CEN

TC 89 Thermal performance of buildings and building components

CEN/TC 89/WG7 rev
30.08.2000

GTR WI 00089072
CEN/TC 89 WI 23.2 (according to document CEN/TC89 N 600)

Title
Thermal performance of windows, doors and shutters
Calculation of thermal transmittance – Part 2: Numerical method for frames

Descriptors: building, window, door, shutter, frame, thermal performance, thermal transmittance, calculation, numerical method

French title
Performance thermique des fenêtres, portes, et fermetures - Calcul du coefficient de transmission thermique - Partie 2: Méthode numérique pour encadrements

German title
Wärmetechnisches Verhalten von Fenstern, Türen und Abschlüssen - Berechnung des Wärmedurchgangskoeffizienten - Teil 2: Numerisches Verfahren für Rahmen

Contents

Foreword

The text of prEN ISO 10077-2:1998 has been prepared by the Technical Committee CEN/TC 89 "Thermal performance of buildings and building components", the secretariat of which is held by SIS, in collaboration with Technical Committee ISO/TC 163 "Thermal insulation".

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

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.

Introduction

The test method according to prEN 12412–2 “Windows, doors and shutters - Determination of thermal transmittance by hot box method – Part 2: Frames“ is an alternative to the calculation method particularly if data are not available or the specimen is of complicated geometrical shape.

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

1 Scope

This standard specifies a method and gives the material data required for the calculation of the thermal transmittance (U_f) of vertical frame profiles, and the linear thermal transmittance (ψ). This latter property is used to characterise the edge effects due to glass or other filling elements (annex C). It is an acceptable approximation to use these thermal transmittance values 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.

The method can also be used to evaluate the thermal resistance of shutter profiles and the thermal characteristics of roller shutter boxes.

The standard does not include effects of solar radiation and heat transfer caused by air leakage and 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 standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publications referred to apply.

EN 673	Glass in building – Determination of thermal transmittance (*U*-value) - Calculation method
prEN 12519	Doors and windows - Terminology
EN ISO 6946	Building components and building elements – Thermal resistance and thermal transmittance – Calculation method
EN ISO 7345	Thermal insulation - Physical quantities and definitions
EN ISO 10211-1	Thermal bridges in building constructions - Heat flows and surface temperatures – Part 1: General calculation methods
prEN 12524	Building materials and products – Energy related properties – Tabulated design values
ISO 10292	Glass in building – Calculation of steady-state *U*-values (thermal transmittance) of multiple glazing
prEN ISO 10077-1	Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 1: Simplified method
prEN 12412-2	Windows, doors and shutters - Determination of thermal transmittance by hot box method – Part 2: Frames

3 Definitions, symbols, units and subscripts

For the purpose of this standard, the definitions given in EN ISO 7345 and prEN 12519 apply.

Symbol	Quantity	Unit
A	Area	m²
E	intersurface emittance	–
F	view factor	–
L^{2D}	two-dimensional thermal conductance or thermal coupling coefficient	W/(m·K)
R	thermal resistance	m²·K/W
T	thermodynamic temperature	K
U	thermal transmittance	W/(m²·K)
b	width, i.e. perpendicular to the direction of heat flow	m
d	depth, i.e. parallel to the direction of heat flow	m
h	heat transfer coefficient	W/(m²·K)
l	length	m
q	heat flow rate	W/m²
ε	emissivity	–

λ	thermal conductivity	W/(m·K)
Ψ	linear thermal transmittance	W/(m·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 complying with EN ISO 10211-1. The elements shall be divided such that any further division does not change the result of the heat flux 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 are assumed. It is assumed that the emissivity of the surface adjoining the air cavities is 0,9. If other values are used they shall be clearly stated with references in the report.

4.2 Verification of the calculation program used

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 annex D.3 in table D.3 by more than ± 3%. This will lead to an accuracy of the thermal transmittance and the ψ-value 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 a filling element according to annex C.

5 Treatment of solid sections and boundaries

5.1 Solid materials

Typical values of thermal conductivity for common materials are given in annex A. Data derived from measurements may be used instead of those in annex A, but this shall be clearly stated in the report.

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, 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 refer to EN ISO 10211-1.

6 Treatment of cavities

6.1 General

The heat flow rate in cavities should be represented by an equivalent thermal conductivity λ_{eq}. This equivalent thermal conductivity includes the heat flux by conduction, by convection and by radiation and depends on the geometric and material characteristics of the cavity.

6.2 Cavities in glazing

The equivalent thermal conductivity of an unvented space between glass panes in glazing shall be determined according to EN 673 or ISO 10292. The resulting equivalent conductivity shall be used in the whole cavity, even 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. New more accurate correlations are given in ISO/CD 15099.

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.

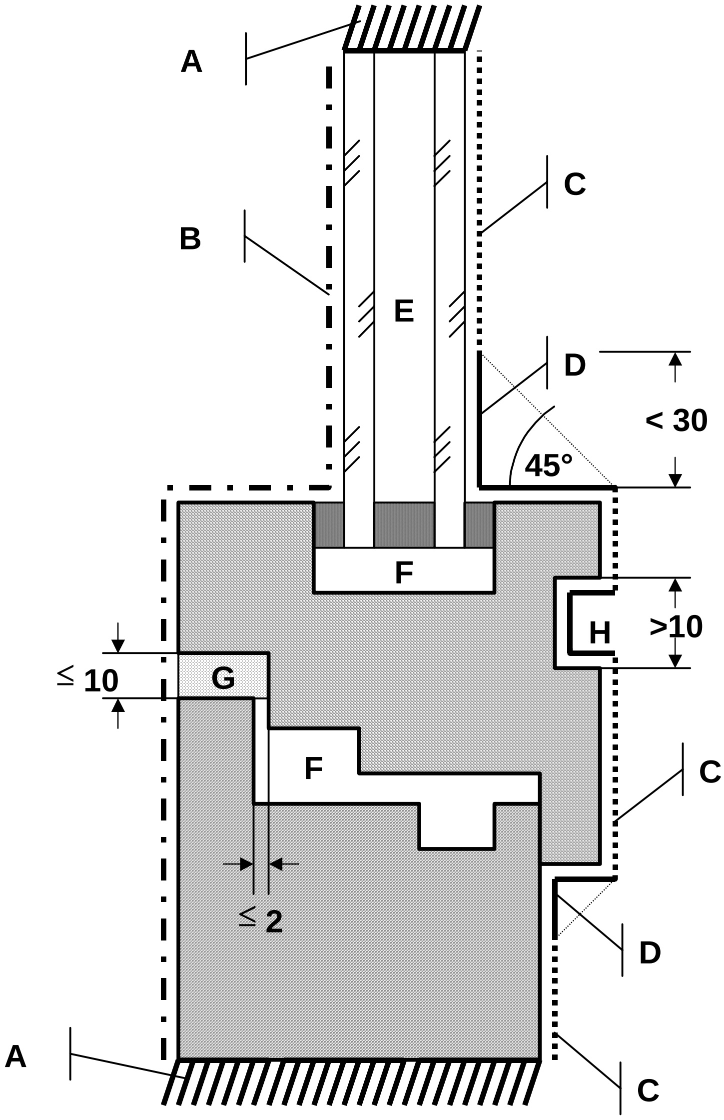


Figure 1: Schematic example for the treatment of cavities and grooves of a frame section and the treatment of the boundaries

Boundaries, see annex B:
A: Adiabatic boundary;
B: Outdoor surface resistance;
C: Indoor 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

6.3.2 Unventilated rectangular cavities

The equivalent thermal conductivity of the cavity is given by

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

where R_s is the thermal resistance

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

and d is the dimension of the cavity in the direction of the heat flux, see Figure 2.

