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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 encadrementes

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

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Foreword

This third edition cancels and replaces the second edition (ISO 10077-2:2012), clause 6, annex C and D have been technically revised and a new annex D is introduced. The necessary editorial revisions were made to comply with the requirements for the EPB set of standards.

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

…...

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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 Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, and by Technical Committee CEN/TC 89, *Thermal performance of buildings and building components* in collaboration.

This second/third/... edition cancels and replaces the first/second/... edition (EN ISO 10077-1:2006), [clause(s) / subclause(s) / table(s) / figure(s) / annex(es)] of which [has / have] been technically revised.

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

⎯ *Part 2: Numerical method for frames*

⎯ *Part [n]:*

⎯ *Part [n+1]:*

Introduction

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

As part of the "EPB set of standards" it complies with the requirements for the set of basic EPB documents (EN 15603 (see Normative references), CEN/TS 16628 and CEN/TS 16629 (see bibliography [1] and [2]) developed under a mandate given to CEN by the European Commission and the European Free Trade Association (Mandate M/480), and supports essential requirements of EU Directive 2010/31/EC on the energy performance of buildings (EPBD).

Where appropriate, the method(s) in each of the EPB standards may provide simplified procedures and/or default values as alternative options.

— Without further specification, these simplified procedures and/or default values may be used without restricting criteria.

NOTE 1   For instance because these are conservative procedures or values.

NOTE 2   The term 'default values' should not be confused with 'informative values'. If the values are given in the normative part of the standard, they are normative values. See also next options.

— In other cases, these simplified procedures and/or default values may be intended to be used only for situations where there is limited information. This may be the case in existing buildings with limited possibilities to acquire all input data. In particular when the EPB set of standards is used in the context of national or regional building regulations, specific criteria when the simplified method and/or default data are allowed, may be given at national or regional level, following the template in Annex A. Annex B provides (informative) default choices.

The set of EPB standards prepared under the responsibility of ISO/TC 163/SC 2 (Thermal performance and energy use in the built environment, Calculation methods) in collaboration with CEN/TC 89 range from calculation procedures on the overall energy use and energy performance of buildings, calculation procedures on the indoor temperature in buildings (e.g. in case of no space heating or cooling) and calculation methods covering the performance and thermal, hygrothermal, solar and visual characteristics of specific parts of the building and specific building elements and components, such as opaque envelope elements, ground floor, windows and facades. ISO/TC 163/SC 2 cooperates with other TC's for the details on e.g. appliances, technical building systems and indoor environment.

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 calculation method of the thermal transmittance of windows, doors and shutters given in Part 1 "General". It is an alternative to the test method specified in EN 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). For calculations made with the glazing units in place, the heat flow pattern and the temperature field within the frame are useful by-products of this calculation.

The standard does not cover building facades and curtain walling, for which see ISO 12631, *Thermal performance of curtain walling – Calculation of thermal transmittance* or ISO 12631, *Thermal performance of curtain walling – Calculation of thermal transmittance*.

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

1   Scope

This International 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 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).

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

This 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.

Figure 1 shows the relative position of this standard within the EPB package of standards.

Sub-module	Overarching Descriptions	Building (as such) Descriptions	Technical Building Systems Descriptions	Heating	Cooling	Ventilation	Humidification	Dehumidification	Domestic Hot water	Lighting	Building automation & control	PV, wind, ..
sub1	**M1**	**M2**		**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**
1	General	General	General									
2	Common terms and definitions; symbols, units and subscripts	Building Energy Needs	Needs									
3	Applications	(Free) Indoor Conditions without Systems	Maximum Load and Power									
4	Ways to Express Energy Performance	Ways to Express Energy Performance	Ways to Express Energy Performance									
5	Building Functions and Building Boundaries	Heat Transfer by Transmission	Emission & control									

6	Building Occupancy and Operating Conditions	Heat Transfer by Infiltration and Ventilation	Distribution & control									
7	Aggregation of Energy Services and Energy Carriers	Internal Heat Gains	Storage & control									
8	Building Partitioning	Solar Heat Gains	Generation & control									
9	Calculated Energy Performance	Building Dynamics (thermal mass)	Load dispatching and operating conditions									
10	Measured Energy Performance	Measured Energy Performance	Measured Energy Performance									
11	Inspection	Inspection	Inspection									
12	Ways to Express Indoor Comfort		BMS									
13	External Environment Conditions											
14	Economic Calculation											

Figure 1 — Position of this standard in the modular structure

2   Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6946, *Building components and building elements — Thermal resistance and thermal transmittance — Calculation method*

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

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

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

ISO 12567-2:2005, *Thermal performance of windows and doors — Determination of thermal transmittance by hot box method — Part 2: Roof windows and other projecting windows*

ISO 17025, *General requirements for the competence of testing and calibration laboratories*

EN 673, *Glass in building — Calculation of thermal transmittance (U-value) — Calculation Method*

EN 12519, *Windows and pedestrian doors — Terminology*

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

FprEN 15603:2014 , *Energy performance of buildings – Overarching standard EPB*

3   Terms and definitions

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

4   Symbols and abbreviations

4.1 Symbols

For the purposes of this Standard, the symbols given in prEN 15603:2013 and the specific symbols listed in Table 1 apply

Table 1 — Symbols and units

Symbol	Name of 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
C	constant in formula for Nusselt number	$W/(m^2 \cdot K^{4/3})$

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
Nu	Nusselt number	–
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	$W/(m \cdot K)$

4.2 Subscripts

For the purposes of this standard, the subscripts given in prEN 15603:2013 and the specific subscripts listed in Table 2 apply.

Table 2 — Subscripts

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

5   Calculation method

5.1 Output of the method

The possible outputs of this standard are the following:

— The thermal transmittance of a frame profile, U_f,

— The thermal transmittance of a shutter box, U_{sb}

— The linear thermal transmittance of a the junction of a frame profile with a glazing or opaque panel, Ψ

5.2 General principle

The calculation is carried out using a two-dimensional numerical method conforming to ISO 10211. The elements shall be 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.

Vertical orientation of frame sections and air cavities is assumed for calculations by this standard for the purposes of assigning equivalent thermal conductivity values (see 6.4.2.3); this applies irrespective of the intended orientation of the actual window, including roof windows.

5.3 Validation of the calculation programs

To ensure the suitability of the calculation program used, calculations shall be carried out on the examples described in Annexes G and H.

The requirements for all validation cases in Annexes G and H shall be fulfilled.

The calculated two-dimensional thermal conductance L^{2D} for the cases in Annex H shall not differ from the corresponding values given in Tables H.3 and H.4 by more than ± 3 %. This will lead to an accuracy of the thermal transmittance, U, and the linear thermal transmittance Ψ, of about 5 %.

6   Calculation of thermal transmittance

6.1 Output data

The outputs of this standard are transmission heat transfer coefficients.

Table 3 — Output data

Description	Symbol	Unit	Destination module	Validity interval	Varying
Thermal transmittance of frame profile	U_f	W/(m²K)	M2-2, M2-3, M2-4, M2-5	0…∞	NO
Thermal transmittance of shutter box	U_{sb}	W/(m²K)	M2-2, M2-3, M2-4, M2-5	0…∞	NO
Linear thermal transmittance	Ψ	W/(m K)	M2-2, M2-3, M2-4, M2-5	0…∞	NO

Kommentar [DvD1]: could be that there are min. requirements to U_frame

Kommentar [DvD2]: Actually I wonder if this output is not only used by M2-5, e.g. ISO 10077-1 and ISO 12631

6.2 Calculation time steps

The calculations described in this standard are steady-state and do not have time steps.

6.3 Input data

6.3.1 Geometrical characteristics

Table 4 – Identifiers for geometric characteristics

Name	Symbol	Unit	Range	Origin	Varying
Geometrical data					
Cross section of the frame profile				Manufacturer	NO
Cross section of the shutter box				Manufacturer	NO
Cross section of the junction frame profile and glazing				Manufacturer	NO
Cross section of the junction frame profile and panel				Manufacturer	NO

For frames with special extensions overlapping the wall or other building elements, such as a Z-shaped profiles, the extensions shall be disregarded as illustrated in Figure 2. This applies to all profiles with special extensions (e.g. H-shape) where the extensions overlap the wall or other building elements. Other boundaries shall be treated as defined in Figure 3.
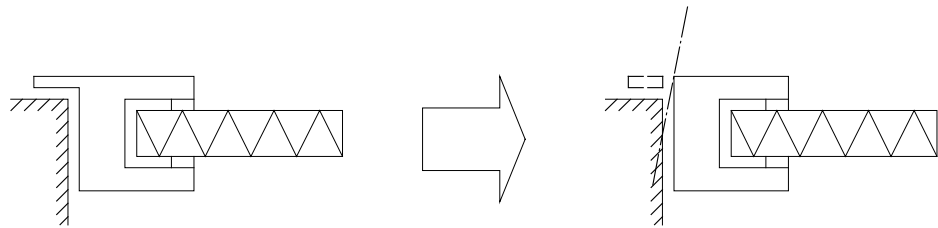
Figure 2 — Treatment of profiles with extensions (Z-shape)

NOTE 1   This approximation is for assessment of thermal transmittance. It is not appropriate for assessment of condensation risk.

NOTE 2   The extension of the frame profile is disregarded in the calculation of the thermal transmittance of the window (see ISO 10077-1).

6.3.2   Thermal conductivity values

For the purpose of this standard, thermal conductivity values used for solid materials shall be obtained according to one of the following:

⸺ Table D.1 of this standard;

⸺ tabulated values given in ISO 10456;

⸺ product standards;

— technical approvals by a recognized national body;

— measurements according to an appropriate international standard.

Measurements shall be used only if there is no tabulated data or data according to relevant product standards or a technical approval. Measurements shall be performed at a mean temperature of 10 °C using the appropriate method by an institute accredited (as specified in ISO 17025) to carry out those measurements, on samples that have been conditioned at 23 °C and 50% RH to constant mass (change in mass not more than 0,1 % over 24 h). To ensure that the thermal conductivity values are representative of the material (that is, that the value incorporates likely variability of the material and the measurement uncertainty), one of the following methods shall be used for obtaining the thermal conductivity value from measured data used in the calculations:

— The thermal conductivity is the declared value obtained from the measured data (at least three different samples from different lots representing the usual product variation, with ageing taken into consideration) according to a statistical evaluation as defined in ISO 10456 Annex C, 90 % fractile.

— If less than three samples, use the mean value multiplied by a factor of 1,25.

