mm;
Example C: Application to a sloped surface; $b = 30$ mm when $d > 30$ mm.

Annex C
(normative)

Determination of the thermal transmittance

C.1 Thermal transmittance of the frame section

The thermal transmittance of the frame section, U_f, is defined as follows. In the calculation model, the glazing or opaque panel is replaced by an insulation panel with thermal conductivity λ = 0,035 W/(m·K); inserted into the frame with clearance b_1, not less than 5 mm, and an overlap b_2 not exceeding 15 mm. The visible length of the panel is at least 190 mm and the thickness d shall be the intended thickness of the glazing or opaque panel (see Figure C.1). The opposite end of the panel is considered as an adiabatic boundary. The frame model shall contain all materials used in manufacturing the window except the glazing or opaque panel, which is replaced by the insulation panel.

Dimensions in millimetres

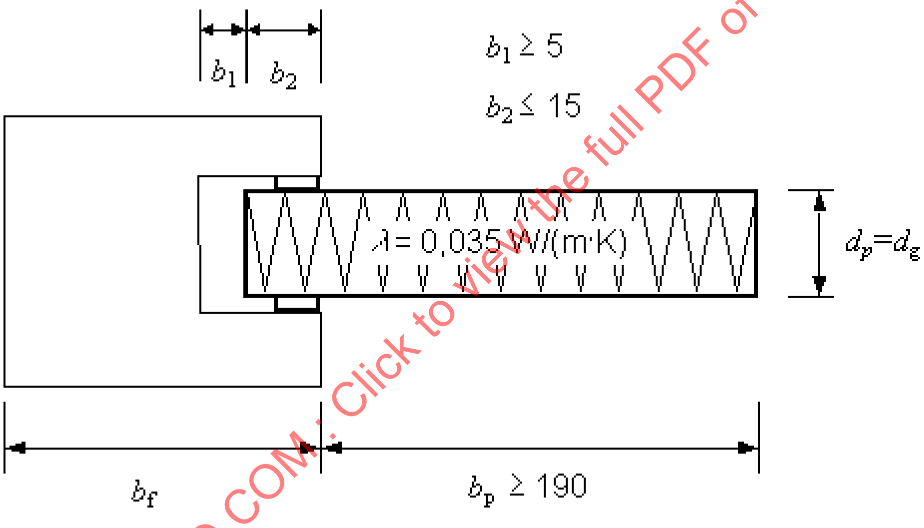


Figure C.1 — Profile section with panel installed

The two-dimensional thermal conductance L_f^{2D}, of the section shown in Figure C.1 consisting of frame and insulation panel is calculated. The value of the thermal transmittance of the frame, U_f, is defined by:

$$U_f = \frac{L_f^{2D} - U_p \cdot b_p}{b_f} \tag{C.1}$$

where

U_f is the thermal transmittance of the frame section, in W/(m²·K);

L_f^{2D} is the thermal conductance of the section shown in Figure C.1, in W/(m·K);

U_p is the thermal transmittance of the central area of the panel, in W/(m²·K);

b_f is the projected width of the frame section, in m;

b_p is the visible width of the panel, in m.

NOTE L^{2D} is calculated from the total heat flow rate per length through the section divided by the temperature difference between both adjacent environments (see EN ISO 10211-1).

C.2 Linear thermal transmittance of the junction with the glazing or opaque panel

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 spacer at the edge of the glazing. The thermal transmittance of the frame, U_f, is applicable in the absence of the glazing. The linear thermal transmittance, Ψ, describes the additional heat flow caused by the interaction of the frame and the glass edge, including the effect of the spacer.

To calculate the two-dimensional thermal coupling coefficient of the section consisting of the frame and the glazing including the spacer effect, the frame section with a projected frame width, b_f, and thermal transmittance U_f is completed by glazing with thermal transmittance U_g and length b_g. (see Figure C.2). The value of the linear thermal transmittance, Ψ, is defined by Equation (C.2).

The same procedure applies to frame sections for doors with opaque panels instead of glazing.