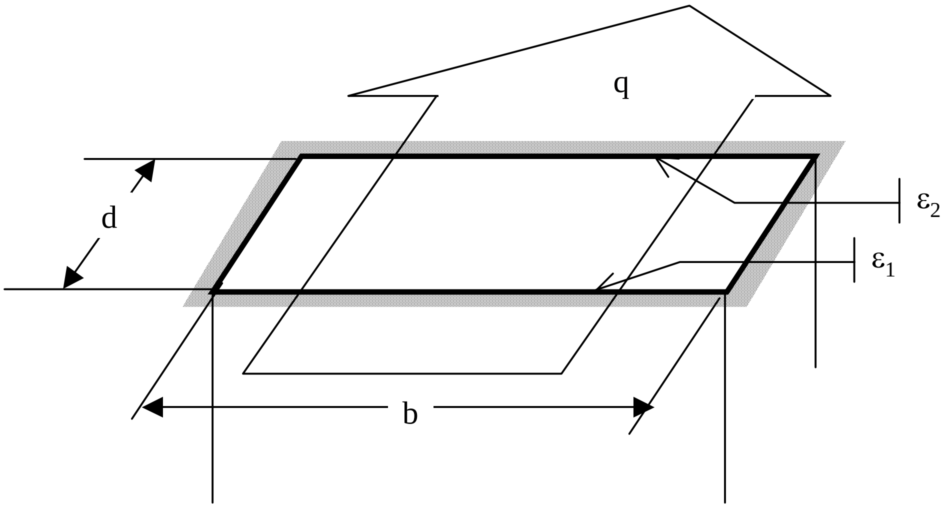


Figure 2: Rectangular cavity and direction of heat flux

The convective part of the heat transfer coefficient is

in case of b less then 5 mm:

$$h_a = C_1 / d \text{ where } C_1 = 0{,}025 \frac{W}{mK}$$

otherwise

$$h_a = \max\left\{C_1 / d; \quad C_2 \cdot \Delta T^{1/3}\right\} \text{ where } C_1 = 0{,}025 \frac{\mathrm{W}}{\mathrm{mK}}; C_2 = 0{,}73 \frac{\mathrm{W}}{\mathrm{m^2K}^{4/3}}$$

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

If no other information is available use $\Delta T = 10$ K for which

$$h_a = \max\left\{ C_1 / d; \quad C_3 \right\} \text{ where } C_1 = 0{,}025 \frac{\mathrm{W}}{\mathrm{mK}} \text{ and } C_3 = 1{,}57 \frac{\mathrm{W}}{\mathrm{m^2\,K}}$$

The radiative part of the heat transfer coefficient is

$$h_r = 4\sigma \cdot T_m^3 \cdot \left(\frac{1}{E} + \frac{1}{F} - 1\right)^{-1}$$

where

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

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

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

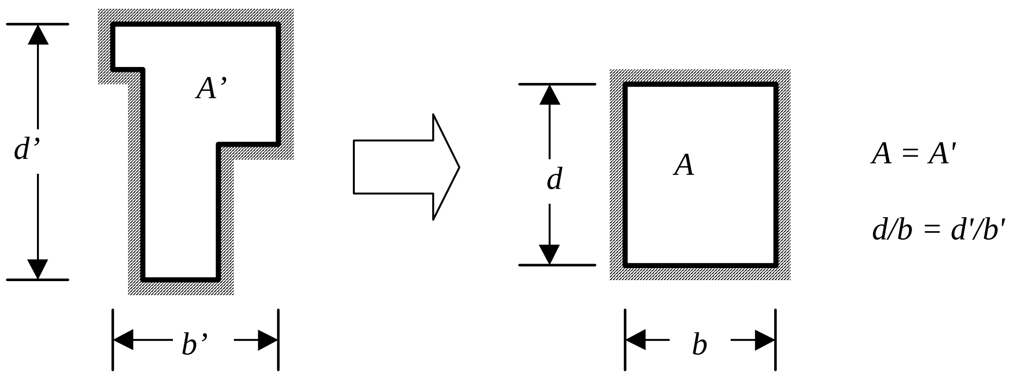
If no other information is available use $\varepsilon_1 = \varepsilon_2 = 0{,}9$ and $T_m = 283\,\mathrm{K}$ for which

$h_r = C_4 \cdot \left(1 + \sqrt{1 + (d/b)^2} - d/b\right)$ where $C_4 = 2{,}11 \frac{\mathrm{W}}{\mathrm{m^2 K}}$

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 and aspect ratio (see Figure 3), then use 6.3.2.

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



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

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 exterior or interior by a slit greater than 2 mm but not exceeding 10 mm are to 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.

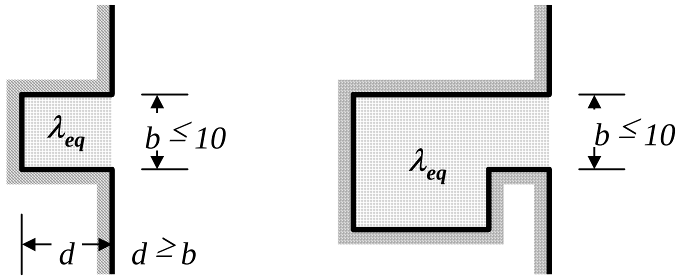


Figure 4: Examples for slightly ventilated cavities and grooves with small cross section

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 is to 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 should be used (see annex B).

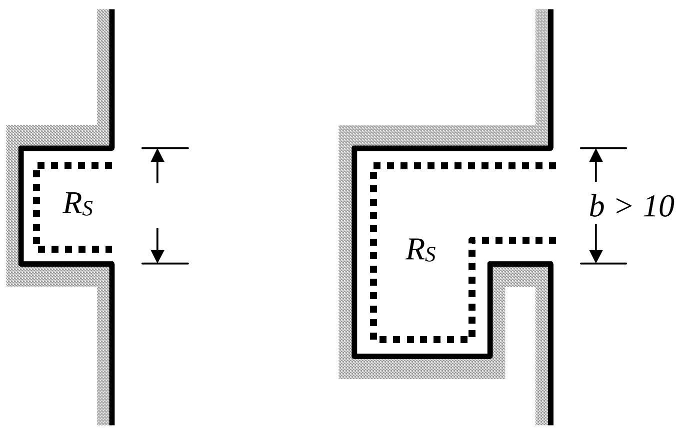


Figure 5: Examples for well ventilated cavities and grooves

7 Report

7.1 General

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

7.2 Geometrical data

A scale drawing of the sections (preferably using 1:1 scale) should be included in the report. The drawings shall give dimensions and a description of the materials used. The most important details that shall be included are listed below:

- 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 frames and the thickness of plastic and PUR–frame material;
- 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 section shall be listed together with the 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 references evidence 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)
Tabulated thermal conductivity (λ-value) of selected materials

For further information refer to prEN 12524

Material group	Material	Density kg/m^3	Thermal conductivity W/(m·K)
Frame	Copper	8900	380
	Aluminium (Si Alloys)	2800	160
	Brass	8400	120
	Steel	7800	50
	Stainless steel	7900	17
	PVC (polyvinylchloride), rigid	1390	0,17
	Hardwood	700	0,18
	Softwood (typical construction timber)	500	0,13
	Fibreglass (UP-resin)	1900	0,40
Glass	Soda lime glass	2500	1,0
	PMMA (polymethylmethacrylate)	1180	0,18
	Polycarbonates	1200	0,20
Thermal break	Polyamid (nylon)	1150	0,25
	Polyamid 6.6 with 25% Glassfibre	1450	0,30
	Polyethylene HD, high density	980	0,50
	Polyethylene LD, low density	920	0,33
	Polypropylene , solid	910	0,22
	Polypropylene with 25% Glassfibre	1200	0,25
	PU (polyurethane), resin	1200	0,25
	PVC (polyvinylchloride), rigid	1390	0,17
Weather stripping	Neoprene (polychloroprene PCP)	1240	0,23
	EPDM (ethylene propylene diene monomer)	1150	0,25
	Silicone, pure	1200	0,35
	PVC, flexible	1200	0,14
	Mohair (polyester) sweep		0,14
	Elastomeric foam, flexible	60-80	0,05
Sealant and glass edge material	PU (polyurethane), rigid	1200	0,25
	Butyl (isobutene) , solid/hot melt	1200	0,24
	Polysulfide	1700	0,40
	Silicone, pure	1200	0,35
	Polyisobutylene	930	0,20
	Polyester resin	1400	0,19
	Silica gel (desiccant)	720	0,13
	Molecular sieve(desiccant)	650-750	0,10
	Silicone foam, low density	750	0,12
	Silicone foam, medium density	820	0,17