6.3.3 Emissivity of surfaces

Normally the emissivity of surfaces bounding an air cavity shall have an emissivity of 0,9. Metallic surfaces such as aluminium alloy frame, steel reinforcement and other metals/alloys have lower emissivity. Typical values of the emissivity for metallic surfaces are given in Table D.3. Values less than 0,9 may be used only if taken from Table A.3 or measured in accordance with an appropriate standard by an institute accredited (as specified in ISO 17025) to carry out those measurements. Where based on measured values there shall be at least three samples and the results shall be evaluated according to the statistical treatment in ISO 10456.

In this standard, it is assumed that the total hemispherical emissivity is equal to the normal emissivity.

6.3.4 General Boundaries

The external and internal surface resistances depend on the convective and radiative heat transfer to the external and internal environments. If an external surface is not exposed to normal wind conditions the convective part may be reduced in edges or junctions between two surfaces. The surface resistances for horizontal heat flow are given in Annex E. These values shall be used for calculations by this standard irrespective of the intended orientation of the actual window, including roof windows. Surface condensation shall be assessed on the basis of the lowest internal surface temperature calculated using the surface resistances in Annex B.

The cutting plane of the infill and the cutting plane to neighbouring material shall be taken as adiabatic (see Figure 4 and Annex H)

The reference temperature conditions shall be 20 °C internal and 0 °C external.

6.3.5 Boundaries for roller shutter boxes

Calculation of the thermal transmittance of a roller shutter box shall be done with the following boundary conditions:

— the top of the roller shutter box: adiabatic;

— at the bottom of the roller shutter box where it adjoins the window frame: adiabatic for a distance of 60 mm;

— surfaces adjacent to the internal environment: surface resistance of 0,13 m^2·K/W;

— surfaces adjacent to the external environment: surface resistance of 0,04 m^2·K/W

The cavity within the roller shutter box shall be treated as (see Figure 1):

— if $e_1 + e_3 \leq 2$ mm: unventilated, The equivalent thermal conductivity of an unventilated air cavity is calculated according to 6.4.2.3. Additional hardware like brushes, gaskets etc. can be taken into account for determination of e_1 and e_3;

— else if $e_{tot} \leq 35$ mm: slightly ventilated. The equivalent thermal conductivity is twice that of an unventilated cavity of the same size;

— if $e_{tot} > 35$ mm: well ventilated taking the air temperature within the cavity equal to the external air temperature but with a surface resistance of 0,13 m^2·K/W.

The relevant height of the roller shutter box, b_{sb}, used for the calculation is the projected distance between the upper and lower adiabatic boundary (see Figure 1).

The assessment may be done with insulation on either or both of the boundaries B and C indicated in Figure 3. If that is the case the thickness and thermal conductivity of the insulation shall be stated in the calculation report.

Dimensions in millimetres
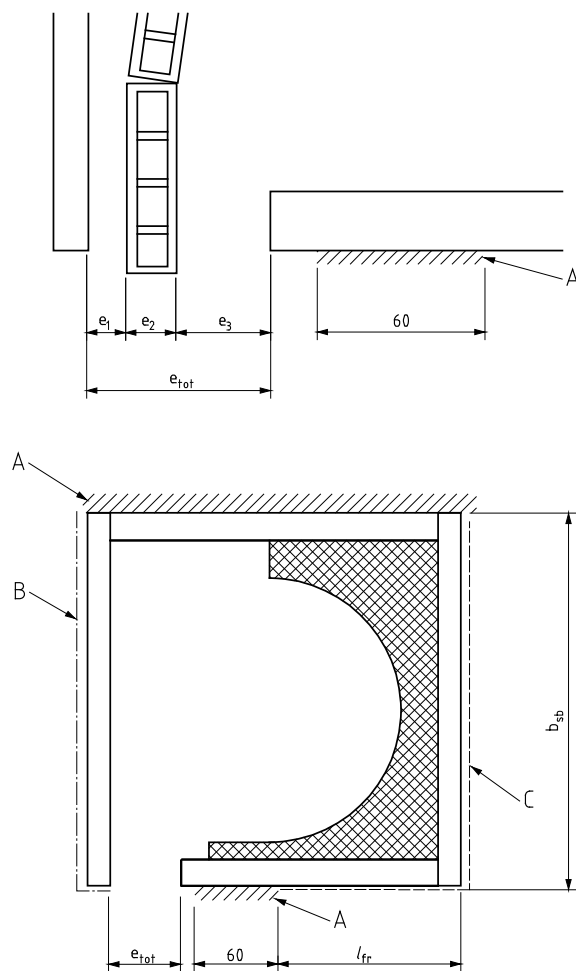
Key
Boundaries (see Annex B):
A   adiabatic boundary
B   external surface resistance
C   internal surface resistance

Note: The window frame (boundary A) is 60 mm wide but located with respect to the roller shutter box according to the actual situation.

Figure 3 — Schematic example for the treatment of the boundaries for roller shutter boxes

6.4 Calculation procedure

6.4.1 Determination of thermal transmittance

The thermal transmittance of a frame section 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. The linear thermal transmittance of the interaction of frame and glazing shall be determined from calculations with the glazing in place and with the glazing replaced by an insulated panel.

NOTE 1   The interaction of the frame and the building structure is considered separately for the building as a whole. It is not as part of the thermal transmittance of the frame section.

NOTE 2   In the case of an overlap between the frame section and part of the wall the linear thermal transmittance could be negative.

6.4.2   Treatment of cavities

6.4.2.1   General

Heat transfer through an air cavity occurs by either radiation and conduction (in case of still air) or by radiation and convecon (in case of moving air).

The conduction calculation is carried out using a two-dimensional numerical method conforming to ISO 10211.

The radiation calculation is carried out using a view factor based radiosity method as explained further in this section.

The convection calculation is carried out as a conduction calculation using an equivalent thermal conductivity for which formulae are given in this section.

6.4.2.2   Cavities in glazing

The equivalent thermal conductivity of an unventilated space between glass panes in glazing shall be determined according to 1) in Table C.1. The resulting equivalent conductivity shall be used in the whole cavity, up to the edge.

6.4.2.3   Unventilated air cavities in frames and roller shutter boxes

6.4.2.3.1   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 5); this applies irrespective of the orientation of the cavity with respect to heat flow direction. Otherwise the cavity shall be treated as ventilated or slightly ventilated (see 6.4.2.4).

Dimensions in millimetres
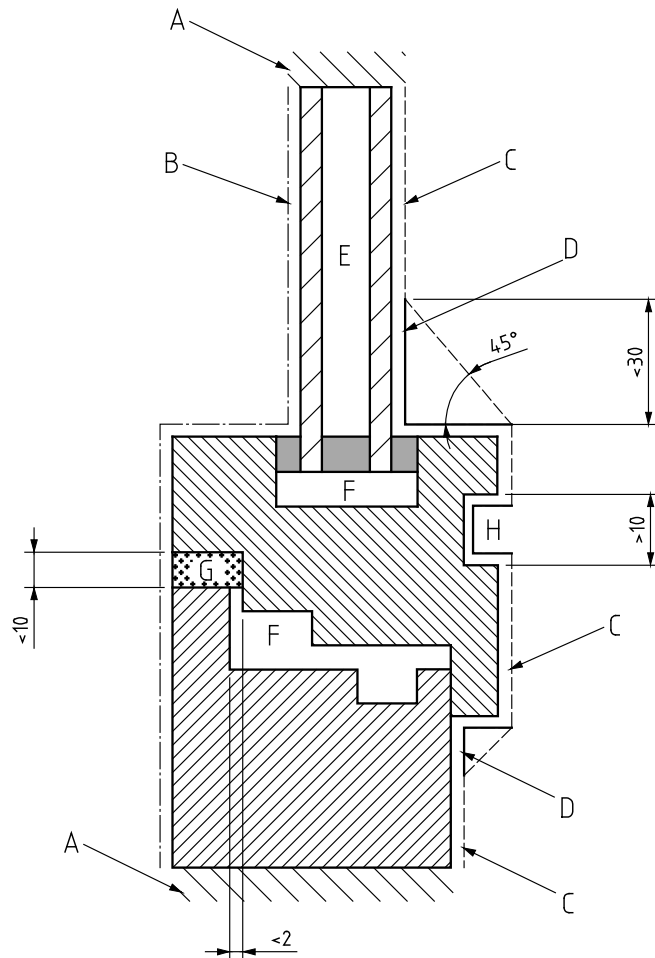
Key

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 6.4.2.2)
F   unventilated cavity (see 6.4.2.3)
G   slightly ventilated cavity or groove (see 6.4.2.4.1)
H   well ventilated cavity or groove (see 6.4.2.4.2)

Figure 4 — Schematic example for the treatment of cavities and grooves of a frame section and the treatment of the boundaries

NOTE   Figure 4 illustrates a window. The same principles are applicable to roof windows, but the adiabatic part of the boundary is different: an example of a roof window is shown in Figure H.6.

Cavities with one dimension not exceeding 2 mm or cavities with an interconnection not exceeding 2 mm shall be considered as separate, see Figure 5.
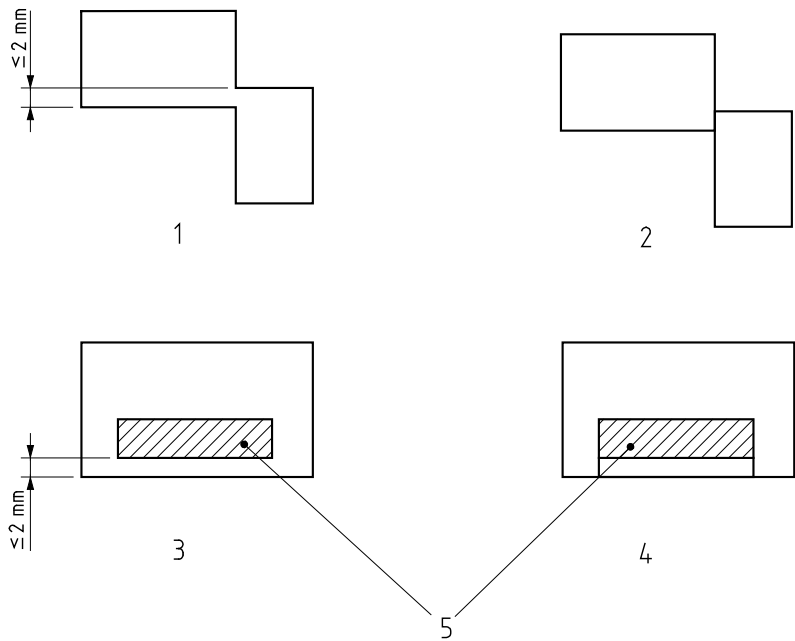
Key

1 Cavities connected by a section less than or equal to 2 mm
2 Cavities in 1 treated as separated cavities
3 Small cavity with a width less than or equal to 2 mm
4 Cavity in 3 treated as separated cavities
5 Solid material

Figure 5 — Division of cavity

6.4.2.3.2 Equivalent thermal conductivity of unventilated rectangular air cavities

In order to simulate convection (in the case of moving air) or conduction (in the case of still air) an equivalent thermal conductivity is used. Its value is given by Equation (1):

$$\lambda_{eq} = \lambda_{\text{air}}\, Nu \tag{1}$$

where

λ_{air} is the thermal conductivity of air = 0,025 W/(m·K);

Nu is the Nusselt number.

