Thermal performance of windows, doors and shutters — Determination of thermal transmittance by hot box method —

Part 4: Roller shutter boxes

The European Standard EN 12412-4:2003 has the status of a British Standard

ICS 91.060.50

British Standards

National foreword

This British Standard is the official English language version of EN 12412-4:2003.

The UK participation in its preparation was entrusted by Technical Committee B/540, Energy performance of materials, components and buildings, to Subcommittee B/540/1, European Standards for thermal insulation, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

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English version

Thermal performance of windows, doors and shutters - Determination of thermal transmittance by hot box method - Part 4: Roller shutter boxes

Performance thermique des fenêtres, portes et fermetures - Détermination du coefficient de transmission thermique par la méthode de la boîte chaude - Partie 4: Coffres de volets roulants

Wärmetechnisches Verhalten von Fenstern, Türen und Abschlüssen - Bestimmung des Wärmedurchgangskoeffizienten mittels des Heizkastenverfahrens - Teil 4: Rolladenkästen

This European Standard was approved by CEN on 2 May 2003.

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

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

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Contents

Foreword

This document EN 12412-4:2003 has been prepared by Technical Committee CEN /TC 89, "Thermal performance of buildings and building components", the secretariat of which is held by SIS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2004, and conflicting national standards shall be withdrawn at the latest by January 2004.

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

Annexes A and B are normative.

Annex C is informative.

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

Introduction

The method described in this European Standard provides data that can be used for calculating the overall thermal performance of windows and doors equipped with roller shutters according to EN ISO 10077-1, *Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 1: Simplified method (ISO 10077-1:2000)*.

1 Scope

This European Standard specifies a method, based on EN ISO 8990 and EN ISO 12567-1, to measure the overall thermal transmittance of a roller shutter box in a hot box. This includes all effects of geometrical and material characteristics in a test specimen.

Edge effects occurring outside of the perimeter of the specimen are excluded. Furthermore, energy transfer due to solar radiation is not taken into account, and air leakage is excluded.

The method is designed to provide both standardised tests which enable a fair comparison of different products to be made, and specific tests on products for practical application purposes. The former includes window standardised specimen sizes and applied test criteria.

The determination of the overall thermal transmittance is performed for conditions which will correspond to a similar situation of the roller shutter box in practice.

Information on the design of the calibration transfer standard is given in EN ISO 12567-1.

2 Normative references

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

EN 1946-4, *Thermal performance of building products and components – Specific criteria for the assessment of laboratories measuring heat transfer properties – Part 4: Measurements by hot box methods.*

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

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

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

EN ISO 8990:1996, *Thermal insulation – Determination of steady-state thermal transmission properties – Calibrated and guarded hot box (ISO 8990:1994).*

EN ISO 9288:1996, *Thermal insulation – Heat transfer by radiation – Physical quantities and definitions (ISO 9288:1989).*

EN ISO 12567-1:2000, *Thermal performance of windows and doors – Determination of thermal transmittance by hot box method – Part 1: Complete windows and doors (ISO 12567-1:2000).*

3 Terms, definitions, symbols, units and subscripts

3.1 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN ISO 7345:1995, EN ISO 8990:1996, EN ISO 9288:1996 and prEN 12519:1996 apply.

3.2 Symbols and units

Symbol	Quantity	Unit
A	area	m^2
F	convective fraction	
R	thermal resistance	m^2∗K/W
T	thermodynamic temperature	K
U	thermal transmittance	W/(m^2∗K)
d	thickness or depth	m
f	view factor	
h	surface coefficient of heat transfer	W/(m^2∗K)
L	perimeter length	m
l	length	m
q	density of heat flow rate	W/m^2
, *T*	temperature difference	K
	thermal conductance	W/(m^2∗K)
	radiation factor	
	heat flow rate	W
	hemispherical emissivity	
	Stefan-Boltzmann constant	W/(m^2∗K^4)
	Celsius temperature	°C
	linear thermal transmittance	W/(m∗K)
w	width	m
v	air velocity	m/s
	thermal conductivity	W/(m∗K)

3.3 Subscripts

b	baffle
c	convective
ca	calibration
e	external, usually cold side
ed	edge zone
fi	infill with known thermal properties
hb	hot box
i	internal, usually hot side
in	input
m	measured
me	average
n	environmental (ambient)

ne	environmental (external)
ni	environmental (internal)
p	reveal of surround panel
r	radiation (mean)
s	surface
sb	roller shutter box
sp	specimen
sur	surround panel
t	total

4 Principle

Tests are carried out using the calibrated or guarded hot box in accordance with EN ISO 8990 and EN ISO 12567-1. Depending on the height of the box, roller shutter boxes located in pairs of the same type of construction equipped with masks (simulation of window frames) form the test specimen.

The surround panel is used to keep the specimen in position. It is constructed with outer dimensions of appropriate size for the apparatus, having an aperture to accommodate the specimen (see Figures 1 and 2).

The principal heat flows through the surround panel and the calibration panel (or test specimen) are shown in Figure 3. The boundary edge heat flow due to the location of the calibration panel in the surround panel is determined separately by a linear thermal transmittance .

The procedure in this standard includes a correction for the boundary edge heat flow, so that standardized and reproducible thermal transmittance properties are obtained.

The magnitude of the boundary edge heat flow as a function of geometry, calibration panel thickness and thermal conductivity is determined by tabulated values given in annex B.

5 Requirements for test specimen and apparatus

5.1 General

The test apparatus shall conform to the requirements specified in EN 1946-4, EN ISO 8990 and EN ISO 12567-1.

5.2 Surround panels

For details see 5.2 of EN ISO 12567-1:2000.

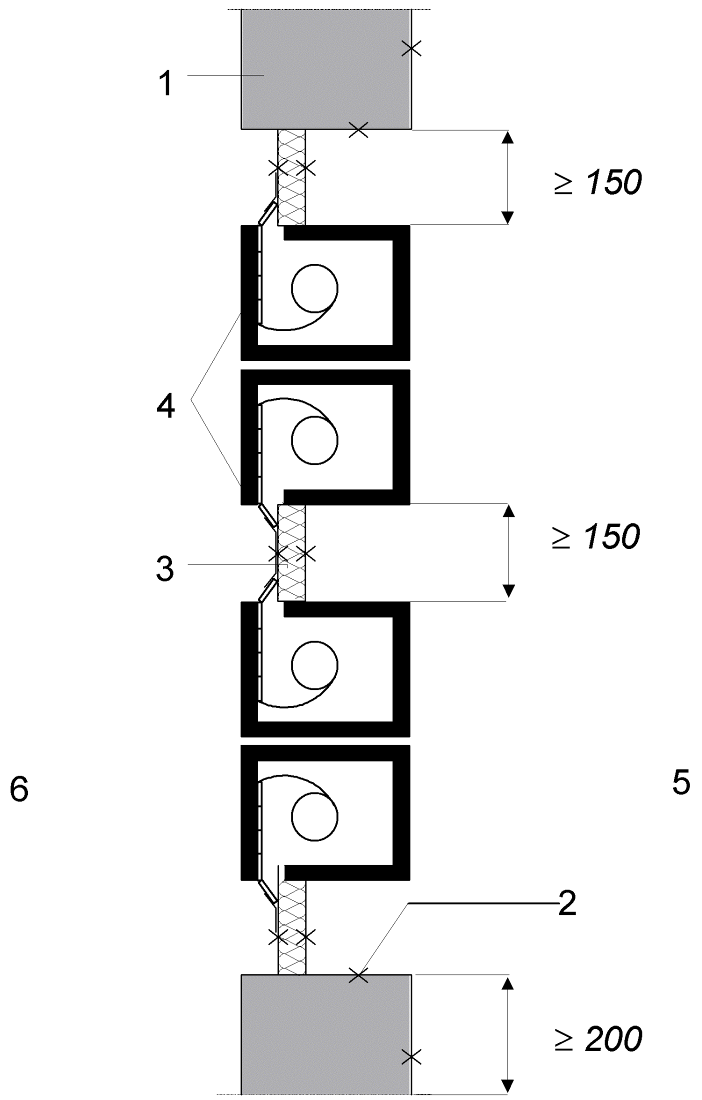
5.3 Specimen requirements and location

The roller shutter boxes shall be at least 1230 mm long and shall be mounted horizontally in the aperture (see Figure 1). For test specimens with metallic-bare surfaces, the inner and outer surfaces should be treated by coating in order to achieve an emissivity of at least 0,8. Any variations from this value have to be justified. Adjacent roller shutter boxes located in pairs lying on top of each other are separated by insulating panels (infill elements). These panels shall be made from material with thermal conductivity less than 0,035 W/(m∗K) and shall be at least 150 mm high and 60 mm thick. The thermal conductivity of the insulating infill elements shall be obtained by measurement according to EN 12664 (guarded hot plate apparatus) or by using panels with certified properties from an accredited source.

Thermocouples to measure the surface temperature shall be placed as shown in Figure 2.

For further information refer to EN ISO 12567-1.

Dimensions in millimetres



Key

1 Surround panel

2 Temperature sensors

3 Panel (infill element)

4 Roller shutter box

5 Warm side

6 Cold side

Figure 1 — Roller shutter boxes in surround panel

It is important that this infill element is located in the same position as the window shutter box would be in practice. The surround panel shall always be thicker than the depth of the shutter box so that the shutter box does not protrude on either side.

The roller shutter boxes shall be tested as used in practice during the night-time, i.e. with roller shutters rolled down.

The roller shutters shall be shortened to the last 4 to 7 slats. The last slat of each shutter box shall be taken to the outside and taped to the insulating panel.

If the specimen area forms less than 30 % of the aperture area of the hot-box, two or more shutter boxes shall be installed so that the total specimen area is at least 30 % of the aperture area, with at least 150 mm between the pair of shutter boxes (see Figure 1).