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 [a]	0,13 [a]
reduced radiation/convection (in edges or junctions between two surfaces, see Figure B1)	0,04	0,20

[a] These values correspond to the surface resistance values given in EN ISO 6946.
EN ISO 6946 gives further information about the influence of convection and radiation on surface resistances.

The above values or those specified in national standards should be used.

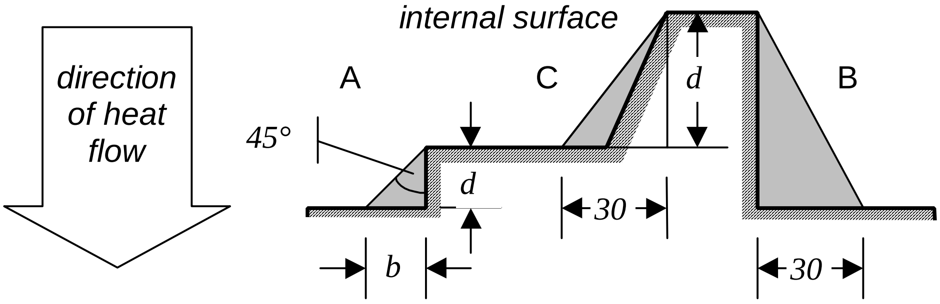


Figure B1: Schematic representation of surfaces with an increased surface resistance due to a reduced radiation/convection heat transfer:

The width b shall be equal to the depth d, but at a maximum of 30 mm
Example A b=d because d<30 mm
Example B b=30 mm
Example C Application to a sloped surface

ANNEX C (normative)
Determination of the thermal transmittance

To evaluate the thermal transmittance the thermal conductance L^{2D} (two dimensional thermal coupling coefficient) through the section is calculated according to this standard. The external and internal surface resistances shall be taken from annex B.

C.1 Frame section
Thermal transmittance

The following gives the definition of the thermal transmittance $U_{f.}$ of the frame section. The frame section is completed by a panel, with thermal conductivity λ equal to 0,035 W/(m·K), the panel is pushed into the frame up to a clearance of 5 mm, but not more than 15 mm. The visible length of the panel is 190 mm at least, the thickness d shall be the intended thickness of the glazing d_g, see figure C.1. It is important that the frame contains all materials which are used in manufacturing the window except the glazing unit (replaced by the insulation panel).

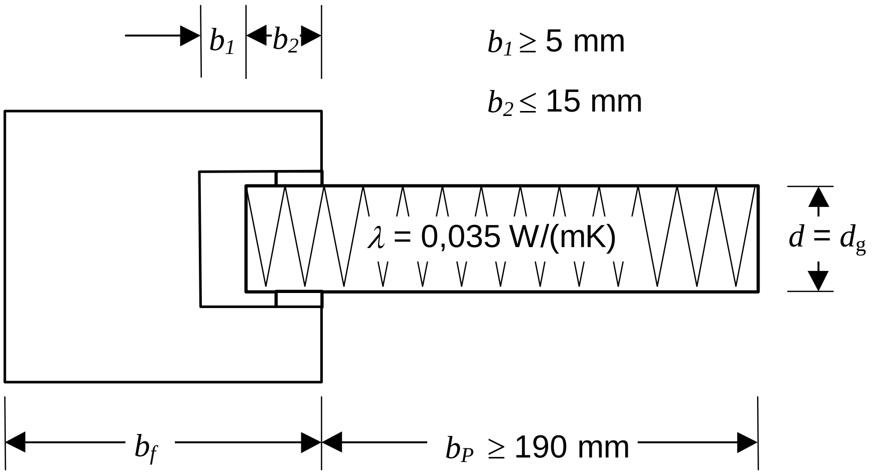


Figure C.1

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 U_f of the frame is defined by:

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

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 centre 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 unit length through the section divided by the temperature difference between indoor and outdoor, refer to EN ISO 10211-1.

C.2 Interaction of frame and glazing Linear thermal transmittance (Ψ-value)

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 glass 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 coefficient Ψ is defined by equation (C.2).

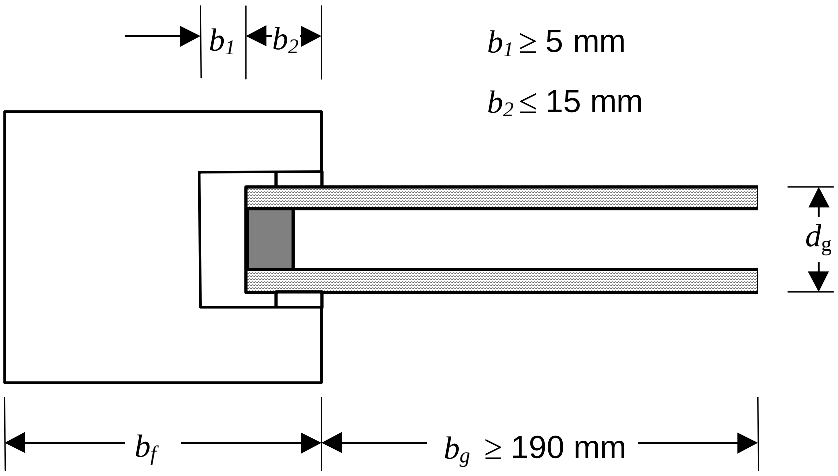


Figure C.2

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

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/(m²·K);
U_g is the thermal transmittance of the glazing, in W/(m²·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: The visible length of the panel or glass of 190 mm is sufficient for a glazing with a thickness up to 60 mm. In other cases the length shall be increased, refer to EN ISO 10211-1.

ANNEX D (normative)
Examples for calculation

D.1 General

The thermal transmittance of the frame sections shown in Figures D.1 to D.9 and the example D 10 for the linear thermal transmittance are to be calculated. The calculation is to be carried out according to the procedure defined in annex C. At first the section is divided into elements and then the appropriate thermal conductivity is assigned to each element. Conductivities of materials are given in table D.2. The air cavities are treated according to clause 6, using ε = 0,9 in all cases.

D 2 Drawings

Legend

In the drawings D 1 to D 10 the following letters are used.