Dimensions in millimetres

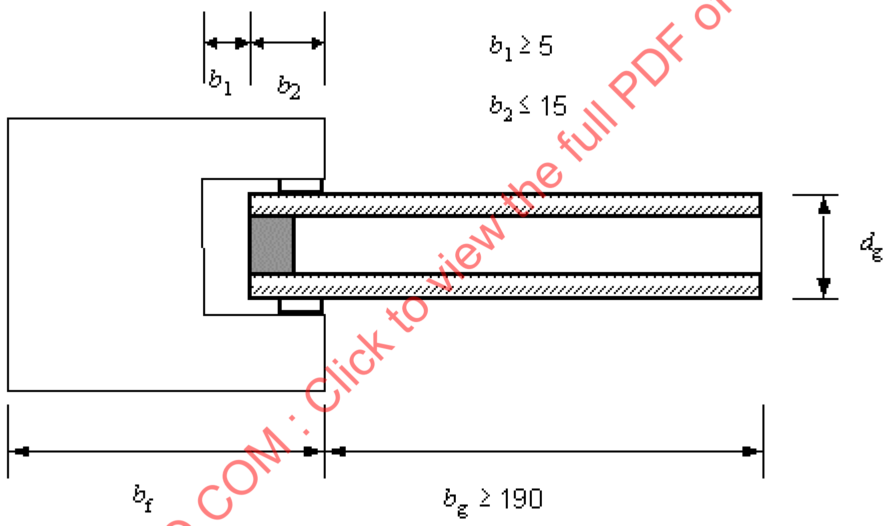


Figure C.2 — Profile section with glazing installed

$$\Psi = L_{\Psi}^{2D} - U_f\, b_f - U_g\, b_g \qquad \text{(C.2)}$$

where

Ψ is the linear thermal transmittance, in W/(m·K);

L_{Ψ}^{2D} is thermal conductance of the section shown in Figure C.2, in W/(m·K);

U_f is the thermal transmittance of the frame section, in W/(m^2·K);

U_g is the thermal transmittance of the central area of the glazing, in W/(m^2·K);

b_f is the projected width of the frame section, in m;

b_g is the visible width of the glazing, in m.

NOTE A visible length of the panel or glass of 190 mm is sufficient for glazing with a thickness up to 60 mm. In other cases the length needs to be increased (see EN ISO 10211-1).

Annex D
(normative)

Examples for the validation of the calculation programs

D.1 General

This annex gives criteria for the validation of a calculation program. As stated in 4.2, application of a program to frame sections in Figures D.1 to D.10 shall lead to results differing by no more than 3 % from those given in Table D.3.

D.2 Figures

In Figures D.1 to D.10 the key shown in Tables D.1 and D.2 applies.

Table D.1 — Boundary

Key	Surface resistance R_s $m^2 \cdot K/W$	Temperature θ °C
A adiabatic	infinity	–
B external	see annex B	0
C internal	see annex B	20

Table D.2 — Materials

Key	Material	Thermal conductivity λ $W/(m \cdot K)$
a	insulation panel	0,035
b	soft wood	0,13
c	PVC	0,17
d	EPDM	0,25
e	polyamide 6.6	0,3
f	glass	1,0
g	steel	50
h	aluminium [a]	160
i	mohair (polyester), sweep	0,14
k	polyamide	0,25
l	PU (polyurethane), rigid	0,25
m	polysulfide	0,40
n	silica gel (desiccant)	0,13
o	gas filling	0,034 [b]

[a] Introduce a remark in the report about the surface treatment, like coated or anodised, if the normal emissivity of the surface is ε_n = 0,85.

[b] Equivalent thermal conductivity of the gas filling.

