
**Thermal performance of windows and
doors — Determination of solar heat
gain coefficient using solar simulator**

*Performance thermique des fenêtres et portes — Détermination du
coefficient de gain thermique solaire au moyen d'un simulateur solaire*

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Contents

	Page
Foreword	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Symbols and subscripts	2
5 Principle	3
5.1 General	3
5.2 Measurement of heat flow rates with irradiance	3
5.3 Determination of the net density of heat flow rate due to thermal transmission	5
5.4 Measurement of heat flow rates without irradiance	6
6 Test apparatus and specimens	8
6.1 Construction and summary of the test apparatus	8
6.1.1 Construction of the test apparatus	8
6.1.2 Summary of the test apparatus	9
6.2 Solar simulator	9
6.3 Climatic chamber	10
6.4 Metering box	10
6.5 Surround panels	11
6.6 Calibration panels	11
6.7 Metering location of temperatures and irradiance	11
6.8 Test specimens	12
7 Measurement procedure	12
7.1 Measurement	12
7.2 Expression of results for reference conditions	13
8 Test report	13
8.1 Report contents	13
8.2 Estimation of uncertainty	14
Annex A (normative) Determination of surface coefficient of heat transfer	15
Annex B (normative) Determination of night time <i>U</i>-value in case of small temperature difference	17
Annex C (normative) Correction of measured solar heat gain coefficient to reference conditions	18
Annex D (informative) Examples of design of measuring apparatus	30
Annex E (informative) Example of temperature measurement	39
Annex F (informative) Measuring method and example of measurement of active solar fenestration systems	42
Annex G (informative) Example of measurement and uncertainty analysis	44
Annex H (informative) Spectral weighting procedures based on ISO 9050 and with analogous solar simulator spectra	47
Bibliography	52

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 1, *Test and measurement methods*.

Introduction

The terms solar heat gain coefficient (SHGC), total solar energy transmittance (TSET), solar factor and g-value are all used to describe the same quantity. Small differences might be caused by different reference conditions (e.g. differences in the reference solar spectrum). In this document, solar heat gain coefficient is used.

This document is designed to provide solar heat gain coefficient values by standardized measurement method and to enable a fair comparison of different products. It specifies standardized apparatus and criteria. The solar heat gain coefficient measuring apparatus applied in this document includes solar simulator, climatic chamber, and metering box. Solar heat gain coefficient values of windows and doors with or without shading devices shall be determined more precisely by means of combination between calculation and measurement.

This document does not deal with the centre of glazing solar heat gain coefficient measurement. However, the centre of glazing solar heat gain coefficient can be measured by either this method or cooled plate method (see Reference [12]).

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Thermal performance of windows and doors — Determination of solar heat gain coefficient using solar simulator

1 Scope

This document specifies a method to measure the solar heat gain coefficient of complete windows and doors.

This document applies to windows and doors

- a) with various types of glazing (glass or plastic; single or multiple glazing; with or without low emissivity coatings, and with spaces filled with air or other gases),
- b) with opaque panels,
- c) with various types of frames (wood, plastic, metallic with and without thermal barrier or any combination of materials),
- d) with various types of shading devices (blind, screen, film or any attachment with shading effects),
- e) with various types of active solar fenestration systems [building-integrated PV systems (BIPV) or building-integrated solar thermal collectors (BIST)].

This document does not include the following:

- a) shading effects of building elements (e.g. eaves, sleeve wall, etc.);
- b) heat transfer caused by air leakage between indoors and outdoors;
- c) ventilation of air spaces in double and coupled windows;
- d) thermal bridge effects at the rebate or joint between the window or door frame and the rest of the building envelope.