The Nusselt number is:

if b < 5 mm Nu = 1 $\tag{2}$

otherwise $\qquad Nu = \max\left[1 \ , \ \dfrac{d\,C\,\Delta T^{1/3}}{\lambda_{\text{air}}} \right]$ $\qquad\qquad$ (3)

where

$\quad d \quad$ is the depth of the cavity in the direction of heat flow, expressed in m;

$\quad C$ = 0,73 W/(m^2·K$^{4/3}$);

$\quad \Delta T \quad$ is the maximum surface temperature difference in the cavity, expressed in K.

As ΔT is initially unknown the calculation is iterative.

6.4.2.3.3   Cavity heat flow direction

The calculation of equivalent thermal conductivity for a cavity requires the determination of the heat flow direction.

The cavity heat flow direction for conduction or convection is a direction in the XY plane of the frame section corresponding to the main direction of the conductive heat flow in the cavity.

NOTE $\qquad$ "conductive heat flow" is used here to represent heat transfer by both conduction and convection.

From a known temperature distribution in the cavity as shown in Figure 6 the conductive heat flow direction equals the direction of the vector q_{m} calculated as

$$\overline{q}_{\text{m}} = \frac{\int_A \overline{q}\,dA}{A} \ = \ \frac{\int_A -\lambda'\,\mathbf{grad}\,\theta\,dA}{A} \qquad\qquad (4)$$

where

$\quad q_{\text{m}} \qquad$ is the mean heat flow density, expressed in W/m^2;

$\quad A \qquad\quad$ is the cross-sectional area of the cavity, expressed in m^2;

$\quad \lambda' \qquad\quad$ is the equivalent thermal conductivity of the cavity, expressed in W/(m·K);

$\quad \mathbf{grad}\,\theta \quad$ is the gradient of temperature, expressed in K/m.

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ **13**
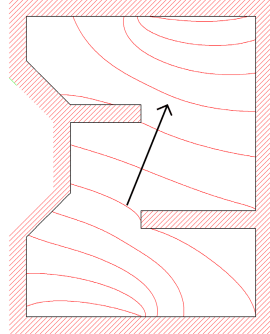
Figure 6 — Cavity conductive heat flow direction

As the temperature field is initially unknown whereas the calculation of the conductive heat flow direction requires a known temperature field, the calculation is iterative.

6.4.2.3.4   Unventilated non-rectangular air cavities

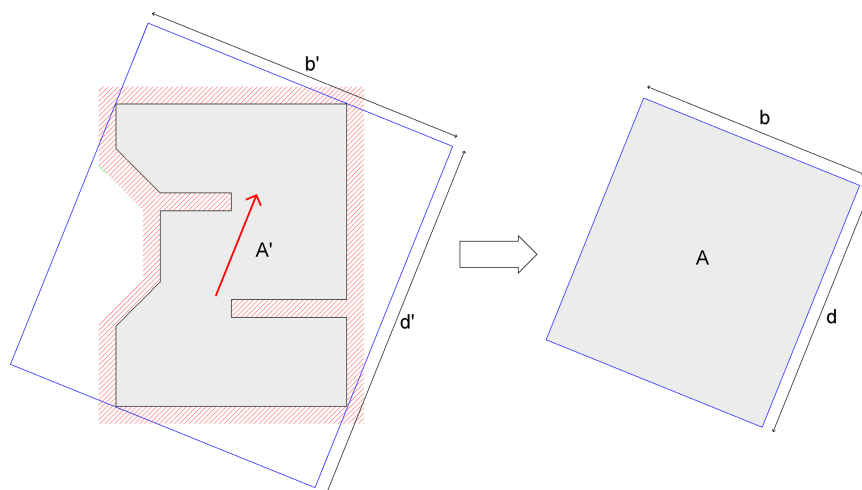Non-rectangular air cavities (T-shape, L-shape etc.) are transformed into rectangular air cavities with the same area ($A = A'$) and aspect ratio ($d/b = d'/b'$), see Figure 7.

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

The transformation is given by

$$b = \sqrt{A' \, \frac{b'}{d'}} \tag{5}$$

$$d = \sqrt{A' \, \frac{d'}{b'}} \tag{6}$$

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 circumscribing rectangle with d' parallel to the heat flow direction

Figure 7 — Transformation of non-rectangular air cavities

6.4.2.3.5   Radiative heat exchange

The radiative heat exchange between the elementary surfaces around the air cavity (resulting from the grid used by the numerical method) shall be calculated using the radiosity method. The radiosity method assumes isothermal elementary surfaces to be characterised by a uniform radiosity and irradiance. The surfaces are assumed to have opaque, diffuse and grey surface behaviour. The air within the cavity is taken to be non-participating (i.e. the gas does not absorb radiation).

Note 1   Definitions of the terms radiosity, irradiance, opaque, diffuse and grey are given in ISO 9288, *Thermal insulation – Heat transfer by radiation – Physical quantities and definitions*.

The radiative heat exchange according to the radiosity method can be represented by a thermal resistance network as shown in Figure 8.

Note 2   Only four elementary surfaces occur in the network shown. In real cavities multiple elementary surfaces will occur.
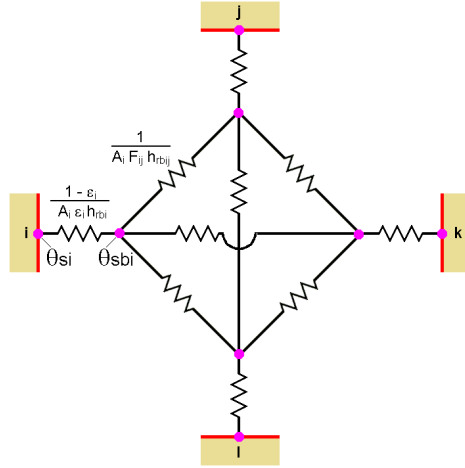
Figure 8 — Radiation thermal resistance network

The network is specified as follows:

— In the surface node i the temperature θ_{si} is applied.

— The node adjacent to the surface node i (so-called black surface node i) has temperature θ_{sbi}.

— The radiative heat flow between two black surface nodes i and j is

$$Q_{ij} = \frac{\theta_{sbi} - \theta_{sbj}}{R_{ij}} \tag{7}$$

$$R_{ij} = \frac{1}{A_i F_{ij} h_{rbij}} \tag{8}$$

$$h_{rbij} = \sigma \left(T_{sbi}^2 + T_{sbj}^2 \right)\left(T_{sbi} + T_{sbj} \right) \tag{9}$$

where

A_i is area of elementary surface i, expressed in m^2;

F_{ij} is the view factor from surface i to surface j ;

h_{rbij} is the black radiation heat transfer coefficient between surface node i and surface node j, expressed in $W/(m^2{\cdot}K)$;

σ is the Stefan-Boltzmann constant equal to $5{,}67 \times 10^{-8}$ $W/(m^2{\cdot}K^4)$;

T_{sbi} is absolute temperature of black surface node i, expressed in K;

T_{sbj} is absolute temperature of black surface node j, expressed in K;

— The radiative heat flow between a black surface node i and a surface node i is

$$Q_i = \frac{\theta_{\text{sb}i} - \theta_{\text{s}i}}{R_i} \tag{10}$$

$$R_i = \frac{1 - \varepsilon_i}{A_i \varepsilon_i h_{\text{rb}i}} \tag{11}$$

$$h_{\text{rb}i} = \sigma \left(T_{\text{sb}i}^2 + T_{\text{s}i}^2 \right) \left(T_{\text{sb}i} + T_{\text{s}i} \right) \tag{12}$$

where

A_i is the area of the elementary surface i, expressed in m2;

ε_i is the total hemispherical emissivity of surface i ;

$h_{\text{rb}i}$ is the black radiation heat transfer coefficient between surface node i and black surface node i, expressed in W/(m2·K);;

σ is the Stefan-Boltzmann constant equal to 5,67 x 10-8 W/(m2·K4);

$T_{\text{s}i}$ is the absolute temperature of surface node i, expressed in K;

$T_{\text{sb}j}$ is the absolute temperature of black surface node i, expressed in K.

The view factor between two infinitesimal surfaces dA_1 and dA_2 is defined as

$$F_{dA1 \to dA2} = \frac{\cos \varphi_1 \cos \varphi_2 \, dA_2}{\pi r^2} \tag{13}$$

where φ_1, φ_2 and r are defined in Figure 9.
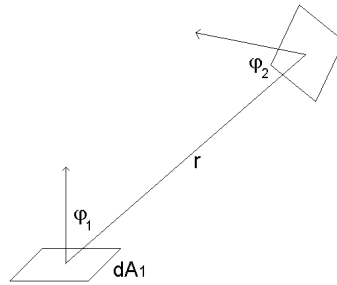

Figure 9 — Definition of the view factor between two infinitesimal surfaces

The view factor between A_1 and A_2 is obtained by integration:

$$F_{ij} = \frac{1}{A_i} \int_{A_i} \int_{A_j} \frac{\cos \varphi_i \cos \varphi_j}{\pi r^2} dA_i \, dA_j \tag{14}$$

As the network resistances depend on the node temperatures, the radiation exchange calculation is iterative.

Small openings can occur in the cavity surface (due to slits with a width not exceeding 2 mm, see 6.4.2.3.1). The small opening can be treated as a surface with zero emissivity.

Where a cavity has an adiabatic boundary, this boundary can be treated as a surface with zero emissivity.