Dimensions in millimetres

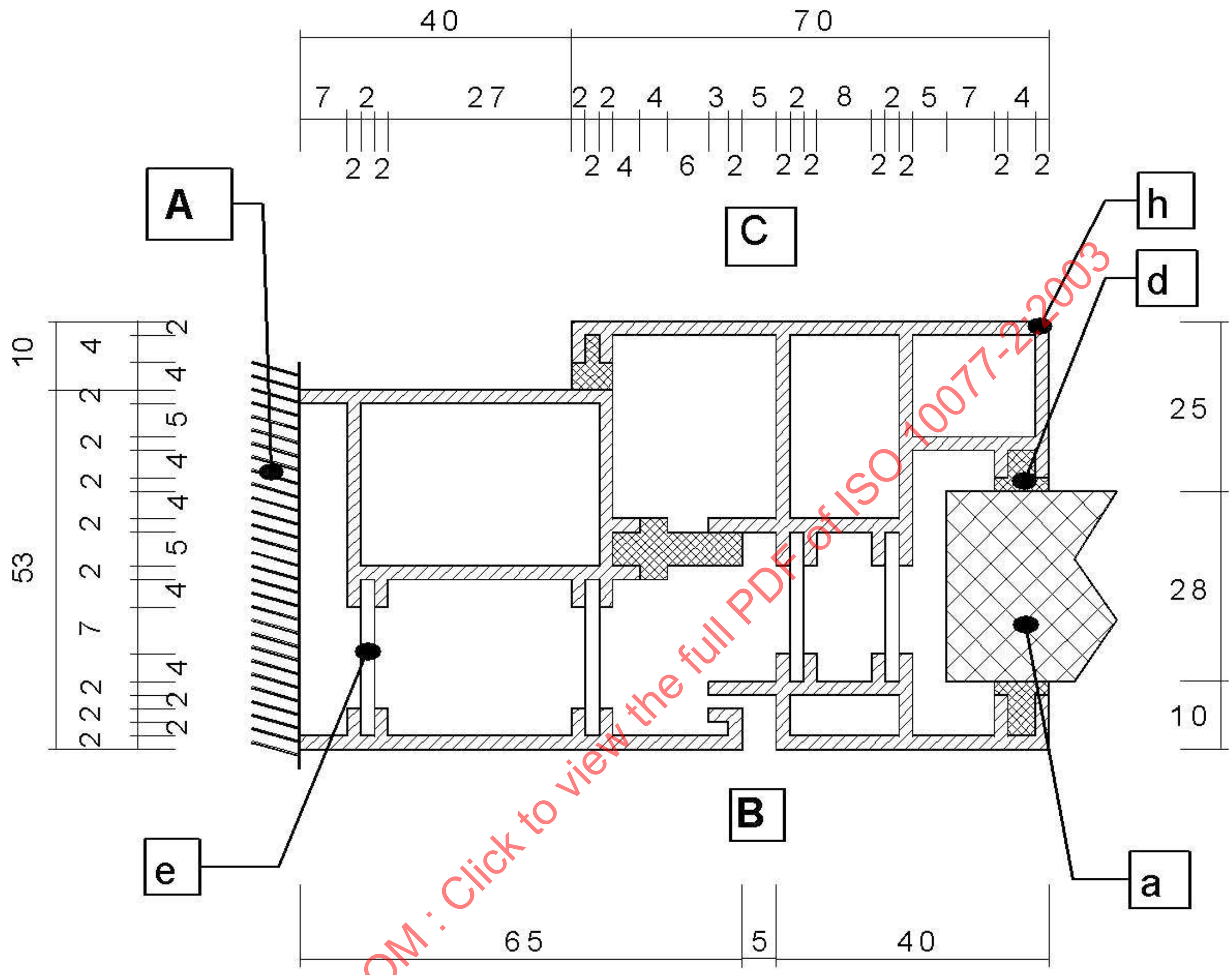


Figure D.1 — Aluminium frame section with thermal break and insulation panel (b_f = 110 mm)