5.4 Calibration panels

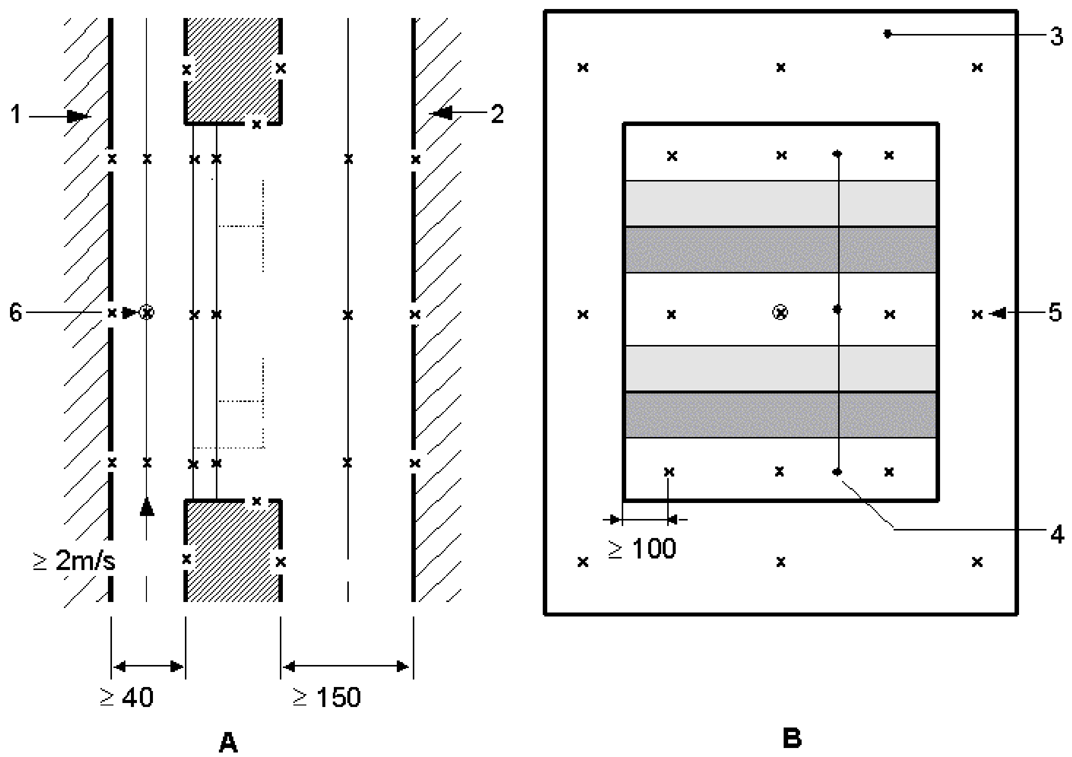
The calibration panel shall be mounted as shown in Figure 3. For further details see 5.4 and 5.5 of EN ISO 12567-1:2000.

5.5 Temperature measurement and baffle position

For further details see 5.5 of EN ISO 12567-1:2000.

The position of the temperature and the air speed sensors are shown in Figure 2.

Dimensions in millimetres



Key

A	Vertical section	3	Surround panel
B	Face elevation	4	Infill element
1	Cold side baffle	5	Thermocouple
2	Warm side baffle	6	Air speed sensor

Figure 2 — Locations of temperature and air speed sensors during measurement

5.6 Air flow measurements

See 5.6 of EN ISO 12567-1:2000.

6 Test procedure

6.1 General

Except as provided herein, the test procedure shall conform with the requirements according to 6.2 and 6.3 of EN ISO 12567-1:2000. An example of the calculations required is given in annex C.

6.2 Calibration measurements

6.2.1 General

Calibration measurements are required to ensure that suitable test conditions are set up and that the surround panel heat flow and surface heat transfer coefficients can be fully accounted for.

The calibration measurements shall be carried out at a minimum of six densities of heat flow rates which cover the required range of specimen testing.

Calibration measurements shall be carried out at three different mean air temperatures $_{c,me}$[$_{c,me}$=($_{c,i}$ + $_{c,e}$)/2] in steps of ± 5 K by varying the cold side air temperature, retaining constant conditions of air movement on the cold side and constant air temperature and natural convection on the warm side. By this procedure, surface resistances and coefficients of heat transfer can be determined as a function of the total density of heat flow rate through the calibration panel.

NOTE It is considered that for non-homogeneous test specimens like window frames or door frames, the mean heat transfer conditions over the measured area will be comparable to those of the given calibration panel.

6.2.2 Total surface resistance

6.2.2.1 Measurement

The calibration panels shall be made as specified in C.1 of EN ISO 12567-1:2000, and the calibration measurements shall be carried out as specified in 6.2 of EN ISO 12567-1:2000 (see also Figure 3).

The first calibration test shall be made with the thin panel (d_{ca} 20 mm) at a mean temperature of approximately 10 °C and a temperature difference, $_{c}$ between warm and cold sides, of (20 ± 2) K (see EN ISO 8990 and annex A for the determination of the environmental temperatures).

The air velocity on the cold side shall be adjusted for the first calibration test by throttling or by fan speed adjustment to give a total surface thermal resistance (warm and cold side) $R_{s,t}$ = 0,17 ± 0,01 m^2·K/W. Thereafter, the fan speed settings and/or the throttling devices shall remain constant for all subsequent calibration measurements. The set-up used for the calibration procedure shall be used for all tests with specimens of shutter boxes.

6.2.2.2 Calculation

Calculate the total surface thermal resistance of the warm and cold side, $R_{s,t}$, expressed in m^{2}K/W, using Equation (1):

$$R_{s,t} = \frac{\Delta\theta_{n,ca} - \Delta\theta_{s,ca}}{q_{ca}} \quad (1)$$

where

$_{\mathrm{n,ca}}$ is the difference between environmental temperatures on each side of the calibration panel, in K, calculated in accordance with annex A;

$_{\mathrm{s,ca}}$ is the surface temperature difference of the calibration panel, in K;

q_{ca} is the density of heat flow rate of the calibration panel determined from the known thermal resistance R_{ca} of the calibration panel (at the mean temperature, $_{\mathrm{me,ca}}$) and the surface temperature difference $_{s,ca}$ calculated using Equation (2):

$$q_{\mathrm{ca}} = \frac{\Delta \;_{\mathrm{s,ca}}}{R_{\mathrm{ca}}} \tag{2}$$

where R_{ca} is the thermal resistance of the calibration panel at the mean temperature of the panel, calculated using Equation (3):

$$R_{\mathrm{ca}} = \sum \frac{d_{\mathrm{j}}}{{}_{\mathrm{j}}} \tag{3}$$

The total surface resistance, $R_{\mathrm{s,t}}$, shall be plotted as a function of the density of heat flow rate, q_{ca}, of the calibration panel. These characteristics are used to determine the total surface resistances of all subsequent measurements of test specimens.

6.2.3 Surface resistance and surface coefficients of heat transfer

6.2.3.1 General

Surface coefficients of heat transfer (convective and radiative parts) are needed in order to determine the environmental temperatures (according to the procedures given in annex A and EN ISO 8990). Surface temperature measurements on the calibration panel at different densities of heat flow rate allow the determination of the surface coefficients of heat transfer. The surface resistances are calculated using Equations (4) and (5):

$$R_{\mathrm{si,\,t}} = \frac{\Delta \;_{\mathrm{ni,ca}} - \Delta \;_{\mathrm{si,ca}}}{q_{\mathrm{ca}}} \tag{4}$$

$$R_{\mathrm{se,\,t}} = \frac{\Delta \;_{\mathrm{ne,ca}} - \Delta \;_{\mathrm{se,ca}}}{q_{\mathrm{ca}}} \tag{5}$$

where

q_{ca} is the density of heat flow rate through the calibration panel, in W/m^2;

$_{\mathrm{ni,ca}}$ is the environmental temperature of the warm side, in degrees Celsius;

$_{\mathrm{si,ca}}$ is the warm side surface temperature of the calibration panel, in degrees Celsius;

$_{\mathrm{se,ca}}$ is the cold side surface temperature of the calibration panel, in degrees Celsius;

$_{\mathrm{ne,ca}}$ is the environmental temperature of the cold side, in degrees Celsius.

NOTE The calculation of environmental temperatures is described in annex A.

6.2.3.2 Convective fraction

Evaluate the radiative and convective parts of the surface coefficients of heat transfer from the calibration data for the warm and cold side according to the procedure given in annex A and determine the convective fraction F_{c} using Equation (6):

$$F_c = \frac{h_c}{h_c + h_r} \quad (6)$$

where

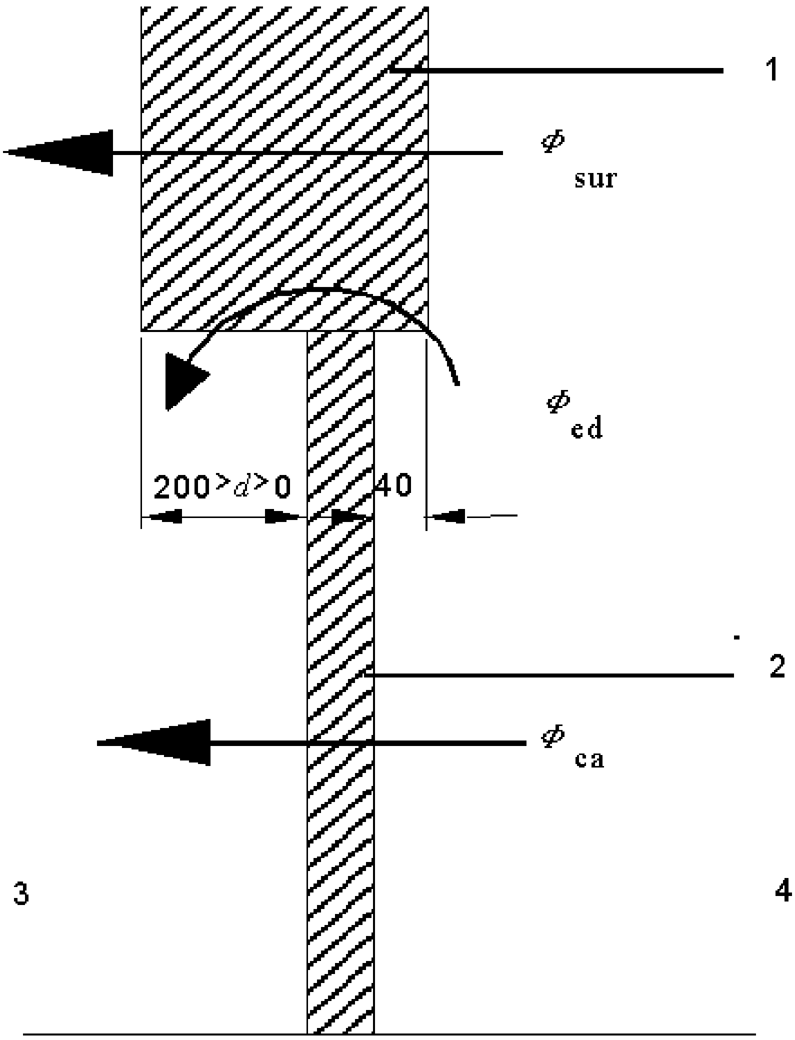
h_c is the convective coefficient of heat transfer, in W/(m^2∗K);

h_r is the radiative coefficient of heat transfer, in W/(m^2∗K).