Table D.1: Boundary

Letter		Surface resistance in $m^2 \cdot K/W$	Temperature in °C
A	adiabatic	infinity	-
B	Outdoor	see annex B	0
C	Indoor	see annex B	20

Table D.2: Materials

Letter	Material	λ in $W/(m \cdot K)$
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	160
i	Mohair (polyester), sweep	0,14
k	Polyamide Nylon	0,25
l	PU (polyurethane), resin	0,25
m	Polysulfid	0,40
n	Silica gel (desiccant)	0,13
o	see D.10	0,034

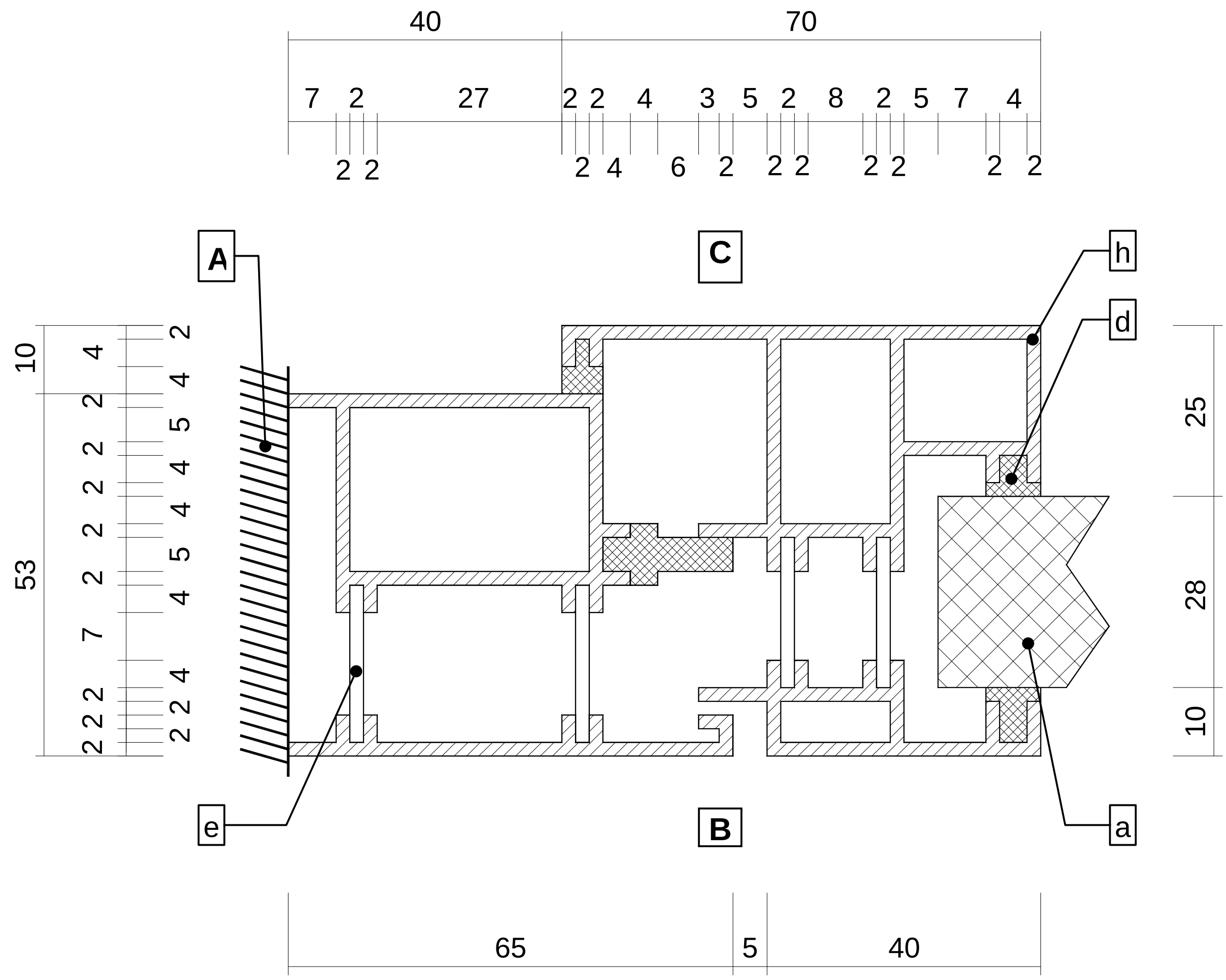


Figure D.1: Aluminium frame section with thermal break and insulation panel (b_f=110 mm)

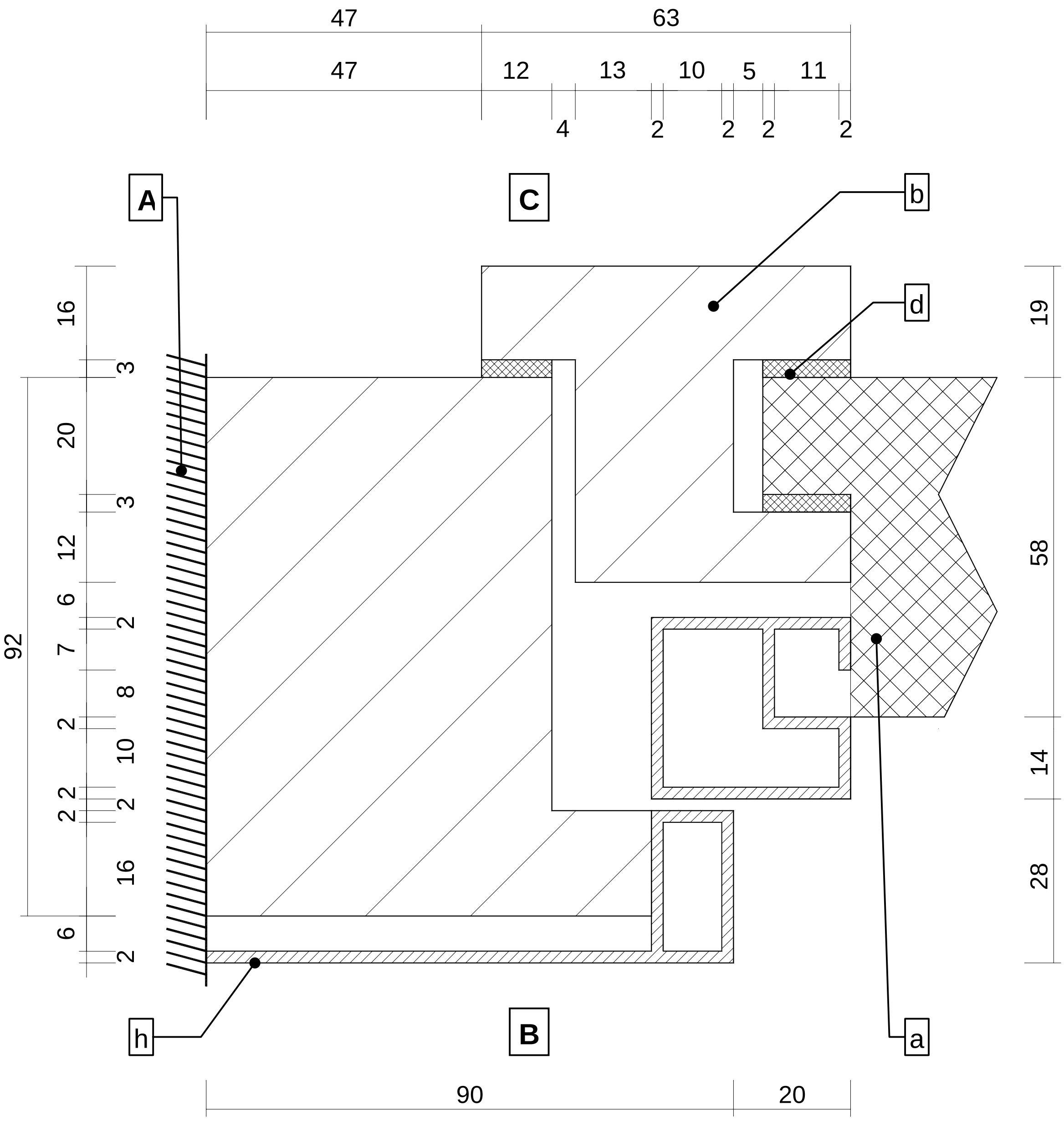


Figure D.2: Aluminium clad wood frame section and insulation panel
(b_f =110 mm)