6.4.2.4   Ventilated air cavities and grooves

6.4.2.4.1   Slightly ventilated cavities and grooves with small cross section

Grooves with small cross sections (see Figure 9) 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. In this case, it is assumed that the whole surface is exposed to the environment and a surface resistance R_s = 0,3 m^2·K/W shall be used at the developed surface, see Figure 10.
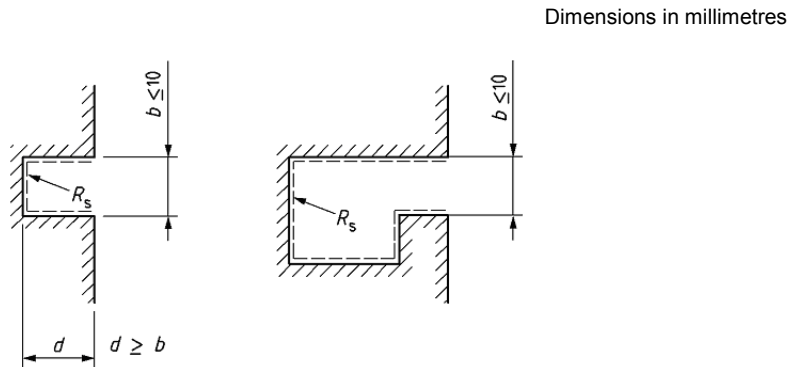
Dimensions in millimetres

Figure 10 — Examples for slightly ventilated cavities and grooves with small cross section

6.4.2.4.2   Well ventilated cavities and grooves with large cross section

In cases not covered by 6.4.2.3 and 6.4.2.4.1, 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 6.3.4 shall be used at the developed surface, see Figure 11.

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).
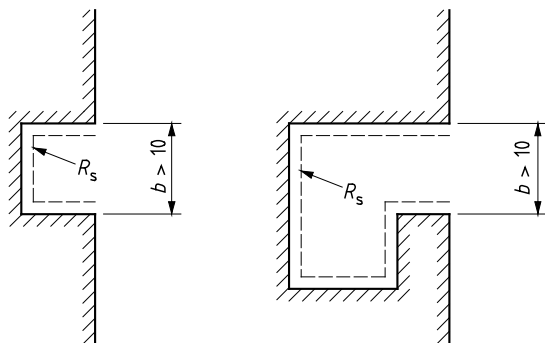
Dimensions in millimetres

Figure 11 — Examples for well ventilated cavities and grooves

7 Report

7.1 Contents of report

The calculation report shall include the following:

— reference to this part of ISO 10077;

— identification of the organization making the calculation;

— date of calculation;

— items listed in 7.2 and 7.3.

7.2 Geometrical data

A technical 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, preferably indicated on a scale drawing;

— the internal and external projected frame areas, preferably indicated on a scale drawing;

— the depth and the thickness of the glazing or panel in the frame;

— for a roller shutter box, the dimensions of the roller shutter box, the position of the window frame and the ventilation of the cavity (see 6.3.5).

7.3   Thermal data

7.3.1   Thermal conductivity

All materials of the frame section shall be listed together with the thermal conductivity values used for the calculation. The data given in Annex D should preferably be used. If other sources are used, this shall be clearly stated and reference made to the sources.

7.3.2   Emissivity

For cavities the emissivity of the surrounding surfaces shall be stated with reference to Table D.3 where appropriate, and supporting evidence, including references, shall be provided if values less than 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. In the case of a roller shutter box the location of any insulation applied to the surfaces of the roller shutter box shall be stated, together with its thickness and thermal conductivity.

7.4   Presentation of results

The total heat flow rate or the density of heat flow rate, the thermal transmittance of the frame section or the roller shutter box and the linear thermal transmittance according to Annex F shall be given to two significant figures (i.e. to one decimal place if greater than or equal to 1,0, to two decimal places if less than 1,0, and to three decimal places if less than 0,1).

Annex A
(normative)

Template for input data and choices

A.1 Introduction

For the correct use of this standard the template given in this Annex shall be used to specify the choices between methods and the required input data.

NOTE 1   Default choices are provided in the informative Annex B.

NOTE 2   Following this template is necessary but not enough to guarantee consistency of data.

In case the standard is used in the context of national or regional legal requirements, mandatory choices may be given at national or regional level for such specific applications.

NOTE 3   In particular for the application within the context of EU Directives transposed into national legal requirements. These choices (either the default choices from Annex B or choices adapted to national/regional needs), but in any case following the template of this Annex A) can be made available as National Annex or as separate (e.g. legal) document.

A.2 Calculation of thermal transmittance

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

Annex B
(informative)

Default input data and choices

B.1 Introduction

NOTE   See introduction to Annex A.

B.2 Calculation of thermal transmittance

NOTE   See Note in A.1.

Annex C
(normative)

Parallel routes in normative references

C.1 Introduction

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

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

In the case of EN ISO standards, where there is a difference between the ISO and the EN ISO version, the EN ISO version shall be used within the CEN area.

Table C.1 — Normative references

Reference	Subject	CEN area [a]	Elsewhere
1)	equivalent thermal conductivity glazing	EN 673	ISO 10292

[a] CEN area = Countries whose national standards body is a member of CEN. Attention is drawn to the need for observance of EU Directives transposed into national legal requirements. Existing national regulations with or without reference to national standards may restrict, for the time being, the implementation of European standards

Annex D
(normative)

Thermal conductivity and other characteristics of selected materials

Table D.1 includes the thermal conductivities of the materials used for the given groups. With a few exceptions the values were taken from ISO 10456, which also includes other materials.

Table D.1 — 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, [b] austenitic or austenitic-ferritic	7 900	17
	Stainless steel, [b] ferritic or martensitic	7 900	30
	PVC (polyvinylchloride), rigid	1 390	0,17
	Hardwood [c]	700	0,18
	Softwood [d]	500	0,13
	Softwood [d]	450	0,12
	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	ABS (acrylonitrile butadiene styrene)	1 050	0,20
	Polyamide (nylon)	1 150	0,25
	Polyamide 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-U (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
	Silicone, filled	1 450	0,50
	PVC, flexible (PVC-P) 40 % softener	1 200	0,14
	Pile weather stripping (polyester mohair) [*]		0,14
	Elastomeric foam, flexible	60 to 80	0,05

Table D.D.1 (concluded)

Group	Material [a]	Density kg/m³	Thermal conductivity W/(m·K)
Sealant and glass edge material	PU (polyurethane)	1 500	0,40
	Butyl rubber, solid/hot melt	1 200	0,24
	Polysulfide	1 700	0,40
	Silicone, pure	1 200	0,35
	Silicone, filled	1 450	0,40
	Polyisobutylene	930	0,20
	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 ISO 10456 except those marked with *

[b] EN 10088-1, *Stainless steels – Part 1: List of stainless steels*, contains extensive lists of properties of stainless steels which may be used when the precise composition of the stainless steel is known

[c] Hardwood: wood of trees of the botanical group Dicotyledonae (see also Table D.2)

[d] Softwood: wood of trees of the botanical group Gymnosperms (see also Table D.2)

For the application of this standard the thermal conductivity of timber can be taken from Table D.2 depending on the timber species.

Table D.2 — Thermal conductivity of timber species

Code for timber species [a]	Thermal conductivity, λ W/(m·K)
ABAL, PCAB, PCST, PNCN, THPL	0,11
KHXX, LADC, LAER, LAGM, LAOC, LAXX, PCGL, PHWS, PNSY, PSMN, SHLR, SWMC, TMIV, TSHT	0,13
ENCY, ENUT, EUXX, HEXM, HEXN, MIXX, OCRB, SHDR, TEGR, TGHC	0,16
AFXX, CLXX, EUGL, EUGR, EUSL, EUUG, EUUP, INXX, PHMG, PMPN, QCXA, QCXE, ROPS	0,18

[a] Annex E contains the list of wood species designated by these codes

For the application of this standard the emissivity of metallic surfaces can be taken from Table D.3 depending on the treatment of the surface.

Table D.3 — Typical emissivities of metallic surfaces

Description	Normal emissivity
untreated aluminium surfaces	0,1
slightly oxidized aluminium surfaces (up to 5 µm)	0,3
metallic surfaces (general, including galvanized)	0,3
anodized, painted or powder coated surfaces	0,9
NOTE An untreated surface is one that has had no artificial treatment (such as anodising, galvanising, painting).	

Annex E
(normative)

Surface resistances

Table E.1 — Surface resistances for profiles (horizontal heat flow)

Position	External, R_{se} m²·K/W	Internal, R_{si} m²·K/W
Normal (plane surface)	0,04	0,13
Reduced radiation/convection (in edges or junctions between two surfaces, see Figure E.1)	0,04	0,20
NOTE These values correspond to the surface resistance values given in ISO 6946, which also gives further information about the influence of convection and radiation on surface resistances.		

Where simulation software requires inclined surfaces to be represented by orthogonal meshing the surface resistance may corrected by multiplying by the ratio of the actual surface length to the length as represented in the simulation model.
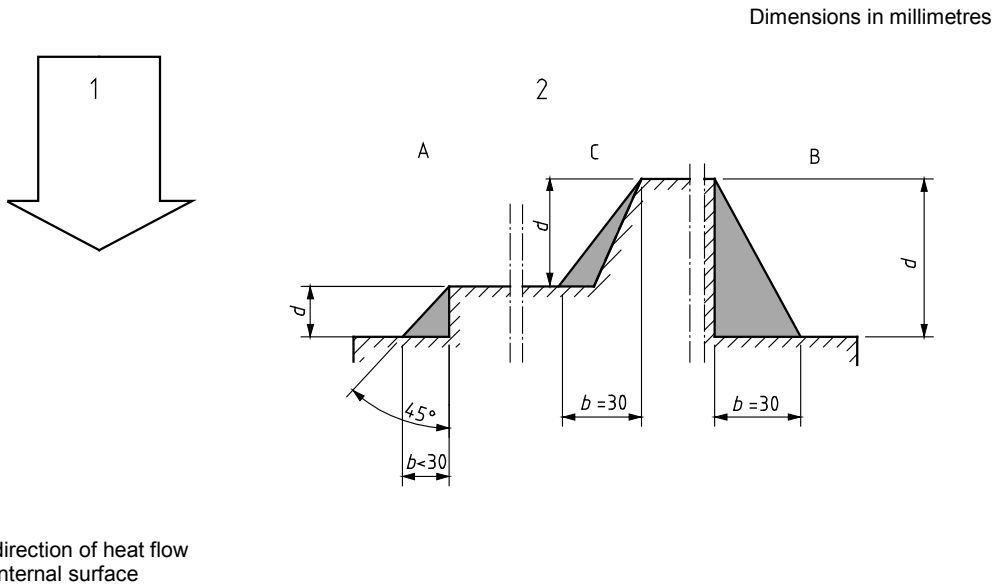
Dimensions in millimetres

Key
1   direction of heat flow
2   internal surface

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

In Figure E.1 the shading indicates the distances over which increased surface resistances apply. These are 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: For application to a sloped surface, $b = 30$ mm when $d > 30$ mm.

Table E.2 — Surface resistances for calculation of roller shutter boxes

Heat flow direction	External, R_{se} m²·K/W	Internal, R_{si} m²·K/W
Horizontal	0,04	0,13
Vertical	0,04	0,13
NOTE The value for the internal surface resistance for vertical heat flow takes into account the effect of heat flow in upward direction and also the effect of reduced radiation/convection.		