The variation of the convective fraction, F_c shall be plotted for both sides as a function of q_{ca} (density of heat flow rate of the calibration panel). It is used by interpolation for the determination of the environmental temperatures of all subsequent measurements of test specimens using Equation (7).

$$_{n} = F_c \; _{c} + (1 \quad F_c) \; _{r} \quad (7)$$

Dimensions in millimetres



Key

1 Surround panel

2 Calibration panel

3 Cold side

4 Warm side

Figure 3 — Surround panel and boundary effects

6.2.4 Surround panel and edge corrections

The major difference compared to the procedures given in EN ISO 12567-1 is that a correction for a change in the total surface resistance is not made and so a graph of the density of heat flow rate against the total surface resistance does not need to be drawn.

From the data set of the thicker calibration panel (d_{ca} 60 mm), calculate and plot the thermal resistance of the surround panel, R_{sur}, as a function of its mean temperature. From the heat flows shown in Figure 3, Equations (8), (9) and (10) are derived:

$$R_{sur} = \frac{A_{sur}\,\Delta \quad {}_{s,sur}}{{}_{in} \quad {}_{ca} \quad {}_{ed}} \tag{8}$$

where

A_{sur} is the projected area of the surround panel, in m^2;

$_{s,sur}$ is the difference between the average surface temperatures of the surround panel, in K;

$_{in}$ is the heat input to the metering box appropriately corrected for heat flow through the metering box walls and the flanking losses, in W (see EN ISO 8990);

$_{ca}$ is the heat flow rate through the calibration panel, in W, given by Equation (9):

$$_{ca} = A_{ca}\, q_{ca} \tag{9}$$

where

A_{ca} is the projected area of the calibration panel, in m^2;

q_{ca} is the density of heat flow rate of the calibration panel, in W/m^2;

$_{ed}$ is the heat flow rate through the edge zone between calibration panel and surround panel, in W, given by Equation (10):

$$_{ed} = L_{ed}\ _{ed}\ _{c} \tag{10}$$

where

L_{ed} is the perimeter length between surround panel and specimen, in m;

$_{ed}$ is the linear thermal transmittance of the edge zone between surround panel and specimen, in W/(m∗K) (values for $_{ed}$ are given in Table B.2 for measurements on roller shutter boxes described in 5.3);

$_{c}$ is the difference between the warm and the cold side air temperatures, in K.

This calibration procedure allows the results from a given size of calibration panel to be applied to a different size of test specimen without repeating the whole calibration measurement process. If the internal and external projected areas are different, the larger one shall be used.

NOTE A worked example is given in annex C.

6.3 Measurement procedure for test specimens

The measurement of the test specimens shall be made under the same conditions as those used in the corresponding calibrations described in 6.2.1 of EN ISO 12567-1:2000 at a mean temperature of approximately 10 °C.

The density of heat flow rate, q_t, through the infill element and shutter box during the measurement shall be calculated using Equation (11):

$$q_t = \frac{_{in}\quad _{sur}\quad _{ed}}{A_t} \tag{11}$$

where

$_{in}$ is the heat input to the metering box appropriately corrected for heat flow through the metering box walls and the flanking losses, in W, (see 2.9.3.3 of EN ISO 8990:1996);

$_{sur}$ is the heat flow rate through the surround panel, in W, given by :

$$_{sur} = \frac{A_{sur}\ \Delta\ _{s,sur}}{R_{sur}} \tag{12}$$

$_{\mathrm{ed}}$ is the edge zone heat flow rate according to Equation (10), in W, (the actual value for $_{\mathrm{ed}}$ shall be taken from Table B.2);

A_{t} is the projected area of the shutter box and the infill area, in m^2;

A_{sur} is the projected area of the surround panel in m^2;

R_{sur} is the thermal resistance of the surround panel in m^2∗K/W determined by calibration (see example given in Figure C.2).

The measured overall thermal transmittance, $U_{\mathrm{m,t}}$, of the infill element and shutter box shall be calculated using Equation (13):

$$U_{\mathrm{m,t}} = \frac{q_{\mathrm{t}}}{_{\mathrm{n}}} \quad (13)$$

where

q_{t} is the density of heat flow rate in the measurement of the infill element and shutter box, in W/m^2;

$_{\mathrm{n}}$ is the difference between the environmental temperatures on each side of the system under test, in K.

The overall thermal transmittance of the shutter box, U_{sb}, is given by:

$$U_{\mathrm{sb}} = \frac{U_{\mathrm{m,t}}\, A_{\mathrm{t}}\, \Delta\ _{\mathrm{n}} \quad _{\mathrm{fi}}\, \Delta\ _{\mathrm{s,fi}}\, A_{\mathrm{fi}}}{A_{\mathrm{sb}}\, \Delta\ _{\mathrm{n}}} \quad (14)$$

where

$U_{\mathrm{m,t}}$ is the measured thermal transmittance, in W/(m^2∗K), of the infill element and the shutter box area A_{sb} (the shutter box area is the larger of the two projected areas seen from both sides in m^2);

A_{fi} is the remaining area of the calibrated infill element in the plane of measurement ($A_{\mathrm{fi}} = A \quad A_{\mathrm{sb}}$), in m^2;

A_{t} is the projected area of the metering area, in m^2;

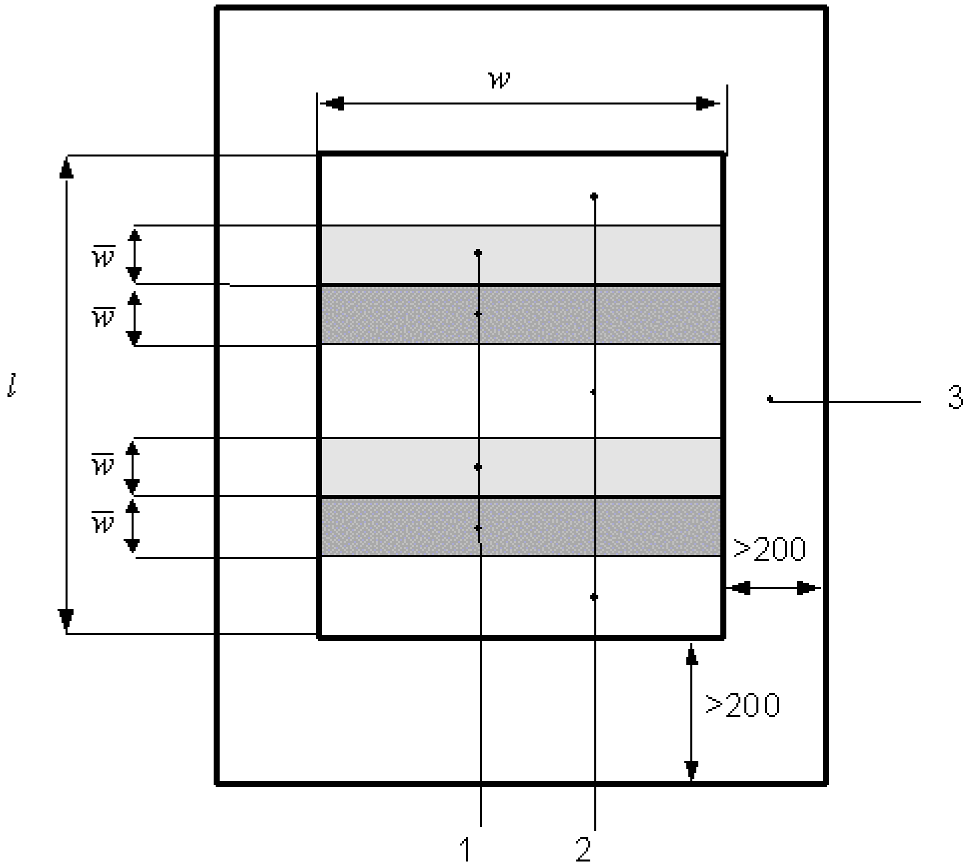
$_{\mathrm{n}}$ is the difference between the environmental temperatures on each side of the system under test, in K;

$_{\mathrm{fi}}$ is the thermal conductance of the infill element, in W/(m^2∗K);

$_{\mathrm{s,fi}}$ is the difference of the temperatures between the surfaces of the infill element, in K;

A_{sb} is the projected area of the shutter box, in m^2.

Dimensions in millimetres



Key

1 Test specimen

2 Surround panel

3 Aperture

Figure 4 — Face elevation of aperture

The area of the aperture is $A = w\,l$

The area of infill is $A_{\mathrm{fi}} = (w\ l) \quad \sum_i (\bar{w}_i\ l_i)$

The projected area of the shutter box is $A_{\mathrm{sb}} = \sum_i (\bar{w}_i\ l_i)$

7 Test report

The test report shall contain all information required for a test report specified in 3.7 of EN ISO 8990:1996. In addition, the following information shall be given:

a) all details necessary to identify the product tested: height, a cross-section of the specimen; a sketch showing the structure of the specimen (e.g. position and thickness of insulating material layers, position of internal foils, composition and geometry of the specimen and the position relevant to the surround panel);

b) method of calibration: summary details of the range of calibrations appropriate to these tests (calibration curves or analytical calibration functions);

c) results of measurements:

¾ basic data set of the measurements (see EN ISO 8990);

¾ mean environmental temperature on the warm side, ${}_{\mathrm{ni}}$, in °C;

¾ mean environmental temperature on the cold side, ${}_{\mathrm{ne}}$, in °C;

¾ air speed and direction on the warm (when measured) and the cold side, in m/s^2;

¾ the measured thermal transmittance, U_{sb}, as obtained from the tests rounded to two significant figures;

¾ estimation of the approximate error of the measurement.

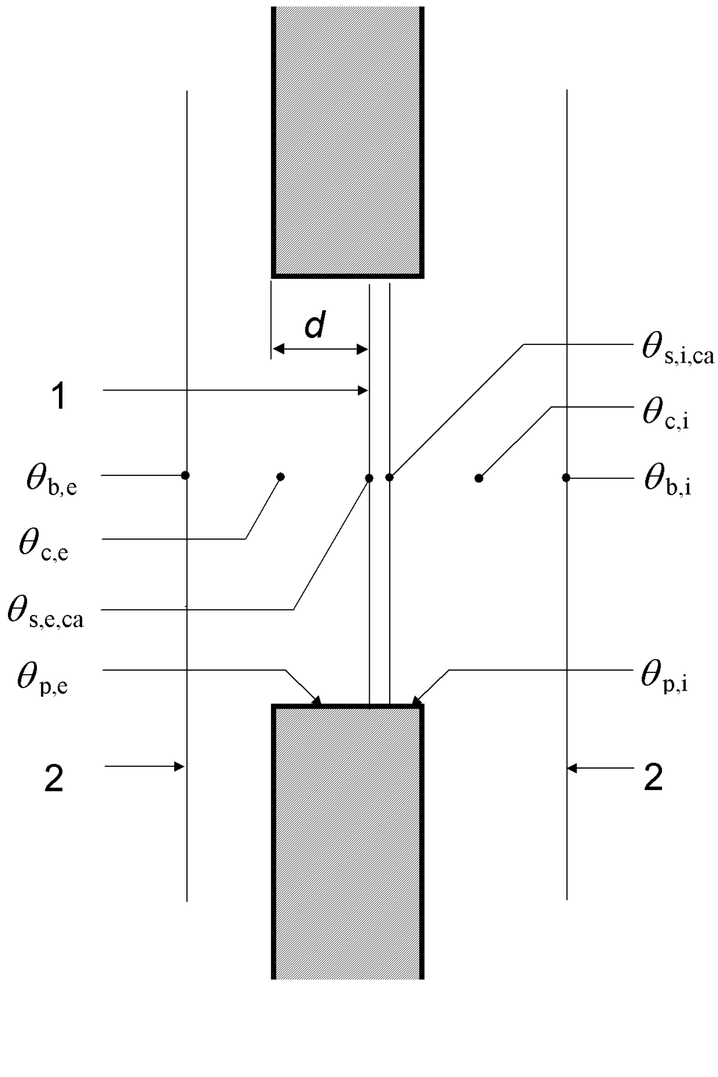
Annex A
(normative)

Determination of the environmental temperature

A.1 General

The procedure in EN ISO 12567-1:2000, annex A shall be applied, with the following modifications given in this annex.