This document does not apply to the following:

- a) non-vertical windows;
- b) curtain walls;
- c) industrial, commercial and garage doors.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9050, *Glass in building — Determination of light transmittance, solar direct transmittance, total solar energy transmittance, ultraviolet transmittance and related glazing factors*

ISO 9845-1, *Solar energy — Reference solar spectral irradiance at the ground at different receiving conditions — Part 1: Direct normal and hemispherical solar irradiance for air mass 1,5*

ISO 12567-1, *Thermal performance of windows and doors — Determination of thermal transmittance by the hot-box method — Part 1: Complete windows and doors*

ISO 15099:2003, *Thermal performance of windows, doors and shading devices — Detailed calculations*

ISO 52022-3¹⁾, *Energy performance of buildings — Thermal, solar and daylight properties of building components and elements — Part 3: Detailed calculation method of the solar and daylight characteristics for solar protection devices combined with glazing*

IEC 60904-9, *Photovoltaic devices — Part 9: Solar simulator performance requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345, ISO 8990, ISO 9288, ISO 9845-1, ISO 12567-1, ISO 15099 and IEC 60904-9 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

4 Symbols and subscripts

Symbol	Quantity	Unit
A	Area	m ²
g	Solar heat gain coefficient (also known as total solar energy transmittance, solar factor or g-value)	—
h	Surface coefficient of heat transfer	W/(m ² ·K)
H	Height	m
I	Irradiance, density of heat flow rate of incident radiation (energy per unit area per unit time resulting from incident radiation)	W/m ²
q	Density of heat flow rate (energy per unit area per unit time resulting from radiative and/or convective and/or conductive heat transfer)	W/m ²
U	Thermal transmittance	W/(m ² ·K)
W	Width	m
θ	Celsius temperature	°C
Φ	Heat flow rate (energy per unit time resulting from radiative and/or convective and/or conductive heat transfer)	W

Subscripts	Significance
B	Planes of peripheral wall of the metering box
C	Cooling device
ex	External
F	Internal fan
g	Glazing
H	Heating device
in	Internal
m	Measured
N	Without irradiance
ne	Environmental external

1) To be published.

Subscripts	Significance
ni	Environmental internal
P	Surround panel
r	Reflection
Solar	Incident radiation
sp	Test specimen
st	Standardized

5 Principle

5.1 General

The solar heat gain coefficient can be determined according to the same principle equations that are described as in ISO 15099:2003, Formula (14) and ISO 52022-3. Therefore, the determination of the solar heat gain coefficient of windows and doors involves two stages. The first stage is to measure the density of heat flow rate through the test specimen with irradiance (solar heat gain + thermal transmission). The second stage is to measure the density of heat flow rate through the test specimen without irradiance (thermal transmission).

The net density of heat flow rate of incident radiation is determined by the radiometer in front of the test specimen during the first stage.

The net density of heat flow rate of the solar heat gain is determined as the difference between the net density of heat flow rate measured in the first stage and the net density of heat flow rate due to thermal transmission, which is evaluated using the thermal transmittance measured in the second stage.

Since the measured solar heat gain coefficient, g_m , of windows and doors is the ratio of the net density of heat flow rate of the solar heat gain to the net density of heat flow rate of incident radiation, it shall be calculated using [Formula \(1\)](#) with or without shading devices:

$$g_m = \frac{q_{in} - q_{in}(q_{Solar} = 0)}{q_{Solar}} \quad (1)$$

where

q_{Solar} is the net density of heat flow rate of incident radiation, in W/m^2 ;

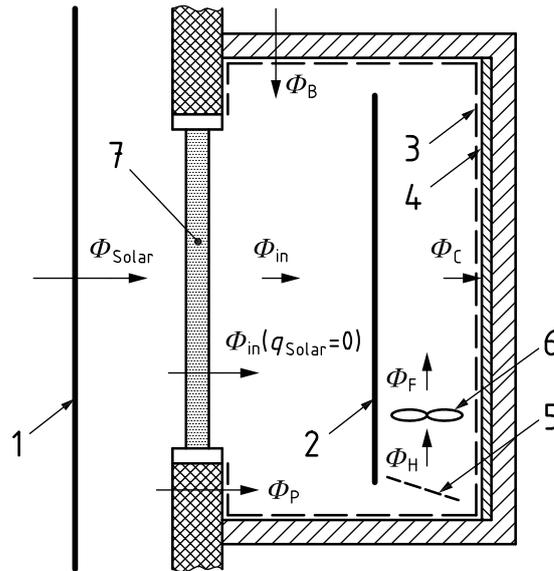
q_{in} is the net density of heat flow rate through the test specimen with irradiance, in W/m^2 ;

$q_{in}(q_{Solar} = 0)$ is the net density of heat flow rate through the test specimen due to thermal transmission without irradiance when the temperature difference between internal side and external side is $(\theta_{ne} - \theta_{ni})$, in W/m^2 .