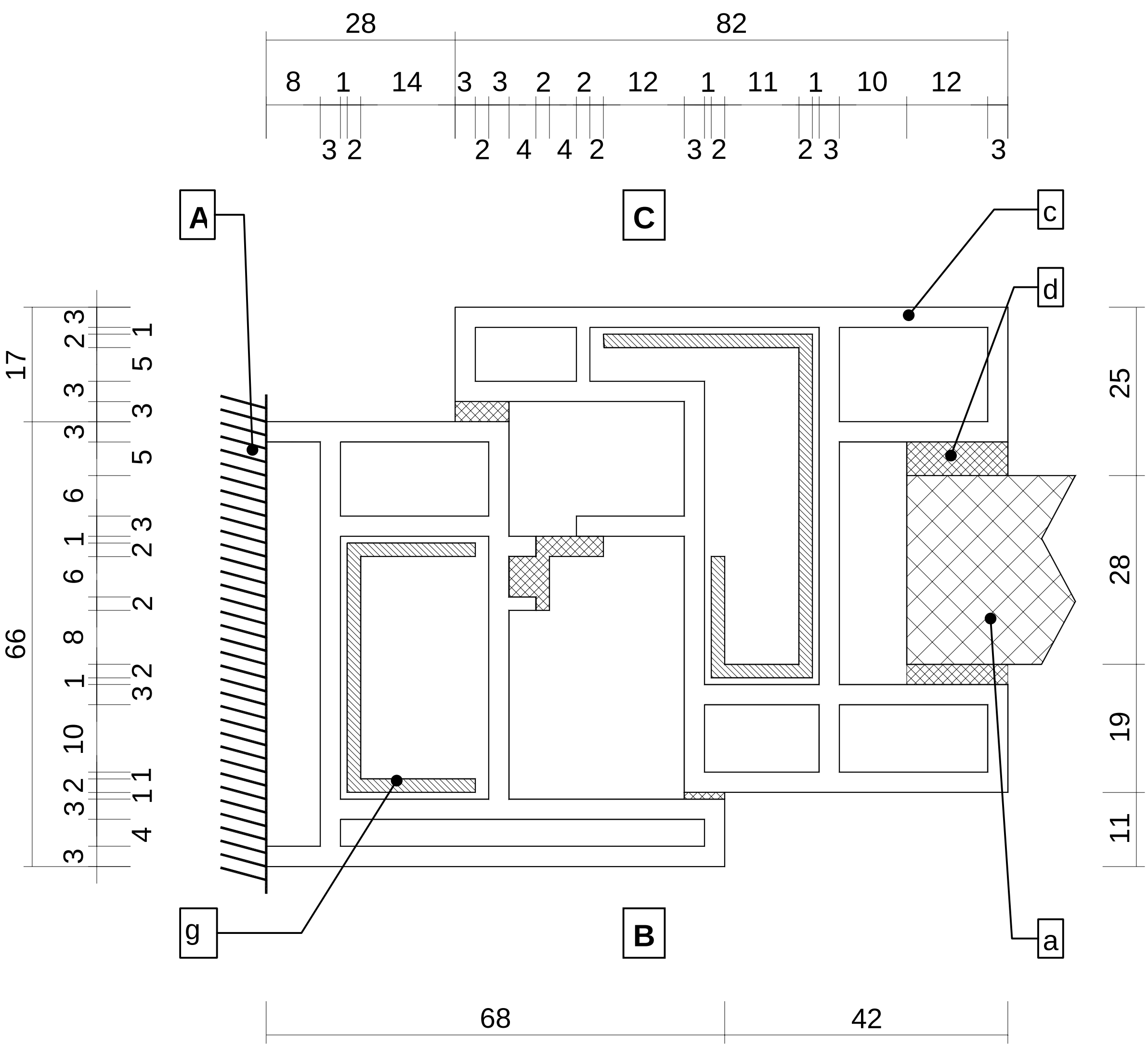


Figure D.3: PVC–frame section with steel reinforcement and insulation panel (b_f=110 mm)

Note: Any possible direct contact between reinforcement and PVC frame is ignored

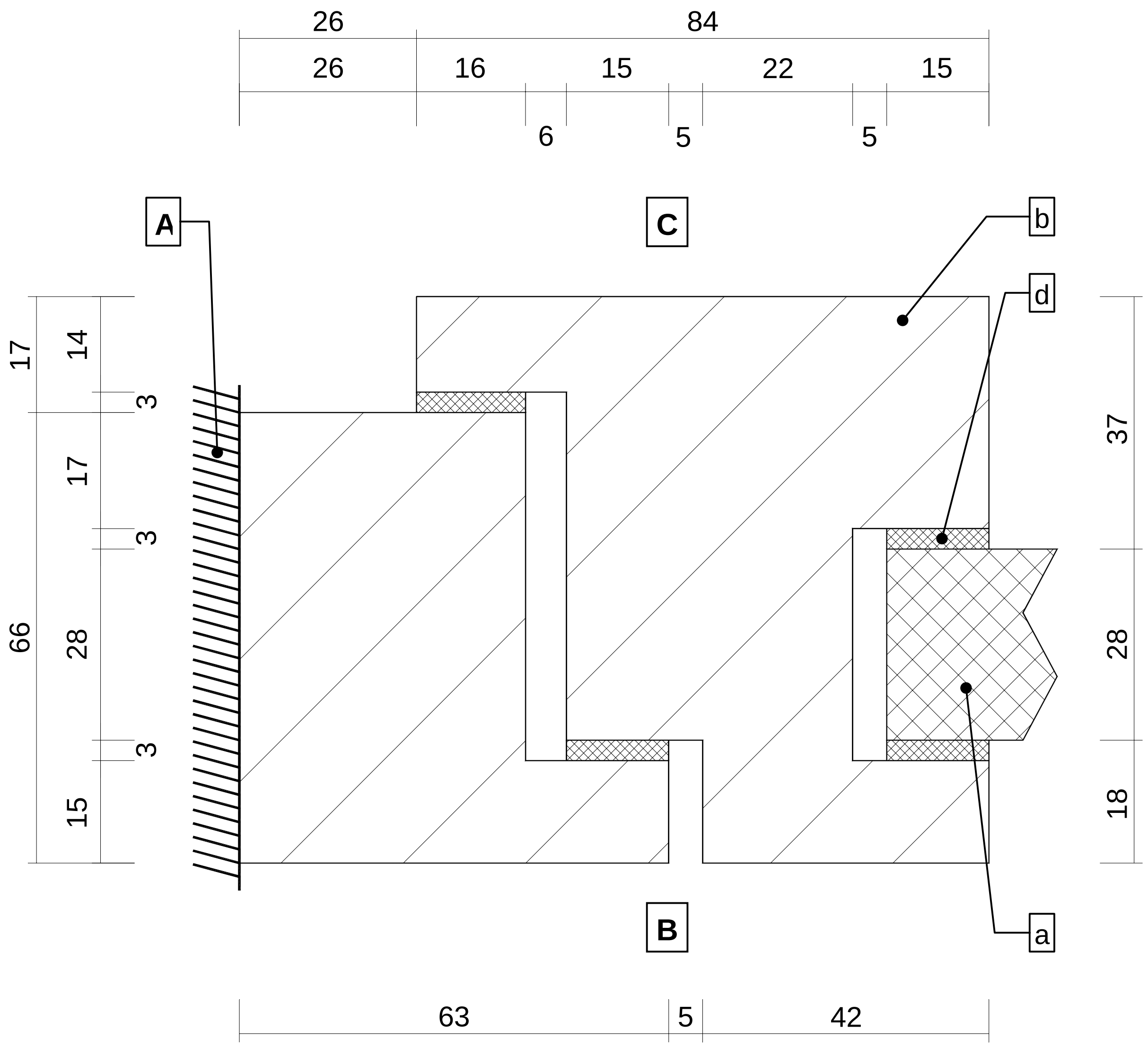


Figure D.4: Wood frame section and insulation panel (b_f =110 mm)