In this annex the notation given in Figure A.1 is used.



Key

1 Calibration panel or test specimen
2 Baffle
s,ca Average surface temperature of the calibration panel, in °C
p Average surface temperature of the reveal of the surround panel (top, side, bottom), in °C
b Average surface temperature of the baffle, in °C;
c Average air temperature, in °C

Figure A.1 — Notation used for the environmental temperature

A.2 Environmental temperature

The environmental temperature, $_n$, is the weighting of the radiant temperature, $_r$, and the air temperature, $_c$. Calculate the environmental temperature on both sides using Equation (A.1):

$$_n = \frac{h_c \; _c + h_r \; _r}{h_c + h_r} \quad \text{(A.1)}$$

where

h are the surface heat transfer coefficients, in W/(m²×K);

c is an index referring to the mean air temperature;

r is an index referring to the mean radiant temperature.

A.3 Mean radiant temperature

The mean radiant temperature, $_r$ in °C, of the surfaces "seen" by the surface of the test specimen (calibration panel or window) shall be calculated using Equation (A.2), (A.3) or (A.4):

¾ if the depth of the surround panel reveal, d 50 mm $\quad _r = \; _b$ (A.2)

¾ if $d > 50$ and | $_b$- $_p$| 5 K $\quad \theta_r = \frac{\alpha_{cb} \; \theta_b + \alpha_{cp} \theta_p}{\alpha_{cb} + \alpha_{cp}}$ (A.3)

¾ otherwise $\quad _r = \frac{_{cb} h_{cb} \; _b + \; _{cp} h_{cp} \; _p}{_{cb} h_{cb} + \; _{cp} h_{cp}}$ (A.4)

The radiant heat transfer coefficient h_r, in W/(m²K), is calculated using Equation (A.5):

$$h_r = \; _{cb} h_{cb} + \; _{cp} h_{cp} \quad \text{(A.5)}$$

where h_{cb}, h_{cp} are the black body radiant heat transfer coefficients calculated using Equations (A.6) and (A.7):

$$h_{cb} = \; (T_c^2 + T_b^2)(T_c + T_b) \quad \text{(A.6)}$$

$$h_{cp} = \; (T_c^2 + T_p^2)(T_c + T_p) \quad \text{(A.7)}$$

where

is the Stefan-Boltzmann constant = 5,67 10^{-8} W/(m²K⁴);

$_{cb}$, $_{cp}$ are radiation factors from the baffle to the calibration panel and from the surround panel reveals to the calibration panel calculated using Equations (A.8) and (A.9).

The values of h_{cb} and h_{cp} are calculated from the data set of the calibration panel and can be used for all specimens with the appropriate cold side temperature.

The radiation factors $_{cb}$ and $_{cp}$, are calculated ignoring second reflections using Equations (A.8) and (A.9):

$$_{cb} \quad _c \; _b \left[f_{cb} + (1 \quad _p) f_{cp} \, f_{pb} \right] \quad \text{(A.8)}$$

$$_{cp} \quad _c \; _p \left[f_{cp} + (1- \; _b) f_{cb} \, f_{bp} + (1- \; _b) f_{cb} \, f_{pp} \right] \quad \text{(A.9)}$$

where

f is the view factor between two surfaces;

is the hemispherical emissivity.

The following subscripts indicate the direction of the radiant heat exchange:

cb from calibration panel to baffle;

cp from calibration panel to surround panel reveal;

pb from surround panel reveal to baffle;

bp from baffle to surround panel reveal;

pp from surround panel reveal to surround panel reveal.

View factors depending on the depth of surround panel reveal, 'd', for the standardised test aperture are given in Tables A.1 and A.2. For other geometries a detailed radiation heat exchange calculation procedure shall be used.

Table A.1 — View factors for a 1230 mm 1480 mm aperture

	Reveal depth d mm				
	0	**50**	**100**	**150**	**200**
f_{cb}	1,0	0,930	0,867	0,809	0,756
f_{pp}	0,0	0,059	0,103	0,142	0,177
f_{cp}= f_{bp} see Equation (A.10)	0,0	0,070	0,133	0,191	0,244
f_{pb} see Equation (A.11)	0,5	0,471	0,449	0,429	0,412

Table A.2 — View factors for a 1200 mm 1200 mm aperture

	Reveal depth d **mm**				
	0	**50**	**100**	**150**	**200**
f_{cb}	1,0	0,922	0,853	0,790	0,733
f_{pp}	0,0	0,068	0,117	0,160	0,198
f_{cp}= f_{bp} see Equation (A.10)	0,0	0,078	0,147	0,210	0,267
f_{pb} see Equation (A.11)	0,5	0,466	0,442	0,420	0,401

$$f_{cp} = f_{bp} = 1 \quad f_{cb} \tag{A.10}$$

$$f_{pb} = \frac{(1 - f_{pp})}{2} \tag{A.11}$$

A.4 Convective surface heat transfer coefficient

The convective surface heat transfer coefficient is calculated according to:

$$h_c = \frac{q_{ca} \quad h_r \left| \ _{r} \quad _{ca} \right|}{\left| \ _{c} \quad _{ca} \right|} \tag{A.12}$$

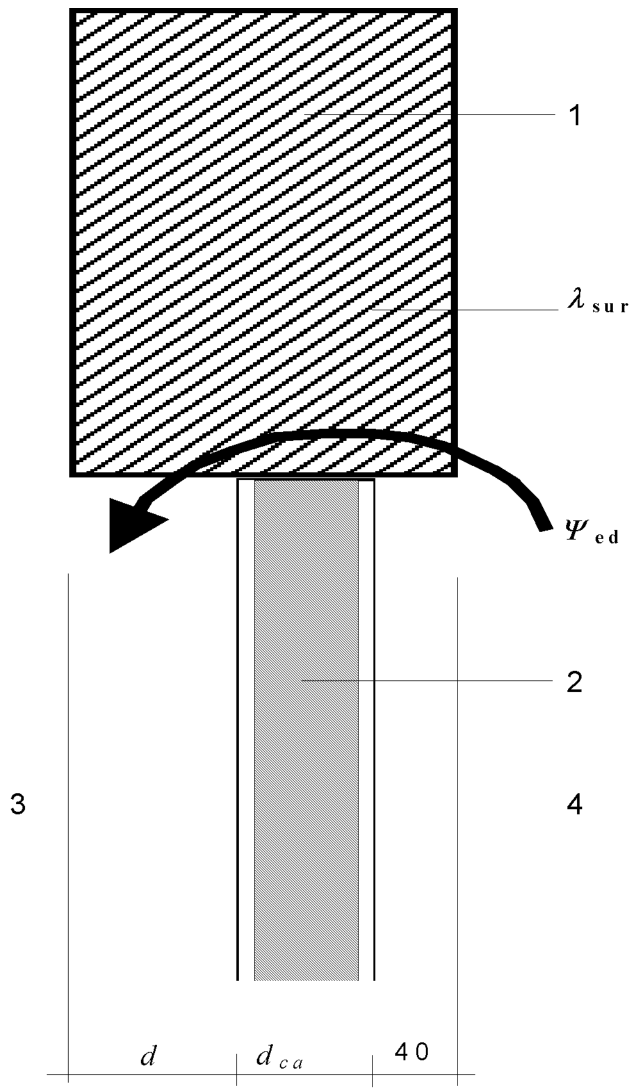
where q_{ca} is the density of heat flow rate through the calibration panel, in W/m^2.

Annex B
(normative)

Linear thermal transmittance of the edge zone

The linear thermal transmittance values of the edge zone (see Figures B.1 and B.2) are given in Tables B.1 and B.2.