Dimensions in millimetres

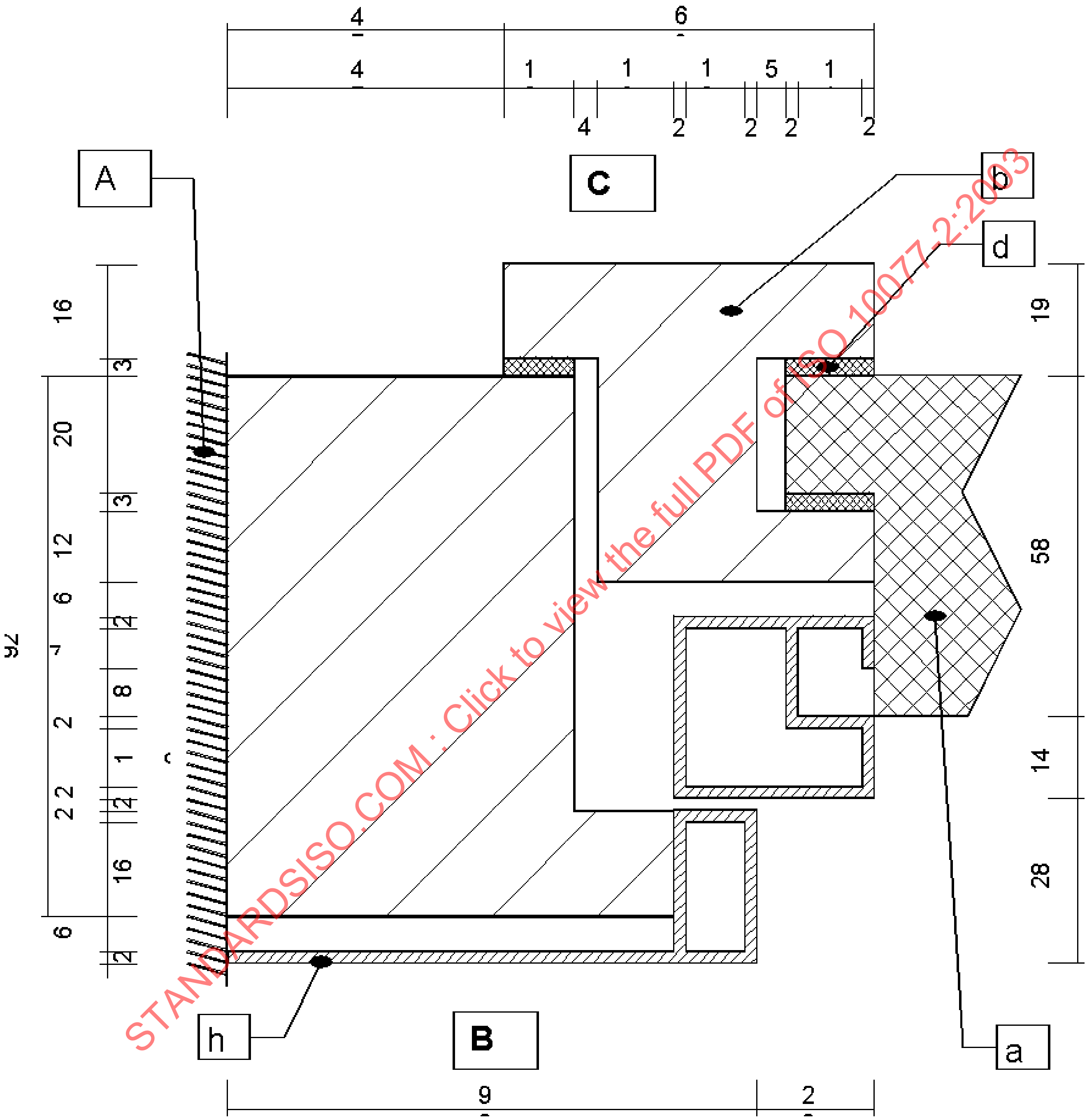


Figure D.2 — Aluminium clad wood frame section and insulation panel (b_f = 110 mm)