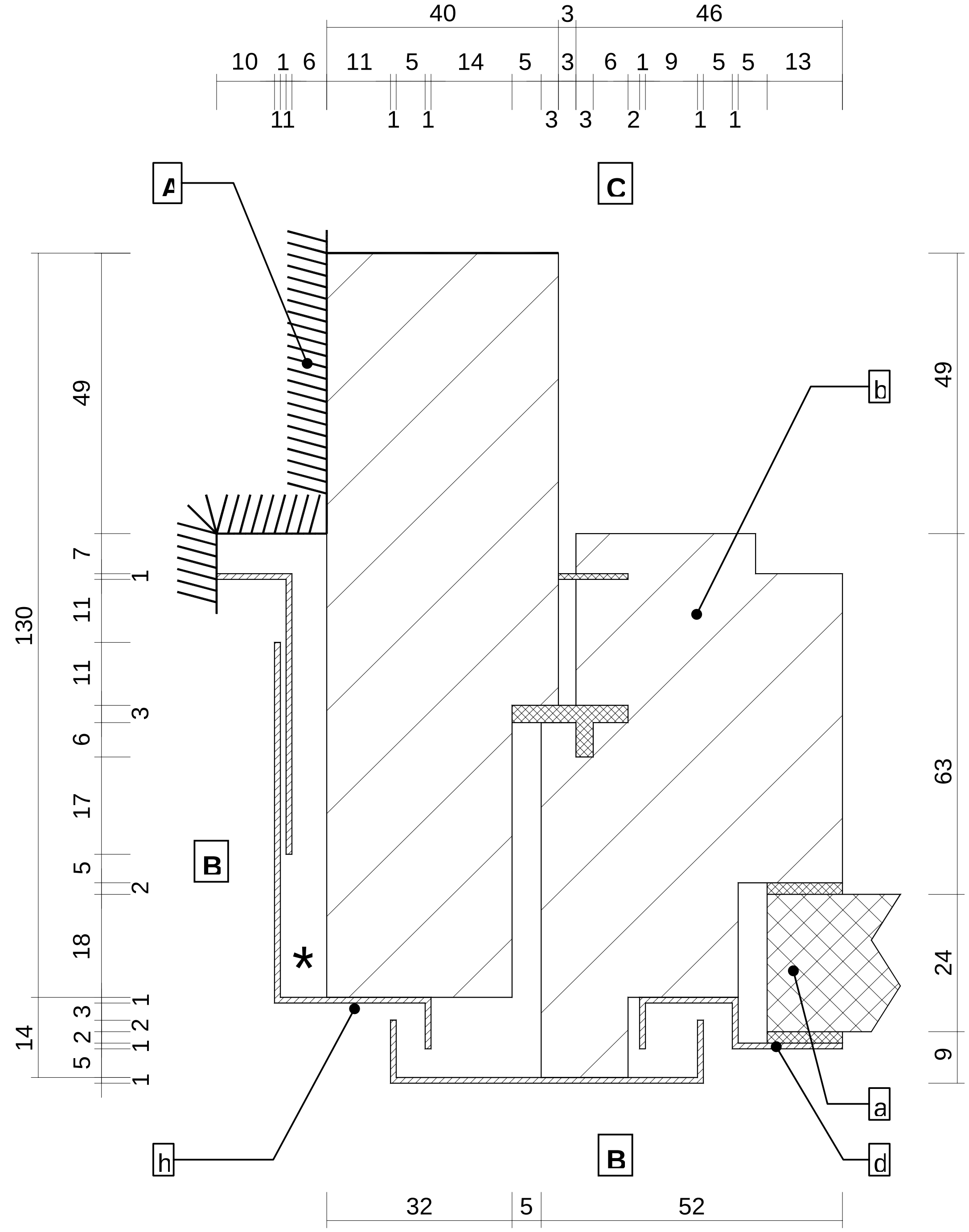


Figure D.5: Roof window frame section and insulation panel (bf= 89 mm)

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

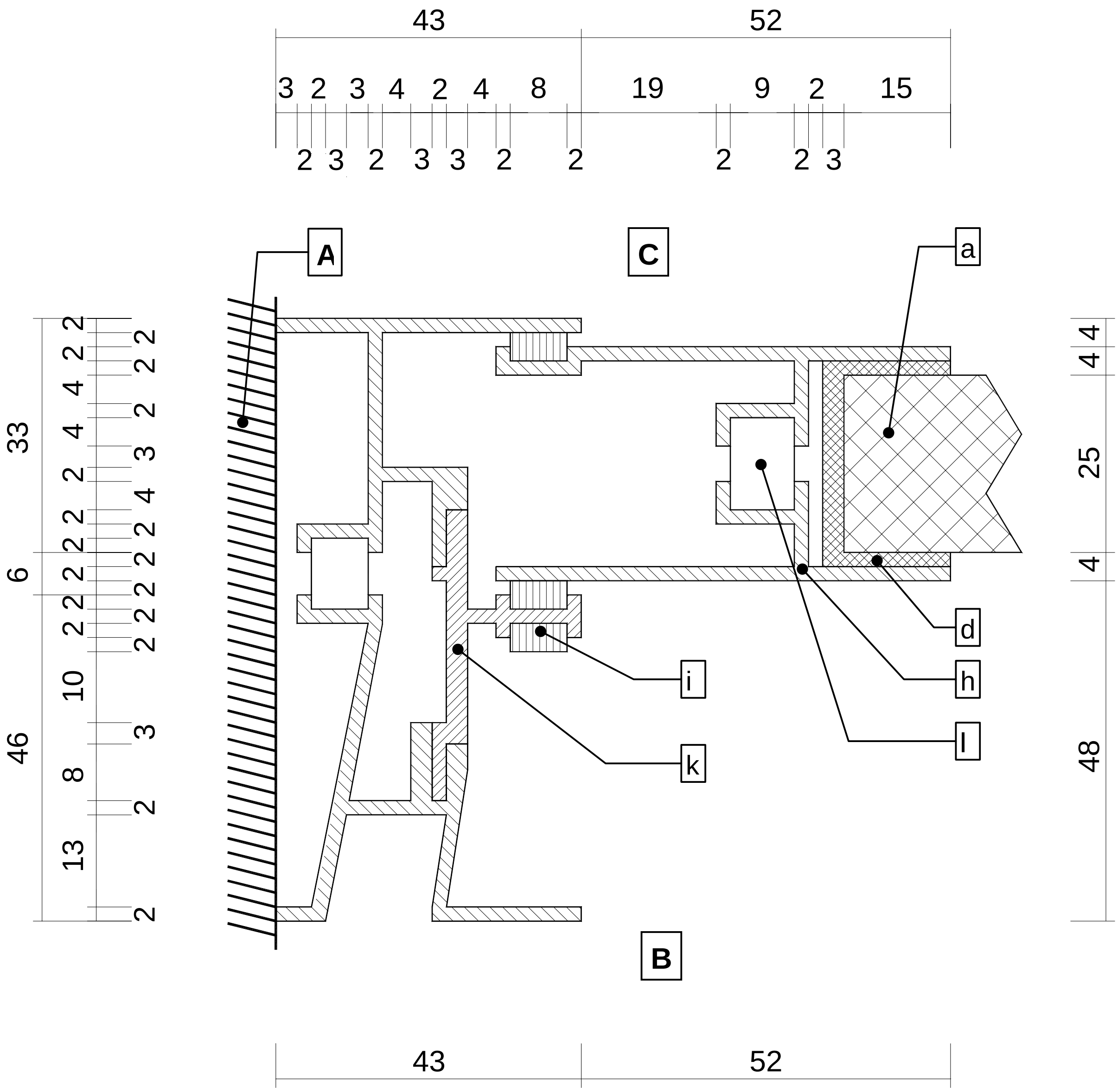


Figure D.6: Sliding window frame section and insulation panel (b_f = 95 mm)