Dimensions in millimetres



Key

1 Surround panel

2 Calibration panel

3 Cold side

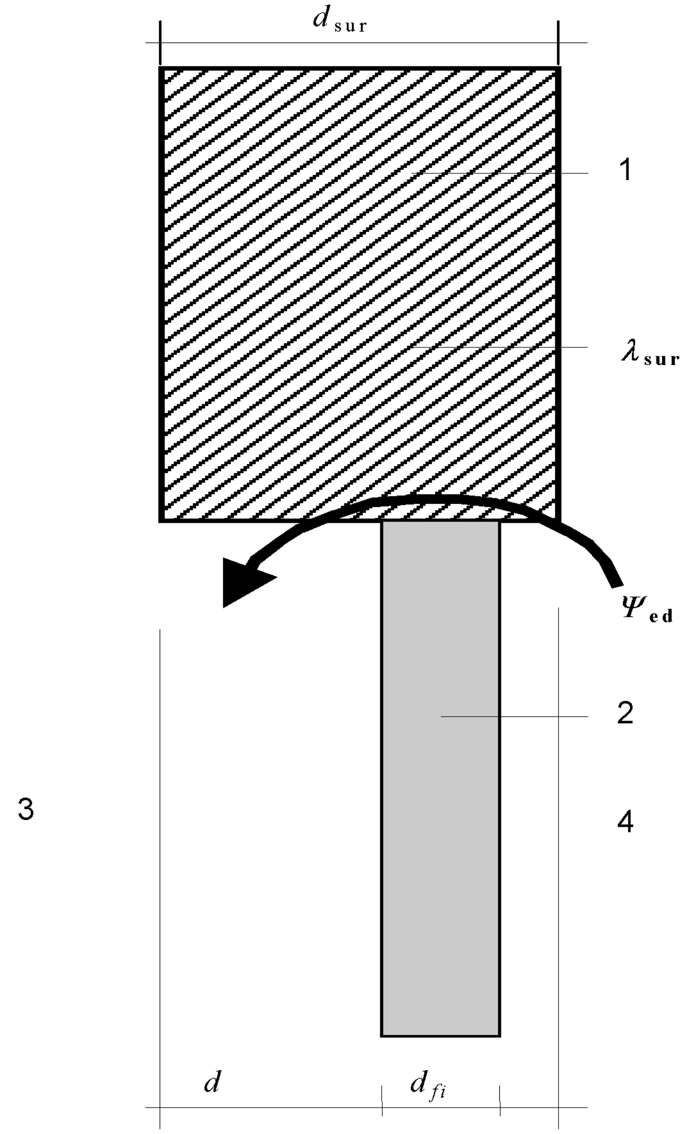
4 Warm side

Figure B.1 — Glazed calibration panel with thickness d_{ca}

Table B.1 — Linear thermal transmittance for glazed calibration panel

	$_{ed}$ for d_{ca} = 20 mm W/(m∗K)			$_{ed}$ for d_{ca} = 60 mm W/(m∗K)			$_{ed}$ for d_{ca} = 100 mm W/(m∗K)		
d	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)
mm	0,030	0,035	0,040	0,030	0,035	0,040	0,030	0,035	0,040
0	0,0109	0,0125	0,0140	0,0044	0,0050	0,0057	0,0023	0,0027	0,0031
20	0,0085	0,0098	0,0110	0,0041	0,0048	0,0054	0,0024	0,0028	0,0032
40	0,0099	0,0113	0,0127	0,0050	0,0058	0,0065	0,0030	0,0035	0,0040
60	0,0118	0,0135	0,0152	0,0063	0,0072	0,0082	0,0039	0,0046	0,0052
80	0,0138	0,0159	0,0178	0,0077	0,0088	0,0100	0,0050	0,0057	0,0065
100	0,0157	0,0181	0,0204	0,0090	0,0104	0,0118	0,0060	0,0070	0,0079
120	0,0176	0,0202	0,0228	0,0104	0,0120	0,0136	0,0071	0,0082	0,0093
140	0,0193	0,0222	0,0250	0,0117	0,0135	0,0153	0,0081	0,0094	0,0107
160	0,0209	0,0240	0,0271	0,0130	0,0150	0,0170	0,0091	0,0106	0,0120
180	0,0223	0,0257	0,0287	0,0142	0,0164	0,0185	0,0101	0,0117	0,0133
200	0,0237	0,0273	0,0308	0,0153	0,0177	0,0200	0,0111	0,0128	0,0145

NOTE - values for intermediate $_{sur}$, d_{ca} and d values are obtained by linear interpolation.



Key

1 Surround panel
2 Infill element
3 Cold side
4 Warm side

Figure B.2 — Infill element with thicknes d_{fi}

Table B.2 — Linear thermal transmittance for the infill element with conductivity values $_{fi}$ = 0,030 to 0,035

		ed for d_{fi} = 20mm W/(m∗K)				ed for d_{fi} = 30mm W/(m∗K)				ed for d_{fi} = 40mm W/(m∗K)		
d	d_{sur}	sur W/(m∗K)	sur W/(m∗K)	sur W/(m∗K)	*d*	sur W/(m∗K)	sur W/(m∗K)	sur W/(m∗K)	*d*	sur W/(m∗K)	sur W/(m∗K)	sur W/(m∗K)
mm	mm	0,030	0,035	0,040	mm	0,030	0,035	0,040	mm	0,030	0,035	0,040
0		0,0185	0,0211	0,0235	0	0,0131	0,0150	0,0165	0	0,0092	0,0105	0,0118
20		0,0106	0,0122	0,0137	20	0,0073	0,0083	0,0091	20	0,0049	0,0056	0,0063
40	100	0,0090	0,0103	0,0115	40	0,0065	0,0075	0,0081	40	0,0050	0,0057	0,0065
60		0,0111	0,0126	0,0142	60	0,0097	0,0111	0,0121	60	0,0096	0,0108	0,0121
80		0,0193	0,0218	0,0242	70	0,0137	0,0155	0,0170				
0		0,0216	0,0246	0,0275	0	0,0161	0,0184	0,0203	0	0,0120	0,0138	0,0155
20		0,0133	0,0152	0,0171	20	0,0097	0,0111	0,0123	20	0,0071	0,0081	0,0092
40	120	0,0107	0,0123	0,0138	40	0,0079	0,0090	0,0099	40	0,0059	0,0067	0,0076
60		0,0109	0,0125	0,0140	60	0,0087	0,0099	0,0109	60	0,0073	0,0084	0,0095
80		0,0138	0,0158	0,0178	80	0,0125	0,0143	0,0158	80	0,0137	0,0142	0,0158
100		0,0225	0,0255	0,0283	90	0,0167	0,0190	0,0210				
0		0,0242	0,0277	0,0309	0	0,0187	0,0213	0,0237	0	0,0145	0,0167	0,0187
20		0,0157	0,0180	0,0202	20	0,0120	0,0138	0,0152	20	0,0092	0,0106	0,0119
40		0,0126	0,0145	0,0162	40	0,0095	0,0110	0,0121	40	0,0073	0,0084	0,0095
60	140	0,0118	0,0135	0,0152	60	0,0092	0,0106	0,0116	60	0,0074	0,0085	0,0096
80		0,0129	0,0148	0,0166	80	0,0107	0,0123	0,0136	80	0,0095	0,0109	0,0123
100		0,0163	0,0187	0,0210	100	0,0151	0,0173	0,0191	100	0,0151	0,0171	0,0192
120		0,0252	0,0286	0,0319	110	0,0194	0,0221	0,0244				
0		0,0265	0,0303	0,0340	0	0,0209	0,0240	0,0267	0	0,0168	0,0192	0,0216
20		0,0179	0,0205	0,0230	20	0,0141	0,0162	0,0179	20	0,0112	0,0129	0,0145
40		0,0145	0,0165	0,0186	40	0,0113	0,0129	0,0143	40	0,0089	0,0102	0,0115
60	160	0,0131	0,0150	0,0168	60	0,0103	0,0118	0,0130	60	0,0082	0,0094	0,0107
80		0,0132	0,0151	0,0170	80	0,0107	0,0123	0,0136	80	0,0090	0,0104	0,0117
100		0,0148	0,0170	0,0191	100	0,0127	0,0146	0,0162	100	0,0116	0,0133	0,0150
120		0,0185	0,0213	0,0239	120	0,0173	0,0199	0,0221	120	0,0173	0,0198	0,0222
140		0,0276	0,0314	0,0350	130	0,0217	0,0248	0,0275				
0		0,0286	0,0327	0,0367	0	0,0230	0,0264	0,0293	0	0,0188	0,0216	0,0243
20		0,0198	0,0227	0,0256	20	0,0160	0,0184	0,0205	20	0,0130	0,0150	0,0169
40		0,0162	0,0186	0,0209	40	0,0129	0,0149	0,0165	40	0,0104	0,0120	0,0135
60		0,0145	0,0166	0,0187	60	0,0115	0,0132	0,0146	60	0,0093	0,0107	0,0121
80	180	0,0140	0,0161	0,0180	80	0,0113	0,0130	0,0144	80	0,0094	0,0108	0,0122
100		0,0147	0,0168	0,0189	100	0,0123	0,0141	0,0156	100	0,0106	0,0123	0,0138
120		0,0166	0,0191	0,0215	120	0,0146	0,0168	0,0187	120	0,0135	0,0155	0,0175
140		0,0206	0,0236	0,0266	140	0,0194	0,0223	0,0248	140	0,0194	0,0222	0,0249
160		0,0297	0,0339	0,0378	150	0,0238	0,0272	0,0303				
0		0,0305	0,0349	0,0391	0	0,0249	0,0285	0,0317	0	0,0206	0,0237	0,0266
20		0,0216	0,0248	0,0279	20	0,0178	0,0204	0,0227	20	0,0147	0,0170	0,0191
40		0,8750	0,0205	0,0230	40	0,0145	0,0167	0,0185	40	0,0119	0,0137	0,0155
60		0,0159	0,0182	0,0204	60	0,0128	0,0147	0,0163	60	0,0105	0,0121	0,0136
80	200	0,0153	0,0172	0,0193	80	0,0122	0,0140	0,0155	80	0,0101	0,0093	0,0131
100		0,0151	0,0173	0,0194	100	0,0125	0,0144	0,0159	100	0,0106	0,0123	0,0138
120		0,0161	0,0185	0,0208	120	0,0138	0,0159	0,0176	120	0,0122	0,0141	0,0159
140		0,0183	0,0210	0,0237	140	0,0163	0,0188	0,0209	140	0,0152	0,0175	0,0198
160		0,0224	0,0257	0,0290	160	0,0213	0,0244	0,0272	160	0,0213	0,0243	0,0273
180		0,0316	0,0361	0,0403	170	0,0257	0,0294	0,0330				

(*continued*)

Table B.2 (*continued*)