Dimensions in millimetres

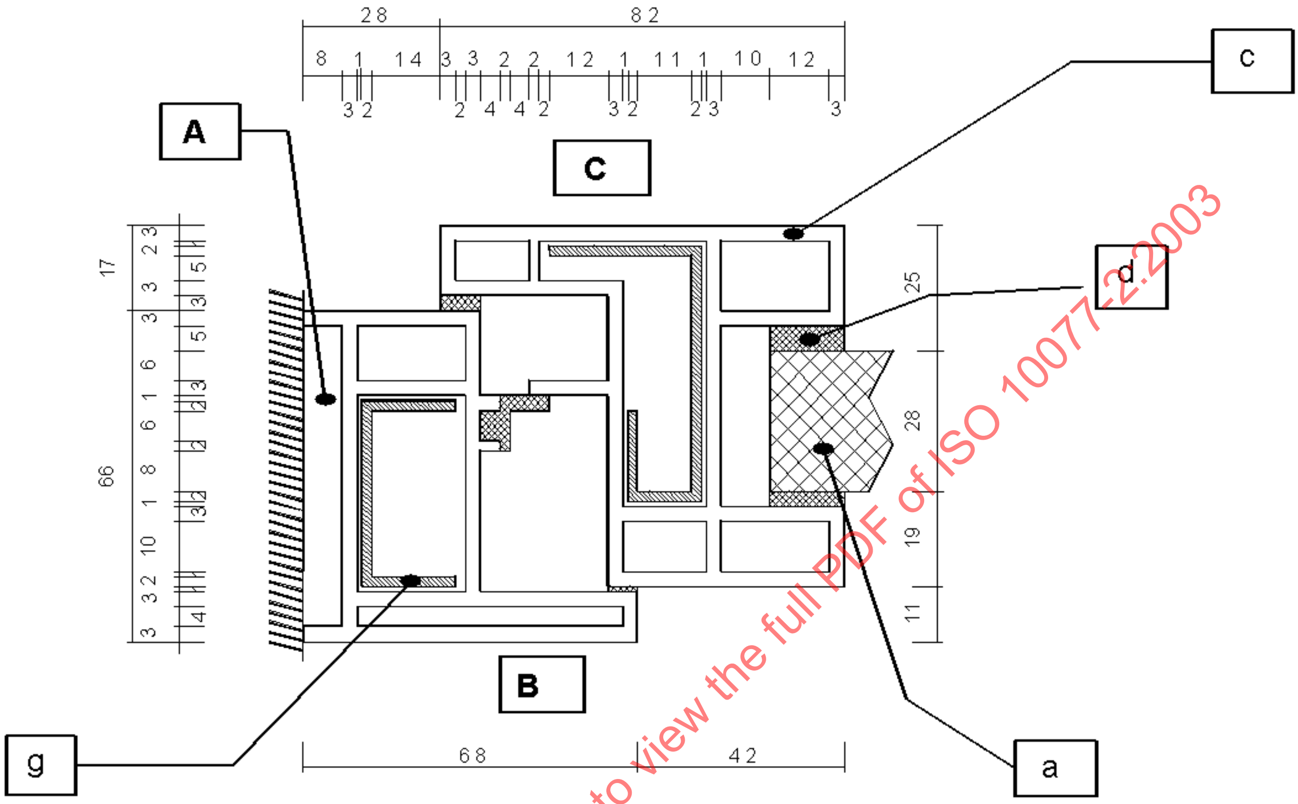


Figure D.3 — PVC-frame section with steel reinforcement and insulation panel (b_f = 110 mm)