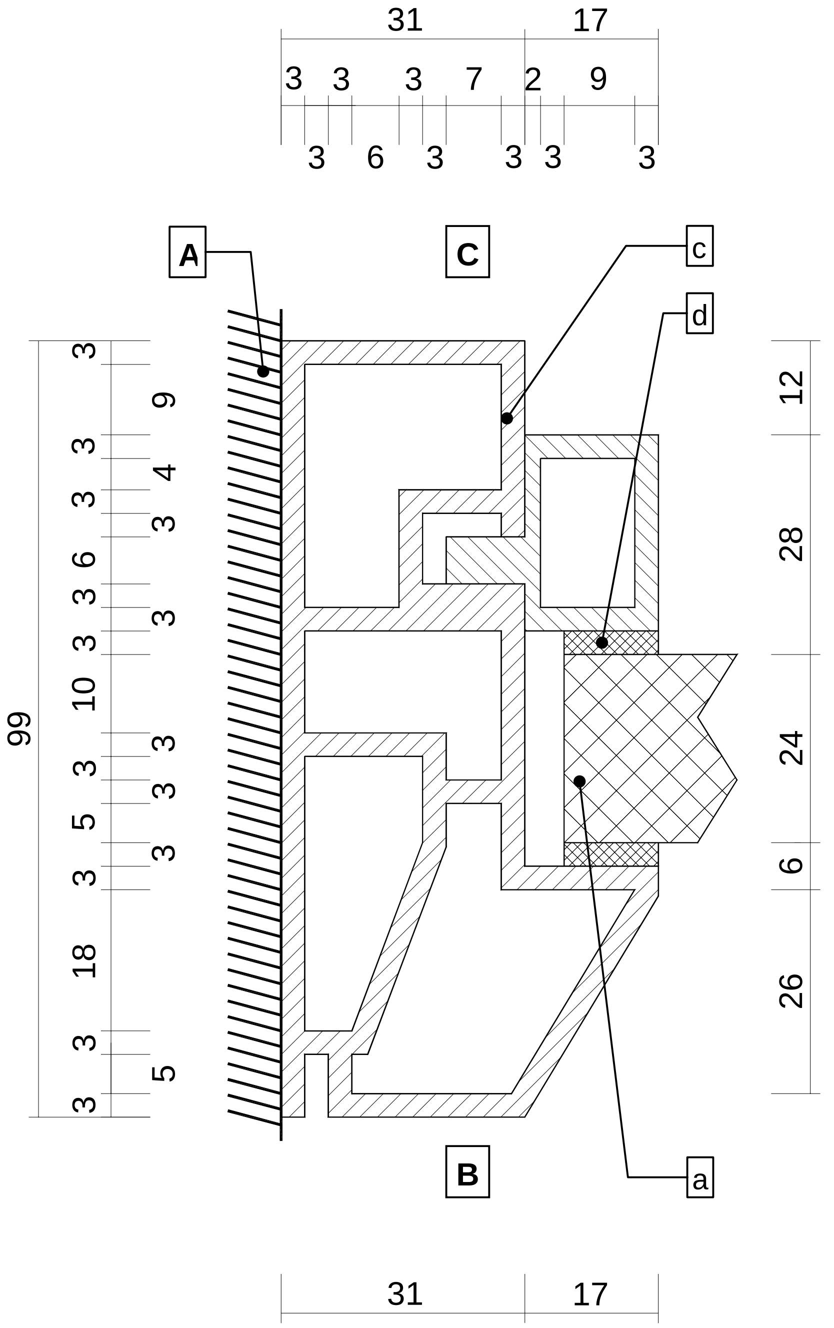


Figure D.7: Fixed frame section and insulation panel (b_f = 48 mm)

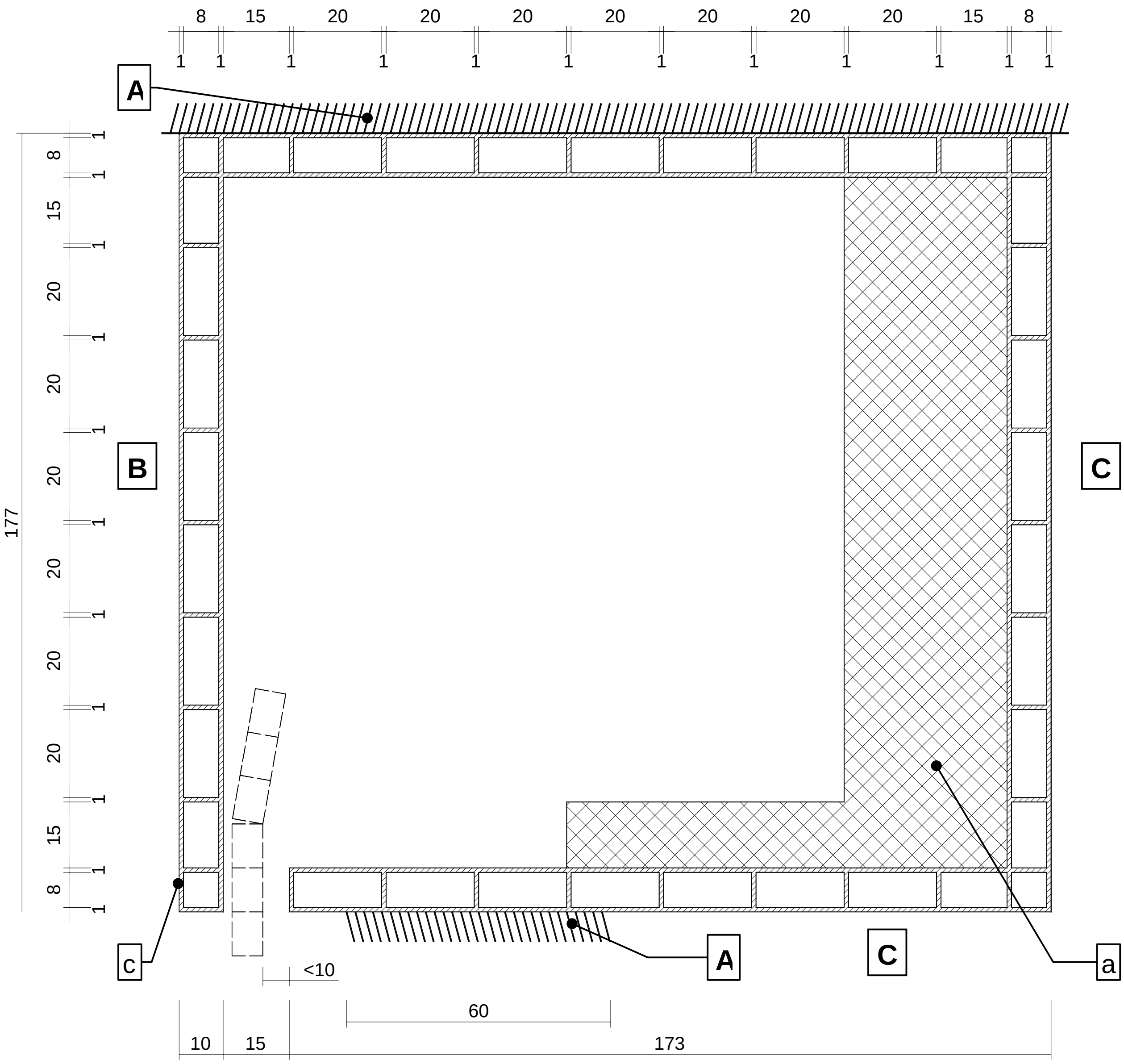


Figure D.8: Roller shutter box (b_{sb} = 177 mm)

Note: The shutter profile shall be ignored but will give a slit less the 10 mm. The U–value of the roller shutter box shall be calculated according $U_{sb} = L^{2D}/b_{sb}$.