		ed for d_{fi} = 20mm W/(m∗K)				ed for d_{fi} = 30mm W/(m∗K)				ed for d_{fi} = 40mm W/(m∗K)		
d	d_{sur}	sur W/(m∗K)	sur W/(m∗K)	sur W/(m∗K)	d	sur W/(m∗K)	sur W/(m∗K)	sur W/(m∗K)	d	sur W/(m∗K)	sur W/(m∗K)	sur W/(m∗K)
mm	mm	0,030	0,035	0,040	mm	0,030	0,035	0,040	mm	0,030	0,035	0,040
0		0,0322	0,0369	0,0414	0	0,0266	0,0305	0,0340	0	0,0223	0,0256	0,0288
20		0,0233	0,0267	0,0301	20	0,0194	0,0223	0,0249	20	0,0163	0,0188	0,0212
40		0,0194	0,0223	0,0250	40	0,0160	0,0184	0,0205	40	0,0134	0,0154	0,0174
60		0,0172	0,0197	0,0222	60	0,0141	0,0162	0,0180	60	0,0117	0,0135	0,0152
80		0,0161	0,0185	0,0207	80	0,0132	0,0152	0,0168	80	0,0110	0,0127	0,0143
100	220	0,0158	0,0181	0,0203	100	0,0131	0,0150	0,0166	100	0,0111	0,0127	0,0144
120		0,0162	0,0186	0,0209	120	0,0137	0,0158	0,0175	120	0,0119	0,0137	0,0155
140		0,0175	0,0201	0,0226	140	0,0141	0,0175	0,0195	140	0,0137	0,0158	0,0178
160		0,0199	0,0229	0,0257	160	0,0179	0,0207	0,0230	160	0,0169	0,0194	0,0219
180		0,0241	0,0277	0,0312	180	0,0230	0,0264	0,0294	180	0,0230	0,0263	0,0296
200		0,0334	0,0381	0,0425	190	0,0275	0,0314	0,0350				
0		0,0338	0,0387	0,0434	0	0,0281	0,0323	0,0360	0	0,0238	0,0274	0,0309
20		0,0248	0,0285	0,0321	20	0,0209	0,0241	0,0268	20	0,0178	0,0205	0,0232
40		0,0208	0,0239	0,0269	40	0,0174	0,0200	0,0223	40	0,0147	0,0170	0,0191
60		0,0185	0,0213	0,0239	60	0,0154	0,0177	0,0196	60	0,0129	0,0149	0,0168
80		0,0172	0,0197	0,0222	80	0,0142	0,0164	0,0181	80	0,0120	0,0138	0,0156
100	240	0,0166	0,0191	0,0214	100	0,0138	0,0159	0,0176	100	0,0117	0,0135	0,0152
120		0,0167	0,0191	0,0215	120	0,0140	0,0161	0,0179	120	0,0121	0,0139	0,0157
140		0,0174	0,0199	0,0225	140	0,0149	0,0171	0,0190	140	0,0131	0,0151	0,0171
160		0,0188	0,0217	0,0244	160	0,0166	0,0183	0,0213	160	0,0151	0,0174	0,0196
180		0,0213	0,0245	0,0277	180	0,0194	0,0224	0,0250	180	0,0183	0,0211	0,0239
200		0,0256	0,0295	0,0332	200	0,0245	0,0282	0,0315	200	0,0245	0,0281	0,0316
220		0,0350	0,0399	0,0447	210	0,0290	0,0332	0,0371				
0		0,0352	0,0404	0,0453	0	0,0295	0,0339	0,0379	0	0,0253	0,0290	0,0327
20		0,0262	0,0301	0,0339	20	0,0223	0,0257	0,0287	20	0,0192	0,0221	0,0250
40		0,0221	0,0255	0,0287	40	0,0187	0,0215	0,0240	40	0,0160	0,0185	0,0209
60		0,0197	0,0227	0,0255	60	0,0166	0,0191	0,0212	60	0,0141	0,0162	0,0183
80		0,0183	0,0210	0,0236	80	0,0153	0,0176	0,0195	80	0,0130	0,0149	0,0169
100		0,0175	0,0201	0,0226	100	0,0146	0,0168	0,0187	100	0,0125	0,0143	0,0162
120	260	0,0173	0,0198	0,0223	120	0,0145	0,0167	0,0186	120	0,0125	0,0144	0,0163
140		0,0176	0,0202	0,0227	140	0,0150	0,0173	0,0192	140	0,0131	0,0151	0,0171
160		0,0185	0,0213	0,0239	160	0,0161	0,0185	0,0206	160	0,0143	0,0165	0,0187
180		0,0201	0,0231	0,0261	180	0,0179	0,0206	0,0230	180	0,0164	0,0189	0,0214
200		0,0227	0,0261	0,0295	200	0,0208	0,0240	0,0268	200	0,0197	0,0227	0,0257
220		0,0271	0,0311	0,0351	220	0,0259	0,0299	0,0334	220	0,0261	0,0299	0,0336
240		0,0364	0,0416	0,0467	230	0,0305	0,0349	0,0390				

(*continued*)

Table B.2 (*continued*)

		$_{ed}$ for d_{fi} = 20mm W/(m∗K)				$_{ed}$ for d_{fi} = 30mm W/(m∗K)				$_{ed}$ for d_{fi} = 40mm W/(m∗K)		
d	d_{sur}	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)	*d*	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)	*d*	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)	$_{sur}$ W/(m∗K)
mm	mm	0,030	0,035	0,040	mm	0,030	0,035	0,040	mm	0,030	0,035	0,040
0		0,0366	0,0419	0,0471	0	0,0309	0,0355	0,0397	0	0,0266	0,0306	0,0345
20		0,0275	0,0316	0,0357	20	0,0236	0,0271	0,0304	20	0,0205	0,0236	0,0267
40		0,0234	0,0269	0,0303	40	0,0199	0,0230	0,0257	40	0,0172	0,0199	0,0225
60		0,0209	0,0240	0,0271	60	0,0177	0,0204	0,0227	60	0,0152	0,0175	0,0201
80		0,0193	0,0222	0,0250	80	0,0163	0,0188	0,0209	80	0,0140	0,0161	0,0182
100		0,0184	0,0211	0,0238	100	0,0155	0,0178	0,0198	100	0,0133	0,0153	0,0173
120		0,0180	0,0207	0,0233	120	0,0152	0,0175	0,0194	120	0,0131	0,0151	0,0170
140	280	0,0180	0,0207	0,0233	140	0,0153	0,0177	0,0196	140	0,0134	0,0154	0,0174
160		0,0185	0,0213	0,0240	160	0,0160	0,0184	0,0205	160	0,0141	0,0163	0,0184
180		0,0196	0,0225	0,0254	180	0,0172	0,0198	0,0221	180	0,0155	0,0179	0,0202
200		0,0213	0,0245	0,0277	200	0,0191	0,0220	0,0246	200	0,0176	0,0203	0,0230
220		0,0240	0,0276	0,0311	220	0,0221	0,0255	0,0285	220	0,0210	0,0243	0,0274
240		0,0284	0,0327	0,0369	240	0,0273	0,0314	0,0351	240	0,0273	0,0314	0,0353
260		0,0378	0,0432	0,0485	250	0,0318	0,0365	0,0410				
0		0,0378	0,0433	0,0487	0	0,0321	0,0369	0,0413	0	0,0278	0,0320	0,0361
20		0,0287	0,0331	0,0373	20	0,0248	0,0285	0,0319	20	0,0217	0,0250	0,0282
40		0,0246	0,0283	0,0319	40	0,0211	0,0243	0,0272	40	0,0184	0,0212	0,0239
60		0,0221	0,0253	0,0285	60	0,0188	0,0217	0,0241	60	0,0163	0,0188	0,0212
80		0,0204	0,0234	0,0263	80	0,0173	0,0199	0,0222	80	0,0149	0,0172	0,0194
100		0,0193	0,0222	0,0250	100	0,0164	0,0188	0,0209	100	0,0141	0,0163	0,0184
120		0,0187	0,0215	0,0242	120	0,0159	0,0183	0,0203	120	0,0137	0,0158	0,0179
140	300	0,0186	0,0213	0,0240	140	0,0158	0,0182	0,0203	140	0,0138	0,0159	0,0179
160		0,0188	0,0216	0,0243	160	0,0162	0,0385	0,0207	160	0,0142	0,0164	0,0185
180		0,0195	0,0224	0,0252	180	0,0170	0,0195	0,0217	180	0,0151	0,0174	0,0197
200		0,0207	0,0237	0,0268	200	0,0183	0,0210	0,0235	200	0,0166	0,0191	0,0216
220		0,0225	0,0258	0,0291	220	0,0203	0,0233	0,0261	220	0,0188	0,0217	0,0245
240		0,0252	0,0290	0,0327	240	0,0233	0,0269	0,0275	240	0,0223	0,0257	0,0290
260		0,0296	0,0341	0,0385	260	0,0285	0,0329	0,0368	260	0,0286	0,0328	0,0369
280		0,0390	0,0447	0,0501	270	0,0331	0,0378	0,0425				

NOTE - values for intermediate $_{sur}$ can be obtained by linear interpolation.

Annex C
(informative)

Example of calibration test and measurement of the shutter box specimen

C.1 Calibration test with panel size 1,23 m 1,48 m

Two calibration panels with total thermal resistance approximately 0,3 and 1,4 m^2×K/ W and total thickness 17 mm and 56 mm respectively are used. The panels were built with core material of expanded polystyrene and covered on both sides with 4 mm float glass in accordance with EN ISO 12567-1 (panel dimensions: 1,23 m 1,48 m).

The basic data for the polystyrene core and surround panel material were measured in a hot plate apparatus according to ISO 8302, *Thermal insulation – Determination of steady-state thermal resistance and related properties – Guarded hot plate apparatus*. The measured data are:

Panel 1 (d = 17 mm) R_{ca} = 0,30009 – 0,00052245× $_{me}$

Panel 2 (d = 56 mm) R_{ca} = 1,490001 0,0081521× $_{me}$

Surround panel (d = 220 mm) $_{sur}$ = 0,0301625 + 0,0000525× $_{me}$

where $_{me}$ is the mean panel temperature in °C.

The calibration data are given in Table C.1.

Table C.1 — Calibration panel

Measured values			Panel 1			Panel 2		
d_{ca}	overall thickness	m	0,017			0,056		
A_{ca}	area of panel	m²	1,82			1,82		
A_{sur}	area of surround panel	m²	2,61			2,61		
$A_{t,hb}$	hot box metering area	m²	4,43			4,43		
L	perimeter length	m	5,42			5,42		
Test number			2	1[a]	3	4	5	6
Cold temperatures								
θ_{ce}	(air)	°C	3,92	0,96	9,94	7,28	2,01	7,86
$\theta_{se,b}$	(baffle)	°C	3,67	1,05	9,97	7,24	2,04	7,85
$\theta_{se,ca}$	(calibration panel)	°C	1,24	3,09	11,21	6,29	2,79	8,39
$\theta_{se,p}$	(reveal panel)	°C	3,56	1,03	9,84	7,22	2,02	7,82
$\theta_{se,sur}$	(surround panel)	°C	3,81	0,94	9,85	7,41	1,95	7,74
Warm temperatures								
θ_{ci}	(air)	°C	22,42	22,40	22,68	23,15	23,20	23,23
$\theta_{si,b}$	(baffle)	°C	24,54	24,15	23,72	23,94	23,75	23,69
$\theta_{si,ca}$	(calibration panel)	°C	16,30	17,31	19,46	20,68	21,45	21,90
$\theta_{si,p}$	(reveal panel)	°C	20,49	20,54	21,60	21,77	21,82	22,17
$\theta_{si,sur}$	(surround panel)	°C	20,72	21,03	21,71	22,03	22,40	22,43
Φ_{in}	(input power)	W	120,11	97,34	57,45	46,55	32,95	24,17
v_i	(air flow warm side, down)	m/s	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2	< 0,2
v_e	(air flow cold side, down)	m/s	~ 1,5	~ 1,5	~ 1,5	~ 1,5	~ 1,5	~ 1,5

[a] This test was used to fix the fan setting on the cold side.