Annex F
(normative)

Determination of the thermal transmittance

F.1 Thermal transmittance of the frame section

The thermal transmittance of the frame section, U_f, is defined as follows. With reference to Figure F.1, 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. The overlap b_2 is equal to that of the glazing which the insulation panel replaces. The length of the panel shall be at least 190 mm measured from the most protruding part of the frame ignoring any protruding gasket(s). For protruding gaskets this means that the visible panel length could be less than 190 mm. 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. The thickness d of the insulation panel shall be:

— where the frame is designed for a specific thickness, that of the glazing or opaque panel being replaced;

— where the frame can be used with several glazing thicknesses, 24 mm for double glazing or 36 mm for triple glazing.
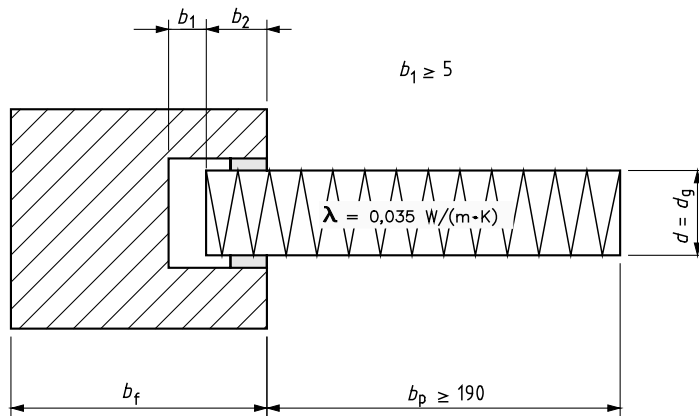
Dimensions in millimetres

Figure F.1 — Schematic of profile section with insulation panel installed

NOTE   Figures H.1 to H.8 illustrate some typical window profiles, indicating the boundary conditions for the numerical calculations.

In the case of a roof window the adiabatic parts of the boundary are those where the frame of the roof window is in contact with the roof, when the roof window is installed according to the manufacturer's instructions. If the method of installation of the roof window cannot be determined from the manufacturer's installation instructions, it shall modelled as depicted in Figure 2 of ISO 12567-2:2005.

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

$$U_f = \frac{L_f^{2D} - U_p \, b_p}{b_f}$$

(F.1)

where

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

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

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

b_f is the projected width of the frame section (without protruding gaskets), expressed in m;

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

b_f is the larger of the projected widths are seen from both sides. b_p is measured on the same side as b_f.

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 ISO 10211).

F.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 F.2). The value of the linear thermal transmittance, Ψ, is defined by Equation (F.2).

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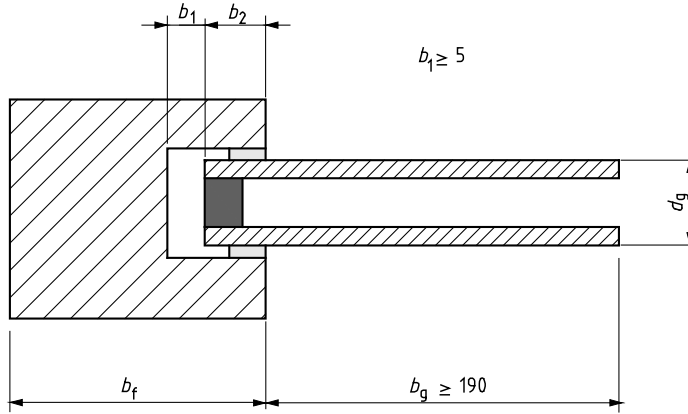
Dimensions in millimetres

Figure F.2 — Schematic of profile section with glazing installed

$$\Psi = L_\Psi^{2D} - U_f\, b_f - U_g\, b_g \tag{F.2}$$

where

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

L_Ψ^{2D} is thermal conductance of the section shown in Figure F-.2, expressed in W/(m·K);

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

U_g is the thermal transmittance of the central area of the glazing, expressed in W/(m²·K);

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

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

b_f is the larger of the projected widths are seen from both sides. b_g is measured on the same side as b_f.

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 ISO 10211).

To calculate Ψ-values for the combination of frame constructions with insulating glazing units (IGU) including metallic spacers when there is no detailed information about the geometry of the metal spacer, the following spacer shall be used,

The depth of the spacer d is the width of the cavity of the IGU reduced by 0,5 mm. This is because of a thickness of 0,25 mm of the inner sealant (butyl rubber) on either size of the spacer. For example if the width of the cavity in the IGU is 16 mm, the depth d of the spacer is 15,5 mm. The general geometry of the spacer and the integration in the IGU is shown in Figure F.3. If no other information is available the outer sealant should be polysulfide of thickness 3 mm.
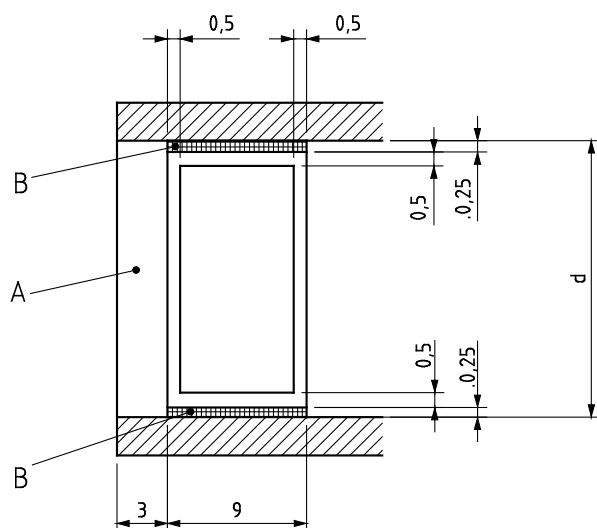
Key
A   polysulfide
B   butylene

Figure F.3 — Representative metal spacer incorporated in an IGU

Representative Ψ-values of thermally improved spacers can be established on the basis of representative profile sections and representative glass units. A detailed procedure is given in Bibliography [5].

Annex G
(normative)

General examples for the validation of calculation programs
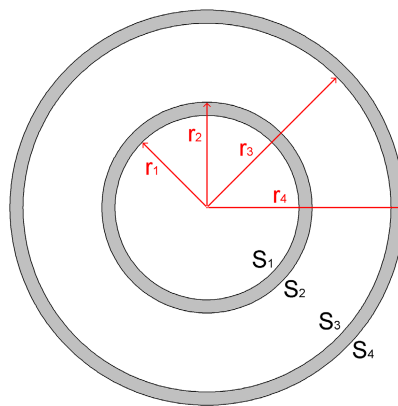
G.1 Concentric cylinders

Figure G.1 – Vacuum cavity between two concentric cylinders

Figure G.1 shows two concentric cylinders with a vacuum between them. The dimensions are given in Table G.1.

The cylinders are perfect conductors ($\lambda \approx \infty$).

At the inner surface of the smaller cylinder (S_1) and at the outer surface of the larger cylinder (S_4) the surface temperatures specified in Table G.2 are applied.

The heat transfer between the outer surface of the smaller cylinder (S_2) and the inner surface of the larger cylinder (S_3) occurs by radiation only. The radiation heat flow is to be calculated by the calculation program for four variants of the surface emissivities of the surfaces S_2 and S_3 as given in Table G.3.

The difference (in relative terms) between the radiation heat flow from the calculation program to be validated and the analytically calculated radiation heat flow listed in Table G.4 shall be less than 0,5 %.

Table G.1 – Dimensions of cylinders

Key (Figure G.1)	Radius m
r_1	0,07
r_2	0,08
r_3	0,14
r_4	0,15

Table G.2 – Known surface temperatures

Surface	Temperature °C
S_1	20
S_4	0

Table G.3 – Surface emissivities

Variant	Emissivity of surface S_2	Emissivity of surface S_3
A	0,9	0,9
B	0,1	0,9
C	0,9	0,1
D	0,1	0,1

Table G.4 – Radiation heat flow from surface S_2 to surface S_3

Variant	Radiation heat flow W/m
A	44,12
B	5,15
C	8,29
D	3,42

G.2 Vacuum within a square cavity
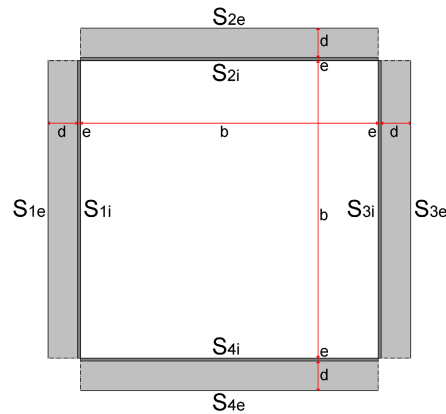
Figure G.2 – vacuum cavity surrounded by four walls

A vacuum cavity is surrounded by four walls. Dimensions are given in Table G.5.

Each wall has two layers. The thicker layer material (with thickness d) has a thermal conductivity of 1 W/(m·K). The thinner layer material (with thickness e) is a perfect conductor ($\lambda \approx \infty$). The emissivity of the thinner layer surface is 0,9. There is no thermal contact between the four thinner layers.

At the external wall surfaces known environmental temperatures and surface heat transfer are applied as listed in Table G.6.

The heat exchange between the internal wall surfaces (S_{1i}, S_{2i}, S_{3i}, S_{4i}) occurs by radiation only.

The temperature distribution is to be calculated by the calculation program being validated. The difference between the central internal surface temperatures and the analytically calculated surface temperatures listed in Table G.7 shall be less than 0,2 °C.