Dimensions in millimetres

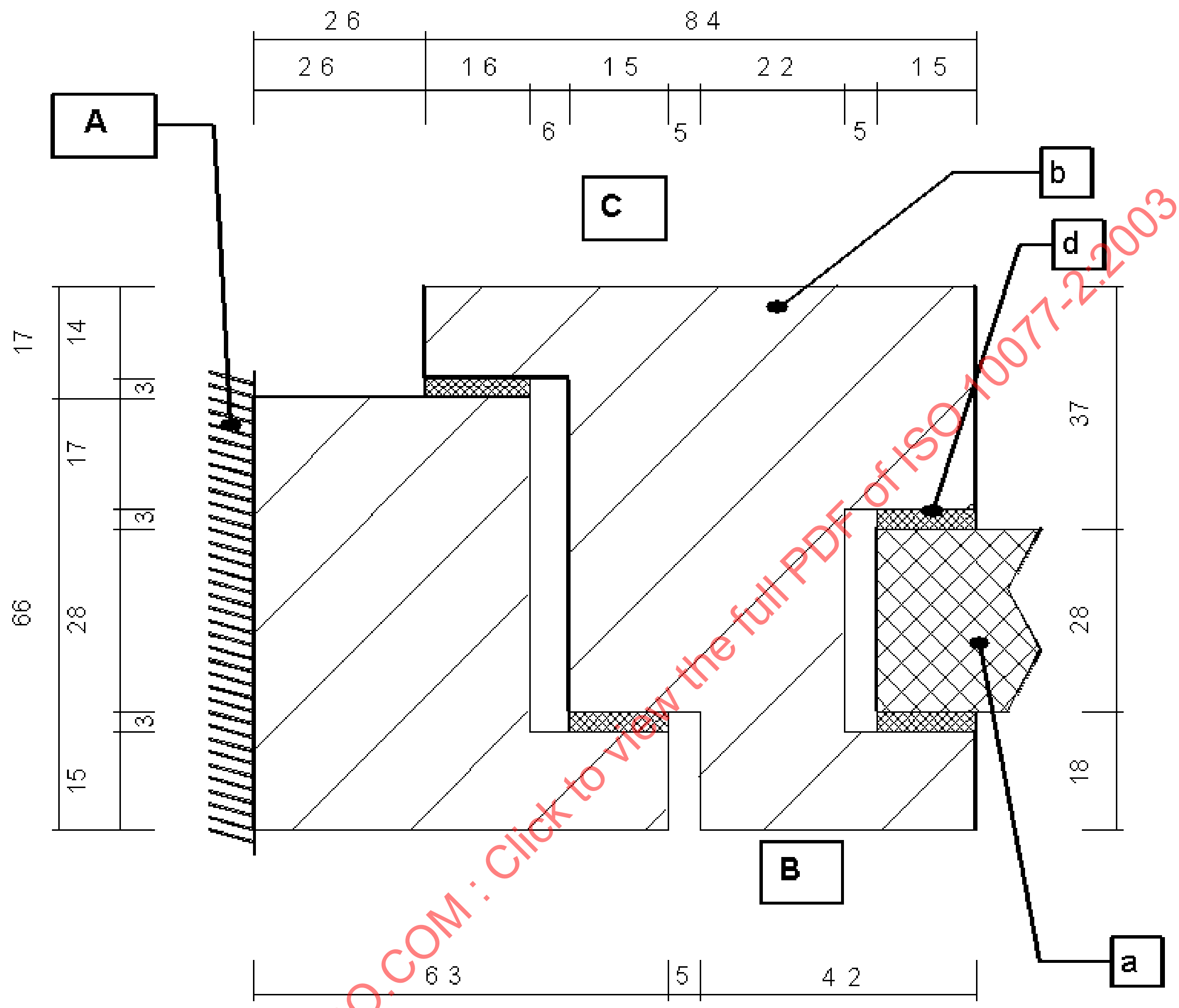
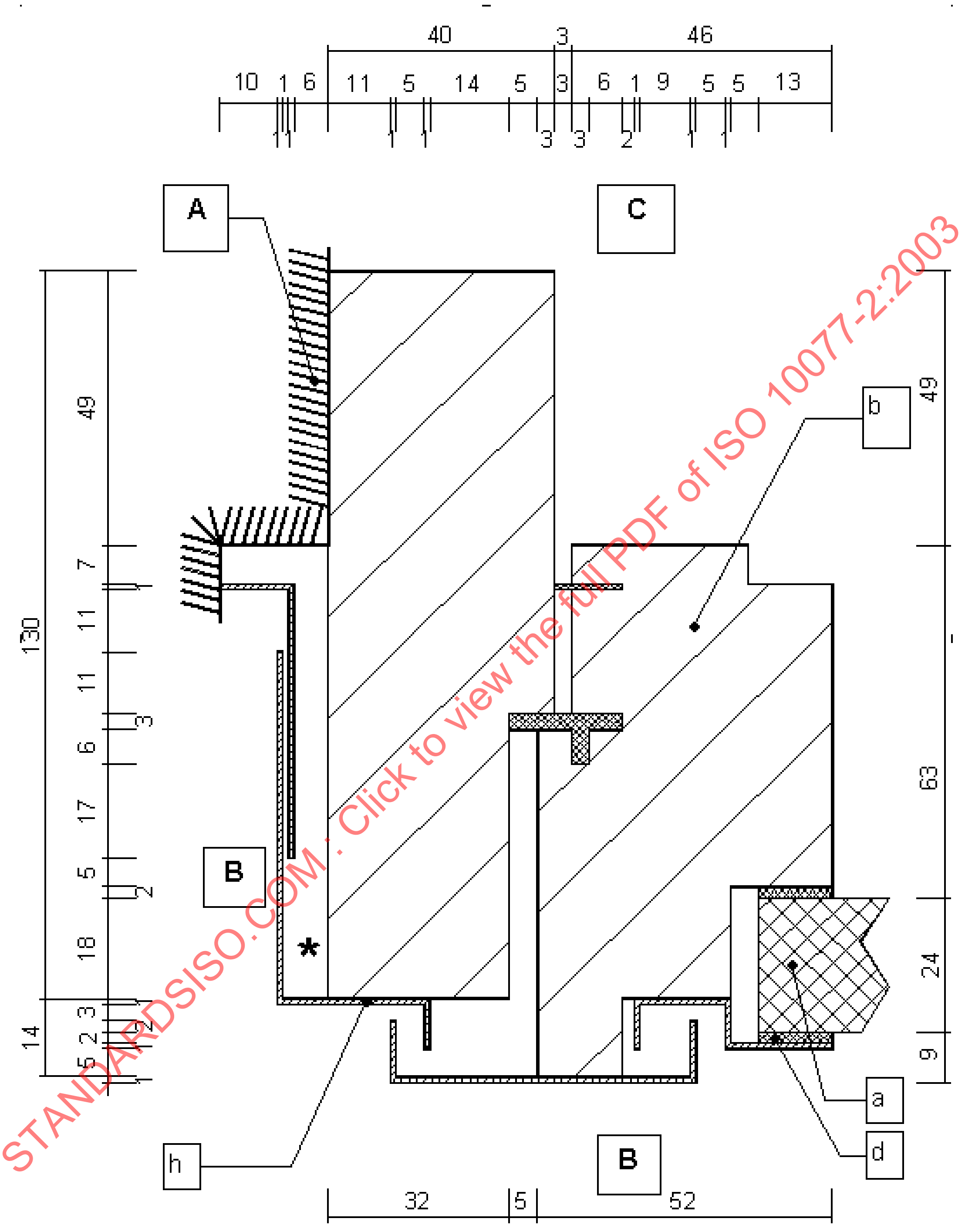