Table C.2 — Linear thermal transmittance and view factors of the calibration panel

Values resulting from mounting instructions			**Source**	**Panel 1**	**Panel 2**
Total thickness of the calibration panel		mm		17	56
Total thickness of the surround panel		mm		220	220
Surround panel reveal depth – warm side		mm		40	40
Surround panel reveal depth – cold side		mm		163	~ 124
$_{\text{ed}}$ for λ = 0,030 W/(m·K)		W/(m*K)	Table B.1	0,0211	0,0107
Warm side	view factors	f_{cbi}	Table A.2	0,944	0,944
		f_{ppi}	Table A.2	0,047	0,047
		f_{cpi}	Equation (A.10)	0,056	0,056
		f_{bpi}	Equation (A.10)	0,056	0,056
		f_{pbi}	Equation (A.11)	0,476	0,476
	radiant factors	$_{\text{cbi}}$	Equation (A.8)	0,750	0,750
		$_{\text{cpi}}$	Equation (A.9)	0,049	0,049
Cold side	view factors	f_{cbe}	Table A.2	0,801	0,845
		f_{ppe}	Table A.2	0,147	0,118
		f_{cpe}	Equation (A.10)	0,199	0,155
		f_{bpe}	Equation (A.10)	0,199	0,155
		f_{pbe}	Equation (A.11)	0,426	0,441
	radiant factors	$_{\text{cbe}}$	Equation (A.8)	0,642	0,675
		$_{\text{cpe}}$	Equation (A.9)	0,174	0,136

NOTE The radiation factors have been calculated with the following emissivities: $_{\text{ca}}$ = 0,84; $_{\text{p}}$ = 0,92, $_{\text{b}}$ = 0,95

Table C.3 — Calculation of surround panel thermal resistance R_{sur}

Quantity		Source	Panel 2		
$\Delta\theta_c$	K		30,43	21,19	15,37
$\Delta\theta_{s,sur}$	K		29,44	20,45	14,69
$\theta_{me,sur}$	°C		7,31	12,18	15,09
$_{in}$	W		46,55	32,95	24,17
$_{ca}$	W	Equation (9)	34,31	24,41	18,00
$_{ed}$	W	Equation (10)	1,76	1,23	0,89
$_{in}$ $_{ca}$ $_{ed}$	W		10,48	7,31	5,28
R_{sur}	m^2·K/W	Equation (8)	7,33	7,30	7,26
Optional check with data of hot plate measurement					
$\theta_{me,sur}$	°C		7,31	12,18	15,09
λ_{sur}	W/(m·K)	linear regression	0,0305	0,0308	0,0310
R_{sur}	m^2·K/W	d/λ_{sur}	7,21	7,14	7,10
$\Delta R_{sur}/R_{sur}$	%	relative difference	1,8	2,2	2,2

Table C.4 — Calculation of surface resistance and convective fraction F_c

Quantity		Source	Panel 1			Panel 2		
$\theta_{me,ca}$	°C		7,53	10,20	15,33	7,20	12,12	15,15
$\Delta\theta_{s,ca}$	K		17,54	14,22	8,25	26,97	18,66	13,51
R_{ca}	m²·K/W	Equation (3)	0,296	0,295	0,292	1,431	1,392	1,366
q_{ca}	W/m²	Equation (2)	59,26	48,20	28,25	18,85	13,41	9,89
$h_{cb,i}$	W/(m²·K)	Equation (A.6)	5,739	5,757	5,807	5,850	5,867	5,879
$h_{cb,e}$	W/(m²·K)	Equation (A.6)	4,499	4,728	5,181	4,287	4,746	5,047
$h_{cp,i}$	W/(m²·K)	Equation (A.7)	5,621	5,651	5,745	5,785	5,810	5,834
$h_{cp,e}$	W/(m²·K)	Equation (A.7)	4,502	4,728	5,177	4,288	4,745	5,046
$h_{r,i}$	W/(m²·K)	Equation (A.5)	4,589	4,604	4,646	4,680	4,694	4,704
$h_{r,e}$	W/(m²·K)	Equation (A.5)	3,628	3,813	4,177	3,450	3,819	4,061
$\theta_{r,i}$	°C	Equation (A.3)	24,54	24,15	23,72	23,94	23,75	23,69
$\theta_{r,e}$	°C	Equation (A.2)	3,65	1,05	9,95	7,24	2,03	7,84
$h_{c,i}$	W/(m²·K)	Equation (A.12)	3,17	2,91	2,21	1,69	1,45	0,91
$h_{c,e}$	W/(m²·K)	Equation (A.12)	18,05	18,02	17,10	16,28	13,32	14,05
$F_{c,i}$		Equation (6)	0,408	0,387	0,322	0,265	0,236	0,161
$F_{c,e}$		Equation (6)	0,833	0,825	0,804	0,825	0,777	0,776
$\theta_{ni,ca}$	°C	Equation (7)	23,67	23,47	23,38	23,94	23,62	23,62
$\theta_{ne,ca}$	°C	Equation (7)	3,88	0,97	9,94	7,27	2,01	7,85
$\Delta\theta_{n,ca}$	K		27,55	22,50	13,44	31,21	21,61	15,17
R_{si}	m²·K/W	Equation (4)	0,129	0,133	0,146	0,157	0,163	0,178
R_{se}	m²·K/W	Equation (5)	0,046	0,046	0,047	0,051	0,058	0,055
$R_{s,t}$	m²·K/W	Equation (1)	0,175	0,179	0,193	0,208	0,221	0,234

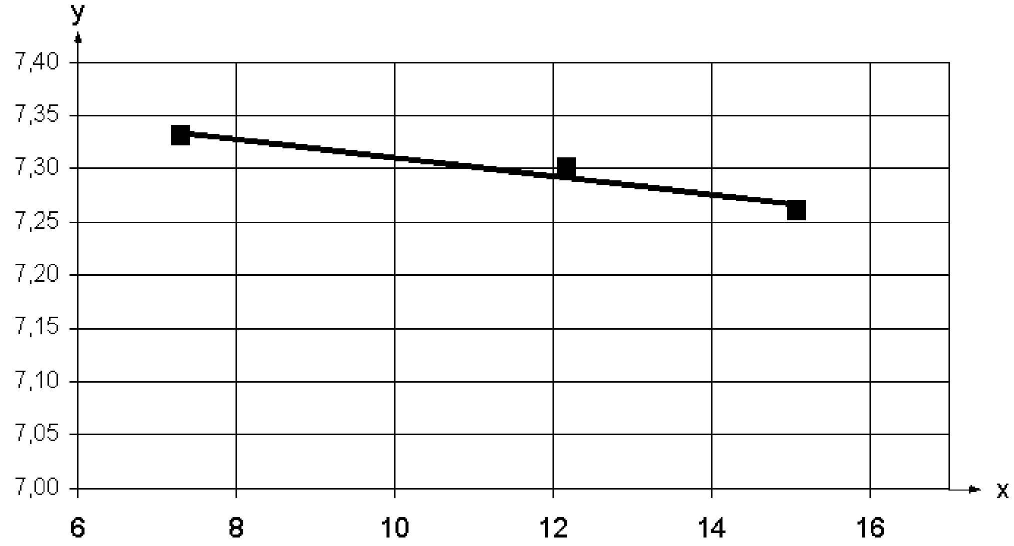
The results from the calibration measurements are plotted in Figures C.1, C.2 and C.3. The following regression curves have been derived by least-square fits from the data set:

thermal resistance of the surround panel: $R_{sur} = 7{,}3970 - 0{,}0087 \times \theta_{me,sur}$

convective fraction: $F_{c,i} = 0{,}1626 + 0{,}0047 \times q_{sp}$

$F_{c,e} = 0{,}7738 + 0{,}0011 \times q_{sp}$

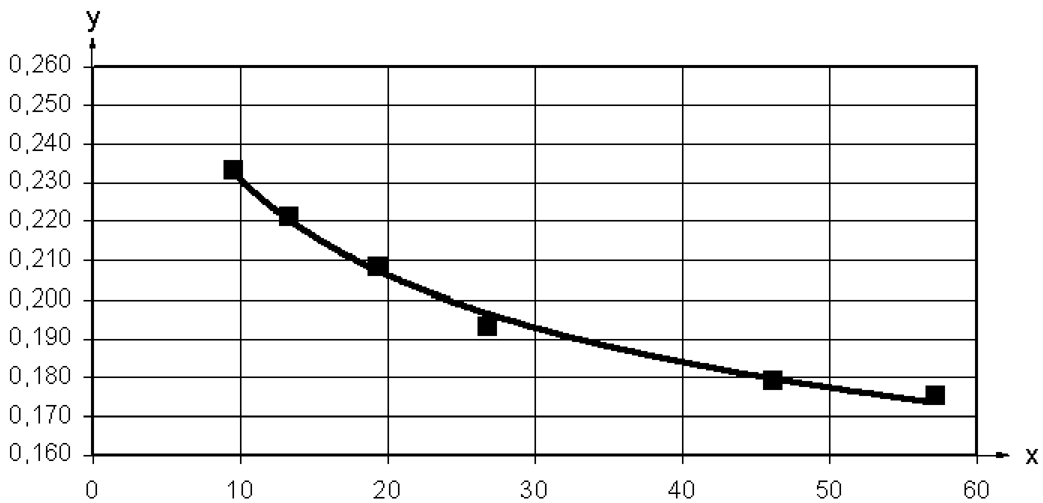
total surface resistance: $R_{s,t} = 0{,}3378 \times q_{sp}^{-0{,}16}$



Key

x-axis: Surround panel mean temperature, in °C
y-axis: $R_{s,t}$, in m^2∗K/W

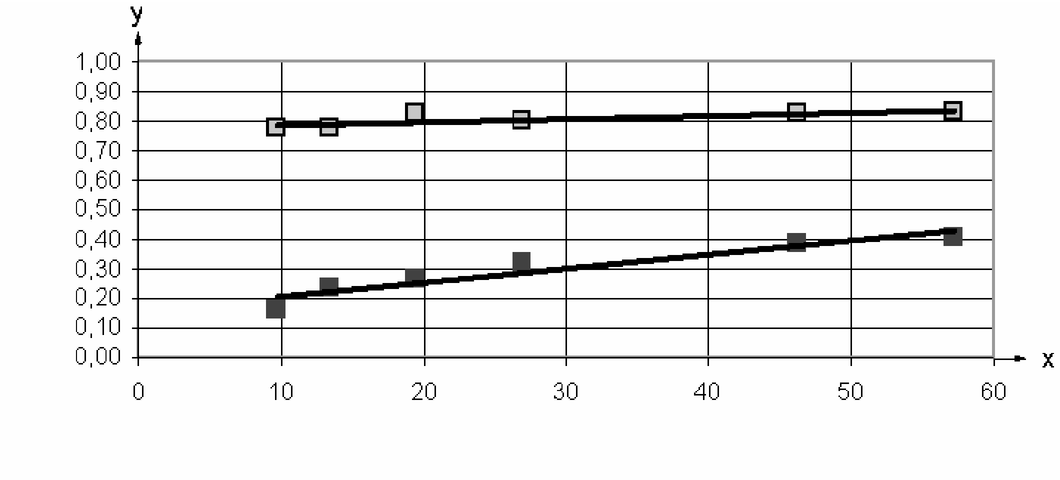
Figure C.1 — Thermal resistance of the surround panel