Table G.5 – Dimensions

Key (Figure G.2)	Thickness m
d	0,10
e	0,01
b	1,00

Table G.6 – External wall surface boundary conditions

Surface	Temperature °C	Surface resistance m²·K/W
S_{1e}	0	0,1
S_{2e}	5	0,1
S_{3e}	10	0,1
S_{4e}	20	0,1

Table G.7 – Internal surface temperatures

Surface	Temperature °C
S_{1i}	4,67
S_{2i}	7,25
S_{3i}	9,18
S_{4i}	13,89

G.3 Half square column with specified surface temperatures

Analytical solution at grid nodes (°C)			
9,7	13,4	14,7	15,1
5,3	8,6	10,3	10,8
3,2	5,6	7,0	7,5
2,0	3,6	4,7	5,0
1,3	2,3	3,0	3,2
0,7	1,4	1,8	1,9
0,3	0,6	0,8	0,9

BC = 2 × AB
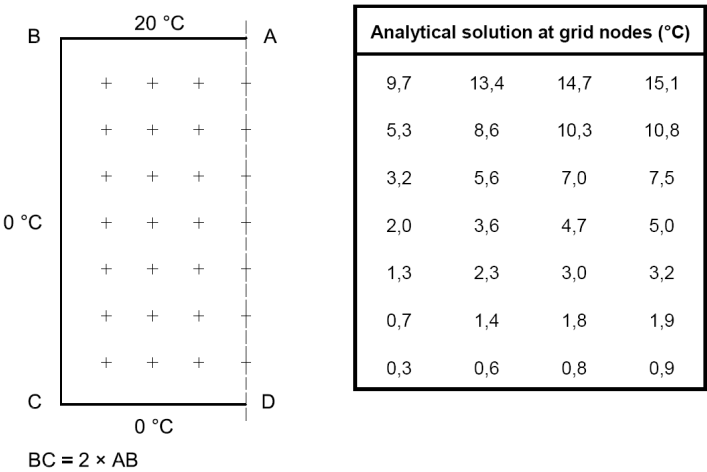
Figure G.3 – Half square column with known surface temperatures: data

The heat transfer through half a square column with known surface temperatures (Figure G.3) can be calculated analytically. The analytical solution at 28 points of an equidistant grid is given in the same figure. The difference between the temperatures calculated by the calculation program being validated and the temperatures listed shall not exceed 0,1 °C.
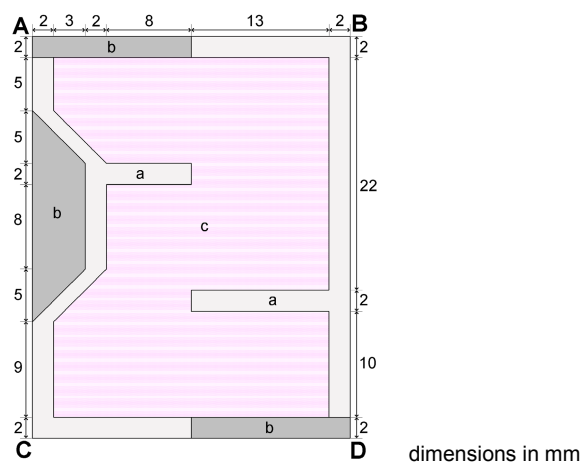
G.4 Air cavity

Figure G.4 – Air cavity surrounded by two materials

An air cavity (c) is surrounded by two materials (a and b), as shown in Figure G.4.

The thermal conductivity of material a is 0,3 W/(m·K). The thermal conductivity of material b is 0,001 W/(m·K). All material surfaces have emissivity 0,9.

Adjacent to surface AB there is an environment with temperature 20 °C and surface resistance 0,13 m^2·K/W.

Adjacent to surface CD there is environment with temperature 0 °C and surface resistance 0,04 m^2·K/W.

AC and BD are adiabatic boundaries.

The heat transfer through the materials and the cavity is by conduction, convection and radiation.

The difference (in relative terms) between the total heat flow from the calculation program being validated and that listed in Table G.8 shall be less than 2 %.

The cavity equivalent conduction direction, relative to the direction up the page and positive in clockwise direction, and the cavity equivalent conductivity are given in Table G.8 for information only.

Table G.8 – Calculated results

Cavity equivalent conduction direction	21,8°
Cavity equivalent conductivity	0,048 W/(m·K)
Total heat flow	0,826 W/K

Annex H
(normative)

Examples of window frames for the validation of calculation programs

H.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 H.1 to H.11 shall lead to results for L^{2D} differing by no more than 3 % from those given in Tables H.3 and H.4.

H.2 Figures

In Figures H.1 to H.11 the key shown in Tables H.1 and H.2 applies.

Table H.1 — Boundaries

Key	Surface resistance, R_s m²·K/W	Temperature, θ °C
A adiabatic	infinity	–
B external	see Annex B	0
C internal	see Annex B	20

Table H.2 — Materials

Key	Material	Thermal conductivity, λ W/(m·K)
a	insulation panel	0,035
b	soft wood	0,13
c	PVC	0,17
d	EPDM	0,25
e	polyamide 6.6 with 25 % glass fibre	0,3
f	glass	1,0
g	steel	50
h	aluminium [a]	160
i	pile weather stripping (polyester mohair)	0,14
k	polyamide	0,25
l	PU (polyurethane), rigid	0,25
m	polysulfide	0,40
n	silica gel (desiccant)	0,13

Key	Material	Thermal conductivity, λ W/(m·K)
o	gas filling	0,034 [b]

[a] All surfaces have emissivity 0,9 except for case H.2.

[b] Equivalent thermal conductivity of the gas filling.
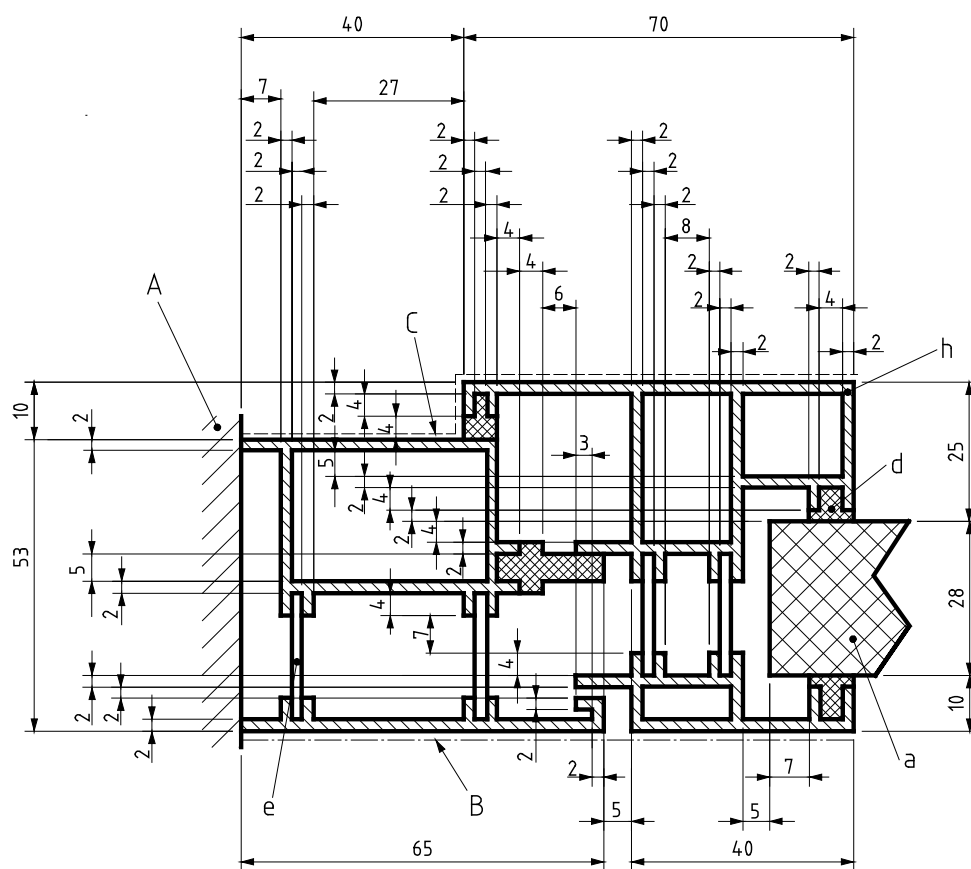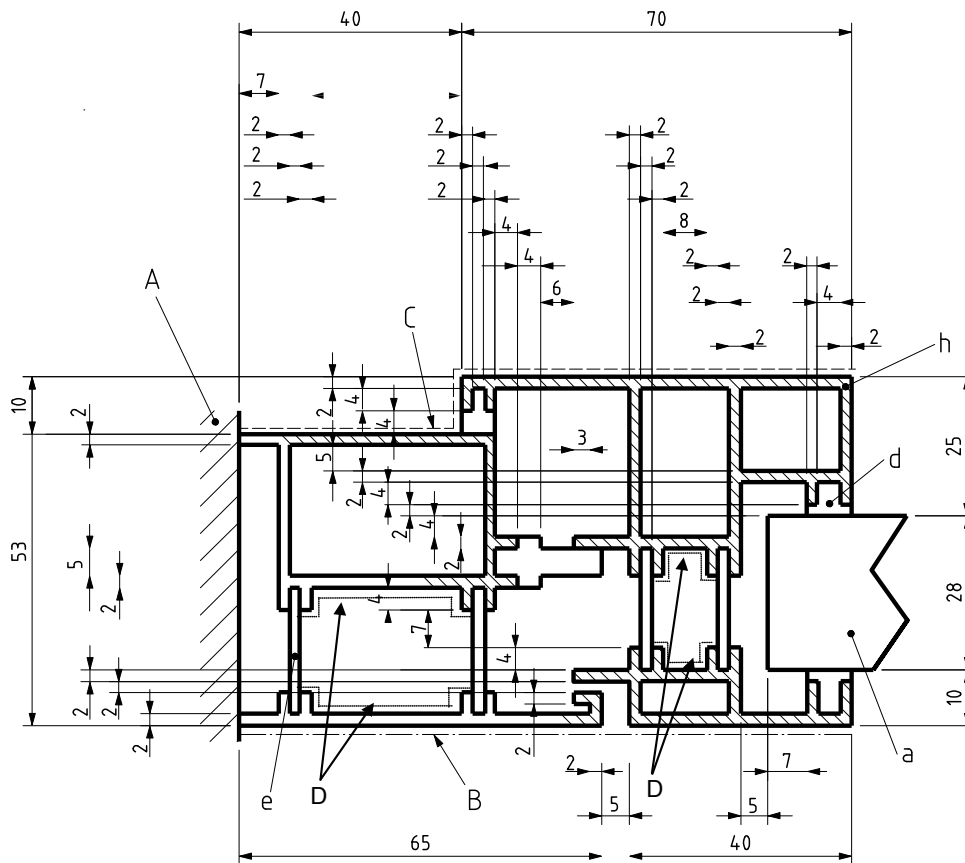
Dimensions in millimetres

Figure H.1 — Aluminium frame section with thermal break and insulation panel (b_f = 110 mm) (emissivity of all surfaces equal to 0,9)

Key
D   emissivity 0,1

Figure H.2 — Aluminium frame section with thermal break and insulation panel (b_f = 110 mm) (emissivity of specified surfaces equal to 0,1; others 0,9)

Dimensions in millimetres

Figure H.3 — Aluminium clad wood frame section and insulation panel (b_f = 110 mm)