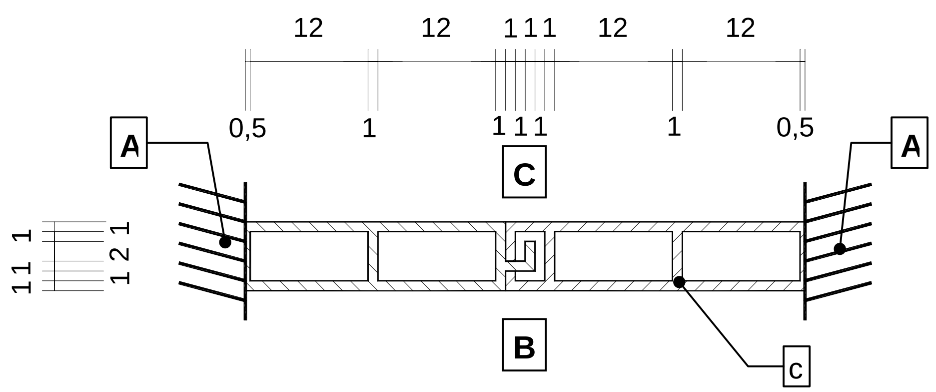


Figure D.9: PVC shutter profile (b = 57 mm)

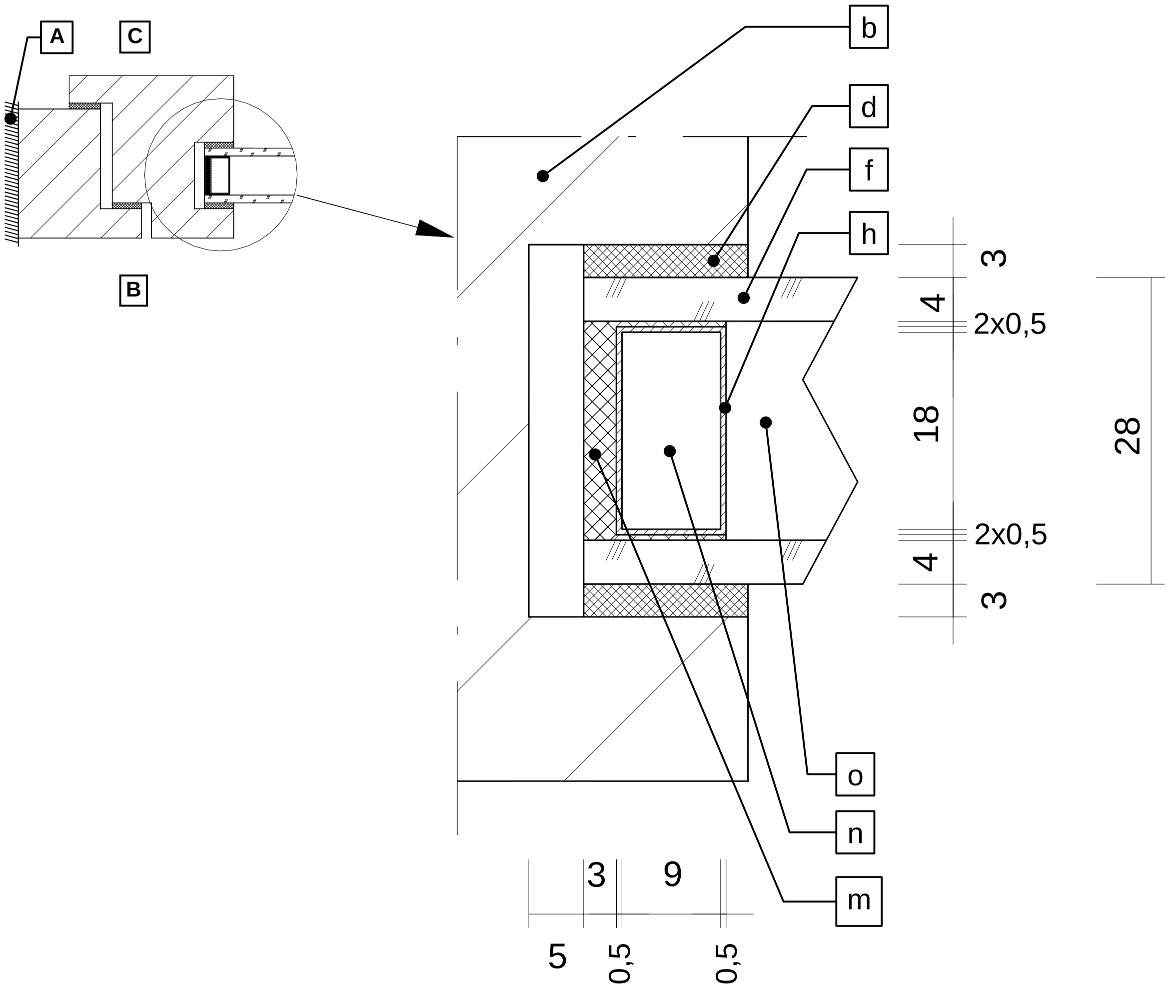


Figure D.10: Example for the determination of a linear thermal transmittance Wood frame section (see D.4) and glazing with U_g=1,3 W/(m²K) with a conventional glass edge system

Note: Material letter “o”:
To get a glass U-value of 1,3 W/(m²K) the space of the insulating glass unit is filled with a solid material with a conductivity of 0,034 W/(mK).

D.3 Results

Table D3 Calculated thermal conductivity L^{2D} and thermal transmittance
(To avoid rounding errors the values are given here to three figures)

Example	L^{2D} in W/(m·K)	U_f in W/(m²·K)
D.1	0,550 ±0,007	3,22 ±0,06
D.2	0,263 ±0,001	1,44 ±0,03
D.3	0,424 ±0,006	2,07 ±0,06
D.4	0,346 ±0,001	1,36 ±0,01
D.5	0,408 ±0,007	2,08 ±0,08
D.6	0,659 ±0,008	4,67 ±0,09
D.7	0,285 ±0,002	1,31 ±0,03
D.8	0,181 ±0,003	1,03 ±0,02
D.9	0,207 ±0,001	3,64 ±0,01

Table D4 Calculated thermal conductance L^{2D} and linear thermal transmittance

	L^{2D} in W/(m·K)	ψ in W/(m·K)
D.10	0,481 ±0,004	0,084 ±0,004

NOTE: The figures given in Table D3 and D4 are the mean and the standard deviation of a round robin calculation of nine institutions from Europe and North America (Jun 00)

Annex ZB (informative)

A-deviations

A-deviation: National deviation due to regulations, the alteration of which is for the time being outside the competence of the CEN/CENELEC member.

This European Standard does not fall under any Directive of the EC.

In the relevant CEN/CENELEC countries these A-deviations are valid instead of the provisions of the European Standard until they have been removed.

Clause	Deviation
6 and 7	**Germany:** Verordnung über einen energiesparenden Wärmeschutz bei Gebäuden (Wärmeschutzverordnung – WärmeschutzV) vom 16. August 1994. The German regulation specifies that the design thermal transmittance for glazing (k_V) and windows and window doors (k_F) shall be in accordance with table 3 of DIN 4108-4:1991-11. NOTE: In accordance with EN ISO 7345, the symbol k for thermal transmittance will be replaced with U in DIN V 4108-4:1998.