Figure D.4 — Wood frame section and insulation panel (b_f = 110 mm)

Dimensions in millimetres



NOTE In general, the heat flow direction is supposed perpendicular to the surfaces, therefore in the cavity, marked *, the heat flow direction is parallel to the glass pane.

Figure D.5 — Roof window frame section and insulation panel (b_f = 89 mm)

Dimensions in millimetres

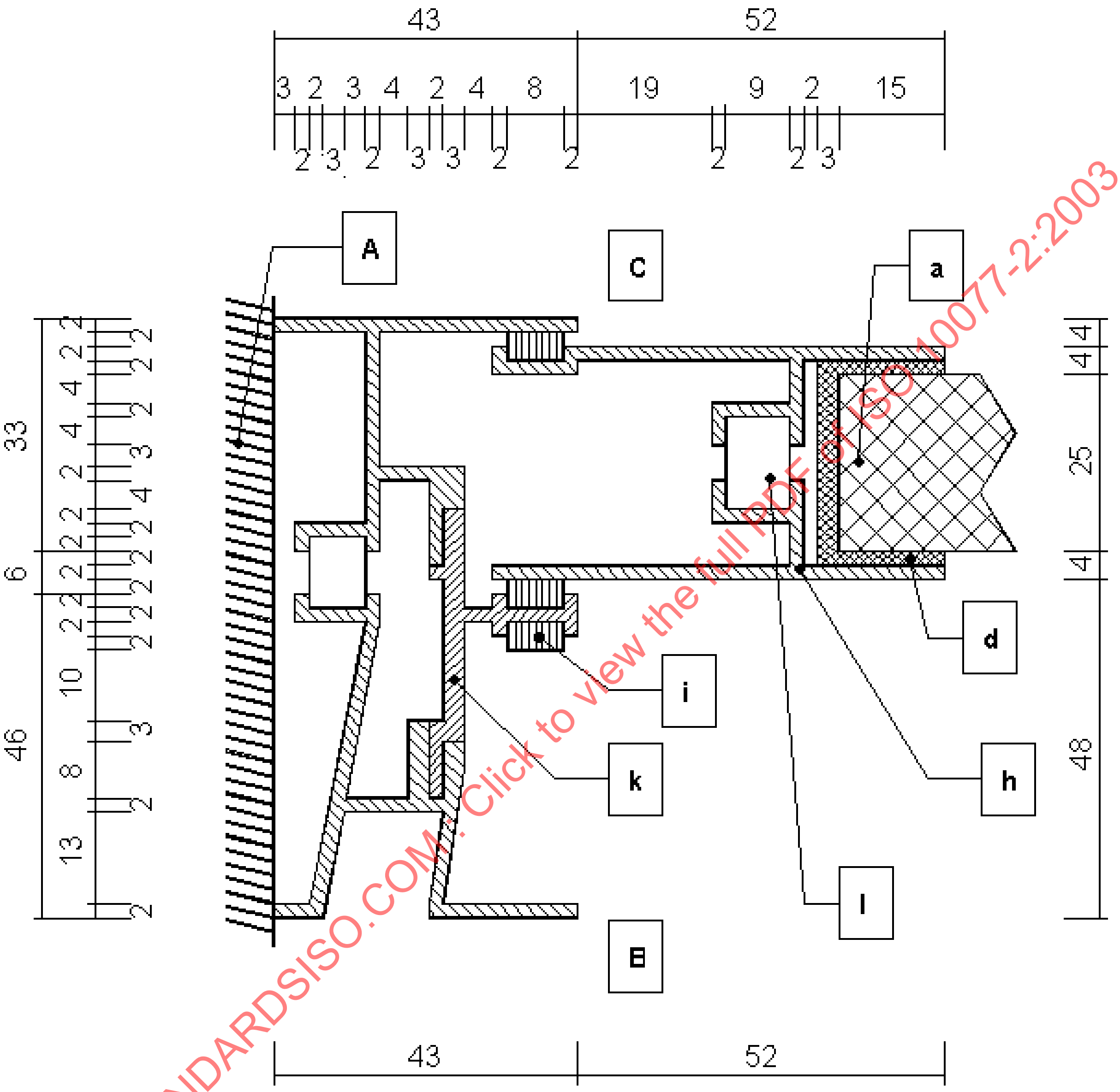


Figure D.6 — Sliding window frame section and insulation panel (b_f = 95 mm)

Dimensions in millimetres

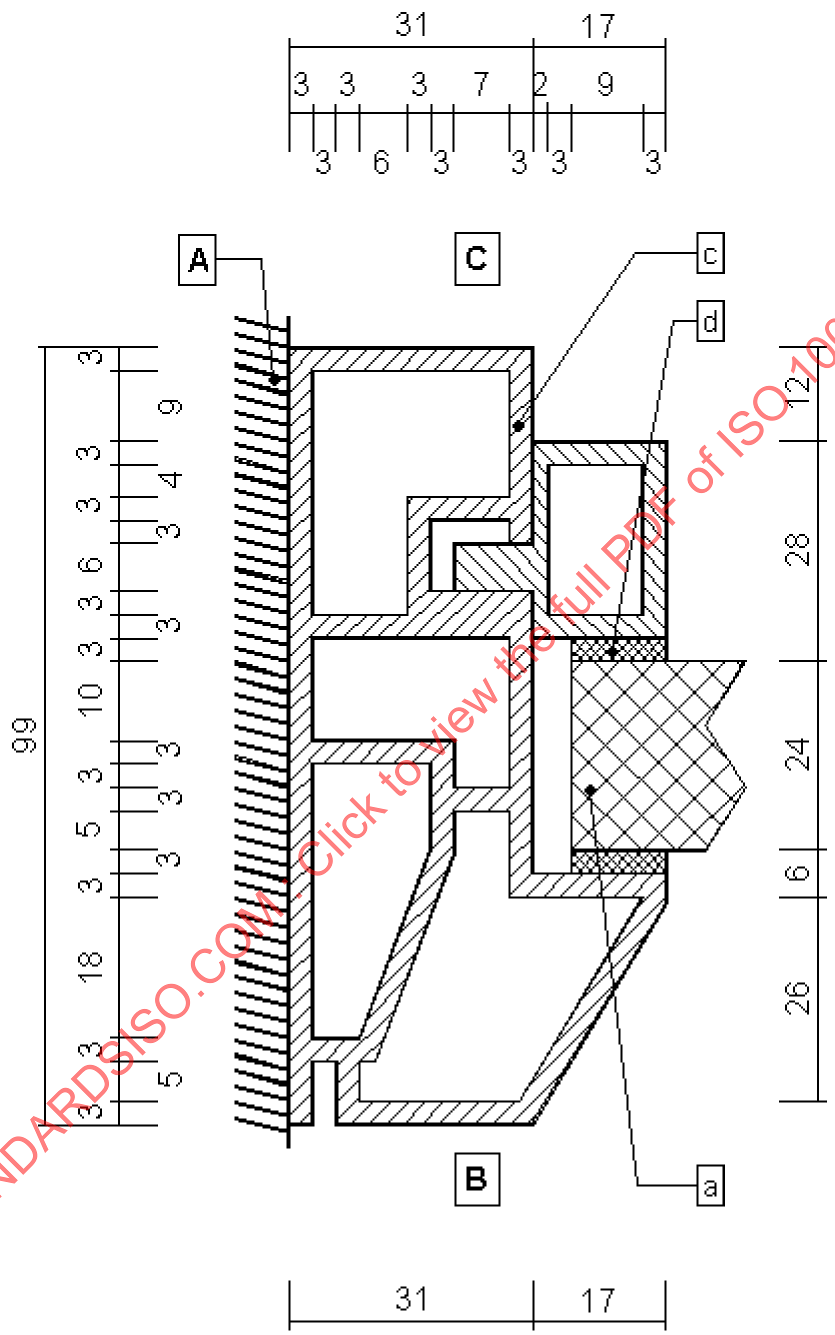


Figure D.7 — Fixed frame section and insulation panel (b_f = 48 mm)