Key

x-axis: Density of heat flow rate, q, in W/m^2
y-axis: $R_{s,t}$, in m^2∗K/W

Figure C.2 — Total surface resistance



Key

x-axis: Density of heat flow rate, q, in W/m^2
y-axis: Convection, F_c

□ Þ $F_{c,e}$

■ Þ $F_{c,i}$

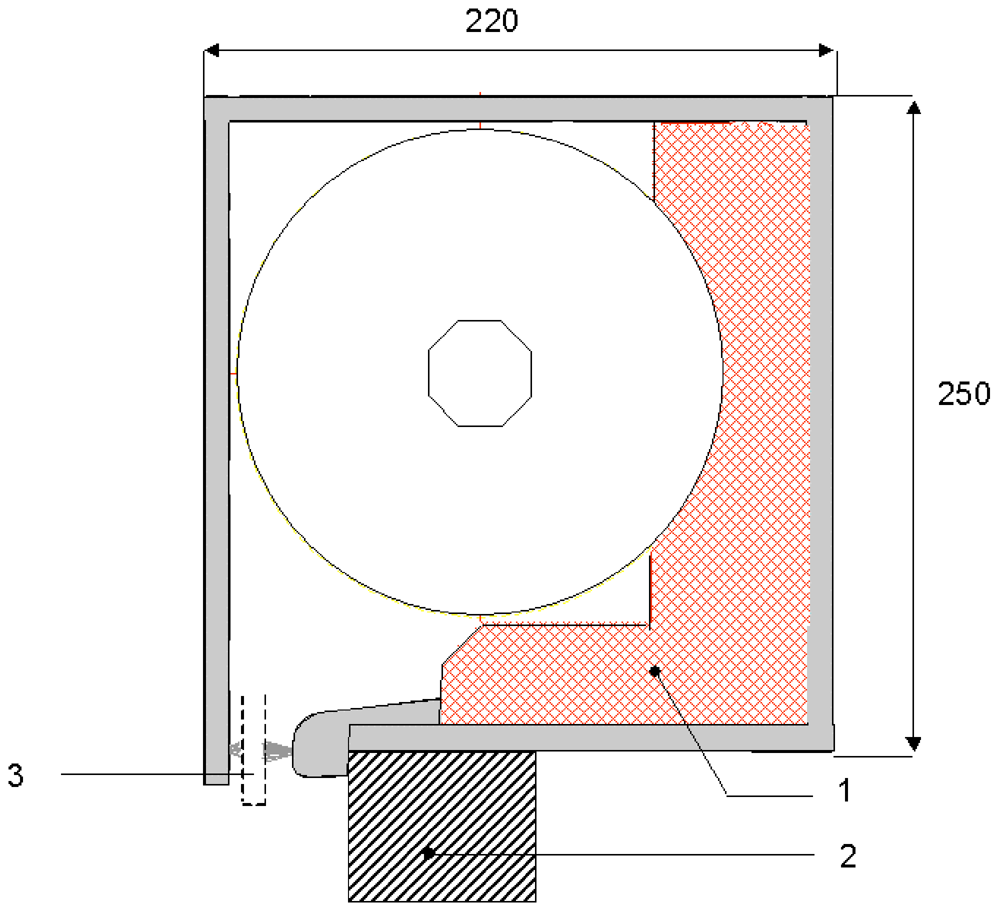
Figure C.3 — Convective fractions cold side and warm side

C.2 Roller shutter box specimen measurement

Description of the specimen:

tested object:	roller shutter box
material:	PVC-U
number of identical test specimens:	2
height of each test specimen:	250 mm
width of each test specimen:	1230 mm
total thickness of each specimen:	220 mm

Dimensions in millimetres



Key

1 Insulating material
2 Infill element
3 Remaining slats

Figure C.4 — Cross section of the specimen

Results of test specimen measurements:

areas:	area of hot box aperture	$A_{t,hb}$	= 2,08 m 2,13 m	=	4,43 m^2
	area of calibration panel aperture	A_{ca}	= 1,23 m 1,48 m	=	1,82 m^2
	projected shutter box area	A_{sb}	= 2 1,23 m 0,25 m	=	0,615 m^2
	infill element area	A_{fi}	$= A - A_{sb}$	=	1,205 m^2
	perimeter length	L_{ed}	=		5,42 m

In this case A_{ca} corresponds to A_t

hemispherical emissivities:

baffle	$_{b}$	= 0,89
specimen	$_{sp}$	= 0,89
calibration panel	$_{ca}$	= 0,89
surround panel	$_{sur}$	= 0,89

infill element data:

thickness d_{fi} = 60,0 mm

Sequence of calculations to determine the U-value (see Tables C.5 to C.7):

q_t	= 12,10 W/m^2	from measurement		
$F_{c,i}\ (q_{ca})$	= 0,219	linear regression of calibration panel data (see Figure C.3)		
$F_{c,e}\ (q_{ca})$	= 0,787	linear regression of calibration panel data (see Figure C.3)		
$_{c,i}$	= 23,29 °C	$_{r,i}$ = $_{b,i}$ = 23,89 °C		
$_{c,e}$	= 2,43 °C	$_{r,e}$ = $_{b,e}$ = 2,39 °C		
$_{ni}$	$= F_{c,i} \times {}_{c,i} + (1 \quad F_{c,i}) \times {}_{r,i}$			
	= 0,219 23,29 + (1 0,219) 23,89	= 23,76 °C		(7)
$_{ne}$	$= F_{c,e} \times {}_{c,e} + (1 \quad F_{c,e}) \times {}_{r,e}$			
	= 0,787 2,43 + (1 0,787) 2,39	= 2,42 °C		(7)
$R_{s,t}(q_t)$	= 0,227 m^2·K/W			
R_{sur}	$= \dfrac{A_{sur}\,\Delta \quad _{s,sur}}{\Phi_{in} \quad \Phi_{ca} \quad \Phi_{ed}}$	$= \dfrac{2{,}61 \quad 20{,}09}{97{,}34 - 87{,}74 \quad 2{,}42}$	= 7,30 m^2·K/W	(8)
$_{ca}$	$= A_{ca}\ q_{ca}$	= 1,82 48,20	= 87,74 W	(9)

Measurement procedure for specimen:

$${}_{ed} = L_{ed}\;{}_{ed}\;{}_{c} \qquad = 5{,}42 \quad 0{,}0183 \quad 20{,}86 \qquad = 2{,}07\ \text{W} \qquad (10)$$

$$q_t = \frac{\Phi_{in} \quad \Phi_{sur} \quad \Phi_{ed}}{A_t} \qquad = \frac{31{,}01 \quad 6{,}91 \quad 2{,}07}{1{,}82} \qquad = 12{,}10\ \text{W/m}^2 \qquad (11)$$

$${}_{sur} = \frac{A_{sur}\,\Delta\theta_{s,sur}}{R_{sur}} \qquad = \frac{2{,}61 \quad 19{,}33}{7{,}30} \qquad = 6{,}91\ \text{W} \qquad (12)$$

$$U_{m,t} = \frac{q_t}{{}_{n}} \qquad = \frac{12{,}10}{21{,}34} \qquad = 0{,}57\ \text{W/(m}^2\text{K)} \qquad (13)$$

$$U_{sb} = \frac{U_{m,t}\,A_t\,\Delta\theta_n \quad {}_{fi}\,\Delta\theta_{s,fi}\,A_{fi}}{A_{sb}\;\Delta\theta_n} = \frac{0{,}57 \quad 1{,}82 \quad 21{,}34 \quad 0{,}503 \quad 17{,}26 \quad 1{,}205}{0{,}615 \quad 21{,}34} = 0{,}89\ \text{W/(m}^2\text{K)} \qquad (14)$$

Table C.5 — Shutter box data

Quantity			Value
w	shutter box width	m	0,250
d_{sur}	surround panel thickness	m	0,220
A_{sb}	area of shutter box	m^2	0,615
A_{sur}	area of surround panel	m^2	2,61
L	perimeter length	m	5,42

Table C.6 — Shutter box measurement results

Quantity			Value
Cold temperatures – measured:			
${}_{ce}$	(air)	°C	2,43
${}_{se,b}$	(baffle)	°C	2,39
${}_{se,sur}$	(surround panel)	°C	2,56
Warm temperatures – measured:			
${}_{ci}$	(air)	°C	23,29
${}_{si,b}$	(baffle)	°C	23,89
${}_{si,sur}$	(surround panel)	°C	21,89
${}_{in}$	(input power in hot box)	W	31,01
v_i	(air flow warm, down)	m/s	< 0,2
v_e	(air flow cold, up)	m/s	~ 1,5

Table C.7 — Calculation of the thermal transmittance of the shutter box

Quantity			Value	Source
$_{me,sur}$	(mean temp. of surround panel)	°C	12,23	
R_{sur}	(surround panel resistance)	m^2∗K/W	7,30	Figure C.1 / regression and Equation (8)
sur	(conductivity of surround panel)	W/(m∗K)	0,030	
$_{ed}$	for infill element 30 mm	W/(m∗K)	0,0183	Table B.2
$_{s,sur}$	(temp. difference of surround panel)	K	19,33	
$_{c}$	(air temp. difference)	K	20,86	
$_{in}$	(input power in hot box)	W	31,01	
$_{sur}$	(surround panel heat flow)	W	6,91	Equation (12)
$_{ed}$	(edge zone heat flow)	W	2,07	Equation (10)
q_t	(heat flow rate through infill element and shutter box)	W/m^2	12,10	Equation (11)
U_{mt}	(measured thermal transmittance of the infill element and shutter box)	W/(m^2∗K)	0,57	Equation (13)
F_{ci}	(convective fraction - warm)		0,219	Figure C.3 / regression
F_{ce}	(convective fraction - cold)		0,787	Figure C.3 / regression
$R_{s,t}$	(total surface resistance)	m^2∗K/W	0,227	Figure C.2 / regression
$_{ri}$	(radiant temperature - warm)	°C	23,89	Equations (A.2) to (A.4)
$_{re}$	(radiant temperature - cold)	°C	2,39	Equations (A.2) to (A.4)
$_{ni}$	(environmental temp. - hot)	°C	23,76	Equation (7)
$_{ne}$	(environmental temperature – cold)	°C	2,42	Equation (7)
$_{n}$	(environmental temperature difference)	K	21,34	
U_{sb}	(measured)	W/(m^2∗K)	0,89	Equation (14)
U_{sb}	(uncertainty of the measurement)	W/(m^2∗K)	0,05	

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