Dimensions in millimetres
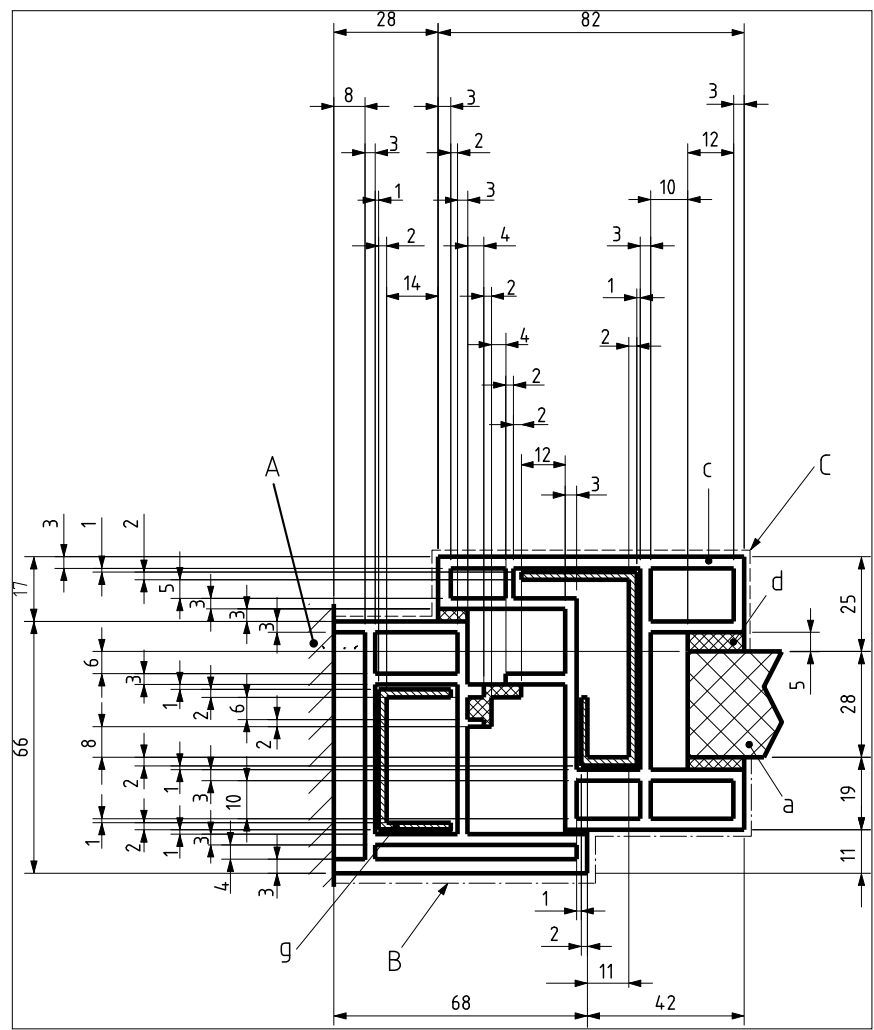
Figure H.4 — PVC-frame section with steel reinforcement and insulation panel (b_f = 110 mm)

Dimensions in millimetres

Figure H.5 — Wood frame section and insulation panel (b_f = 110 mm)
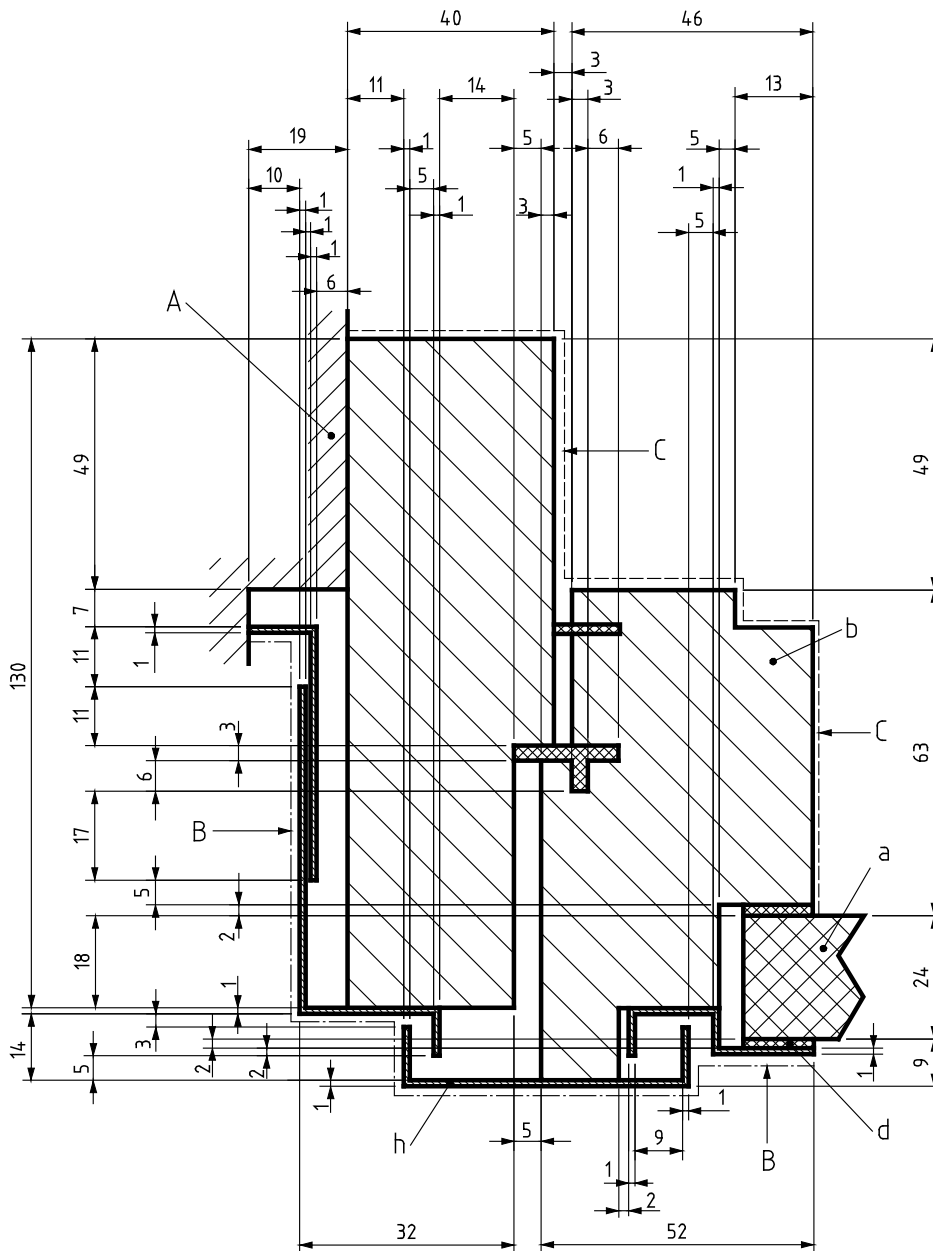
Dimensions in millimetres

Figure H.6 — Roof window frame section and insulation panel

Dimensions in millimetres
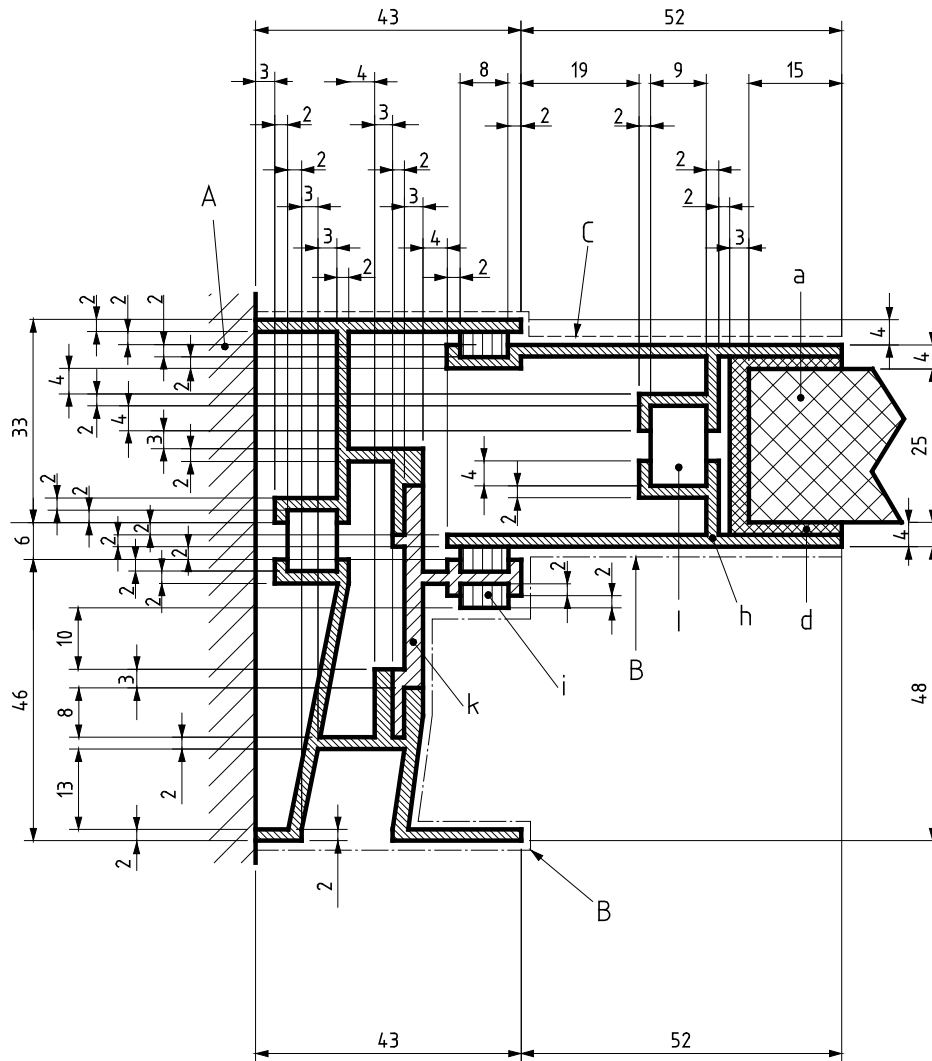
Figure H.7 — Sliding window frame section and insulation panel (b_f = 95 mm)

Figure H.8 — Fixed frame section and insulation panel (b_f = 48 mm)

Dimensions in millimetres

Figure H.9 — Roller shutter box (b_{sb} = 177 mm)

Dimensions in millimetres

Figure H.10 — PVC shutter profile (b = 57 mm)

Dimensions in millimetres
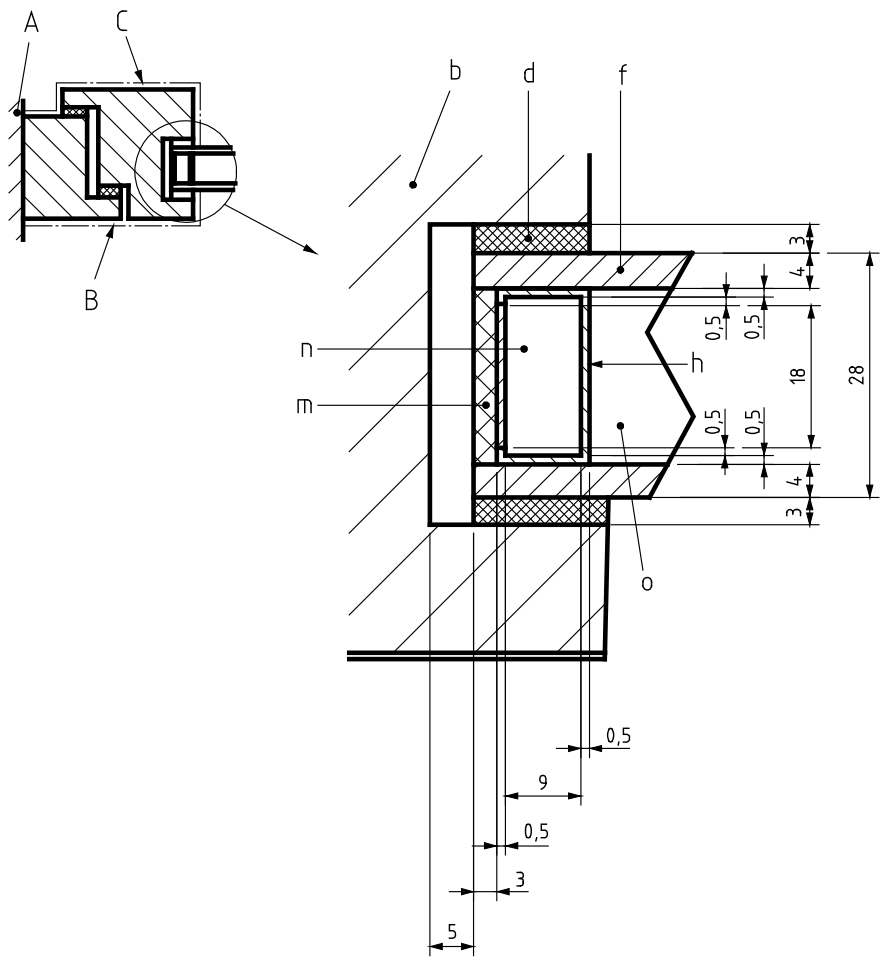
Figure H.11 — Example for the determination of a linear thermal transmittance of a wood frame section (see Figure H.5) and of a glazing with U_g = 1,3 W/(m²·K) with a conventional glass edge system

To achieve a thermal transmittance of the insulating glass unit, U_g, of 1,3 W/(m²·K), the space of the insulating glass unit is filled with a solid material, marked "o", with a thermal conductivity of 0,034 W/(m·K).

H.3 Results

Table H.3 — Calculated thermal conductance L^{2D} and thermal transmittance

Example	L^{2D} W/(m·K)	U_f W/(m²·K)

Figure H.1	0,539	3,11
Figure H.2	0,508	2,83
Figure H.3	0,252	1,35
Figure H.4	0,400	1,86
Figure H.5	0,344	1,34
Figure H.6	0,407	2,07
Figure H.7	0,637	4,44
Figure H.8	0,281	1,23
Figure H.9	0,188	1,06
Figure H.10	0,208	3,64
NOTE To avoid rounding errors the values are given to three significant figures.		

Table H.4 — Calculated thermal conductance L_{Ψ}^{2D} and linear thermal transmittance

Example	L_{Ψ}^{2D} W/(m·K)	Ψ W/(m·K)
Figure H.11	0,478	0,083

Annex I
(normative)

Wood species listed in Annex A

Annexe I
(normative)

Espèces de bois énumérées dans l'Annexe A

Anhang I
(normative)

In Anhang A aufgeführten Holzarten

Botanical name Dénomination botanique Botanischer Name	Code Code Kurzzeichen	English name	Dénomination française	Deutscher Name
Abies alba	ABAL	silver fir	sapin blanc	Tanne, Weißtanne
Afzelia spp.	AFXX	afzelia	doussié	Afzelia
Calophyllum spp.	CLXX	bintangor	bintangor	Bintangor
Entandrophragma cylindricum	ENCY	sapele	sapelli	Sapelli
Entandrophragma utile	ENUT	utile	sipo	Sipo
Eucalyptus delegatensis *Eucalyptus obliqua* *Eucalyptus regnans*	EUXX	"Tasmanian oak"	« chêne de Tasmanie »	„Tasmanian oak"
Eucalyptus globulus	EUGL	southern blue gum	eucalyptus bleu	Blue gum, Globulus
Eucalyptus saligna *Eucalyptus grandis* *Eucalyptus urophylla* *Eucalyptus uro-grandis*	EUSL EUGR EUUP EUUG	saligna gum eucalyptus	eucalyptus saligna eucalyptus	Sidney blue gum Eukalyptus
Heritiera spp.	HEXM	mengkulang	mengkulang	Mengkulang
Heritiera utilis *Heritiera densiflora*	HEXN	niangon	niangon	Niangon
Intsia bijuga *Intsia palembanica*	INXX	merbau	merbau	Merbau
Khaya spp.	KHXX	African mahogany	Acajou d'afrique	Khaya (Mahagoni)
Larix spp. *Larix decidua* *Larix x eurolepis* *Larix gmelina* *Larix oocarpa*	LAXX LADC LAER LAGM LAOC	Larch European larch Dunkeld larch Siberian larch Western larch	mélèze mélèze d'Europe mélèze de Dunkeld mélèze de Sibérie western larch	Lärche Lärche Dunkeld-Lärche Sibirische Lärche Kanadische Lärche
Milicia excelsa *Milicia regia*	MIXX	iroko	iroko	Iroko, Kambala
Ocotea rubra	OCRB	red louro	louro vermelho	Louro vermelho

Botanical name / Dénomination botanique / Botanischer Name	Code / Code / Kurzzeichen	English name	Dénomination française	Deutscher Name
Picea abies	PCAB	Norway spruce	épicéa	Fichte
Picea glauca	PCGL	white spruce	eastern spruce	Western white spruce, Weißfichte
Picea sitchensis	PCST	Sitka spruce	Sitka spruce	Sitka spruce, Sitkafichte
Parashorea spp.	PHMG	meranti gerutu	gerutu	Gerutu, Heavy White Seraya
Parashorea spp.	PHWS	white seraya	white seraya	Light white seraya
Pometia pinnata	PMPN	taun	kasai	Kasai, Matoa
Pinus contorta	PNCN	lodgepole pine	pin de Murray	Lodgepole Pine, Drehkiefer
Pinus sylvestris	PNSY	Scots pine	pin sylvestre	Kiefer, Föhre
Pseudotsuga menziesii	PSMN	Oregon pine "Douglas fir"	Douglas (pin d'Oregon)	Oregon Pine, Douglasie
Quercus spp.	QCXA	American White Oak	Chêne blanc d'Amérique	Amerikanische Weißeiche
	QCXE	European oak	chêne	Eiche
Robinia pseudoacacia	ROPS	robinia (Black locust)	robinier	Robinie
Shorea spp.	SHDR	dark red meranti	dark red meranti	Dark red meranti
Shorea spp.	SHLR	light red meranti	light red meranti	Light red meranti
Swietenia macrophylla	SWMC	American mahogany [a]	Acajou d'Amérique [a]	Amerikanisches Mahagoni [a]
Tectona grandis	TEGR	teak	teck	Teak
Terminalia ivorensis	TMIV	idigbo	framiré	Framiré
Tieghemella africana	TGAF	makoré	douka	Makoré
Tieghemella heckelii	TGHC	makoré	makoré	Makoré
Thuja plicata	THPL	"western red cedar"	« western red cedar »	„western red cedar", Rotzeder
Tsuga heterophylla	TSHT	western hemlock	western hemlock	Western hemlock, Hemlock
		[a] The species Swietenia macrophylla (SWMC, American Mahogany) is listed as "endangered species" under the CITES agreement. The availability may therefore be restricted.	[a] L'espèce Swietenia macrophylla (SWMC, Acajou d'Amérique) est énumérée en tant qu' « espèce en danger de disparition » selon la convention CITES. En conséquence la disponibilité peut être limitée.	[a] Die Holzart Swietenia macrophylla (SWMC, Echtes Mahagoni) wird laut CITES-Abkommen als gefährdete Holzart geführt. Die Verfügbarkeit kann daher beschränkt sein.

NOTE 1   The codes and names were taken from EN 13556 wherever possible (see Bibliography [3]).

NOTE 2   The abbreviation spp. (species pluralis) means that such an assortment may comprise (similar) timbers originating from several botanical species.

NOTE 3   Names in "quotation marks" are commercial names which have become common by long-standing use. Such denominations are, however, not correct from the botanical point of view.

NOTE 1   Les codes et dénominations ont été pris de l'EN 13556 autant que possible (voir Bibliographie [3]).

NOTE 2   L'abréviation spp. (species pluralis) signifie qu'un tel assortiment peut contenir des bois (similaires) de plusieurs espèces botaniques.

NOTE 3   Les dénominations entre « parenthèses » sont des noms commerciaux qui sont devenu communs par un long usage. Du point de vue botanique, de telles dénominations ne sont toutefois pas correctes.

ANMERKUNG 1   Die Kurzzeichen und Namen wurden soweit möglich aus EN 13556 übernommen (siehe Literaturhinweise [3]).

ANMERKUNG 2   Das Kürzel spp. (species pluralis) besagt, dass in dem entsprechenden Sortiment (ähnliche) Hölzer mehrerer botanischer Arten enthalten sein können.

ANMERKUNG 3   Namen in „Anführungszeichen" sind Handelsnamen, die sich durch langjährigen Gebrauch eingebürgert haben. Botanisch sind diese Bezeichnungen jedoch nicht korrekt.

Bibliography

[1]   prCEN/TS 16628, *Energy Performance of Buildings — Basic principles for the set of EPB standards (in preparation)*

[2]   *prCEN/TS 16629, Energy Performance of Buildings — Detailed technical rules for the set of EPB standards (in preparation)*

[3]   ISO/TR 52022-2, *Energy performance of buildings (EPB) – Energy performance of buildings - Building and Building Elements - Thermal, solar and daylight properties of building components and elements – Part 2: Explanation and justification (in preparation)*

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

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

[6]   EN 13556, *Round and sawn timber — Nomenclature of timbers used in Europe*

[7]   ISO 15099, *Thermal performance of windows, doors and shading devices — Detailed calculations*

[8]   ift Guideline WA-08engl/2, Thermally improved spacers – Part 1: Determination of representative Ψ-values for profile sections of windows, ift Rosenheim, September 2013