All of the effects such as changes in the surface coefficient of heat transfer caused by the irradiance shall be included in the solar heat gain coefficient.

5.2 Measurement of heat flow rates with irradiance

The heat flow rates with irradiance are shown in [Figure 1](#).



Key

1	external side baffle (optional)	Φ_B	heat flow rate through the planes of peripheral wall of the metering box with irradiance
2	internal side baffle (optional)	Φ_C	heat flow rate removed by the cooling device with irradiance
3	heat flow measuring device	Φ_F	heat flow rate supplied by the one or more internal fans with irradiance (optional)
4	cooling device	Φ_H	heat flow rate supplied by the heating device with irradiance (optional)
5	heating device (optional)	Φ_{in}	net heat flow rate through the test specimen with irradiance
6	one or more internal fans (optional)	$\Phi_{in}(q_{Solar}=0)$	net heat flow rate through the test specimen due to thermal transmission without irradiance when the temperature difference between internal side and external side is $(\theta_{ne} - \theta_{ni})$
7	test specimen	Φ_P	heat flow rate through the surround panel with irradiance
		Φ_{Solar}	net heat flow rate of incident radiation

NOTE This figure shows the case of a condition when the environmental external temperature is higher than the environmental internal temperature. In the case of a reverse condition, the directions of the heat flow through the test specimen and the surround panel due to thermal transmission will be reversed.

Figure 1 — Heat flow rates with irradiance

The net density of heat flow rate of the incident radiation, q_{Solar} , shall be calculated using [Formula \(2\)](#):

$$q_{Solar} = \frac{\Phi_{Solar}}{A_{sp}} = \frac{I_{Solar} \times A_{sp} - I_r \times A_g}{A_{sp}} \quad (2)$$

where

Φ_{Solar} is the net heat flow rate of incident radiation, in watts;

I_{Solar} is the density of heat flow rate of the incident radiation, in W/m²;

A_{sp} is the projected area of the test specimen, in m²;

I_r is the density of heat flow rate of the incident radiation that is transmitted to the external side of the metering box after being reflected in the internal side of the metering box, in W/m²;

A_g is the glazing area of the test specimen, in m².

If I_r is proved to be negligible (I_r approximately 0), the net density of heat flow rate of the incident radiation, q_{Solar} , shall be calculated using [Formula \(3\)](#) which results in the second term on the right side of [Formula \(2\)](#) to become 0.

$$q_{\text{Solar}} = \frac{\Phi_{\text{Solar}}}{A_{\text{sp}}} = I_{\text{Solar}} \quad (3)$$

Whether I_r is negligible or not, it shall be evaluated by means of [7.2](#) and [Annex C](#). In the case of ripped cooling devices with multi reflection between the cooling lamella, I_r can be neglected if the coating of the cooling lamella has a solar reflectance of 0,05 or lower.

The net density of heat flow rate through the test specimen with irradiance, q_{in} , shall be calculated using [Formula \(4\)](#):

$$q_{\text{in}} = \frac{\Phi_{\text{in}}}{A_{\text{sp}}} = \frac{\Phi_{\text{C}} - \Phi_{\text{B}} - \Phi_{\text{F}} - \Phi_{\text{H}} - \Phi_{\text{P}}}{A_{\text{sp}}} \quad (4)$$

where

Φ_{in} is the net heat flow rate through the test specimen with irradiance, in watts;

Φ_{C} is the heat flow rate removed by the cooling device with irradiance, in watts;

Φ_{B} is the heat flow rate through the planes of peripheral wall of the metering box with irradiance, in watts;

Φ_{F} is the heat flow rate supplied by the one or more internal fans with irradiance (optional), in watts;

Φ_{H} is the heat flow rate supplied by the heating device with irradiance (optional), in watts;

Φ_{P} is the heat flow rate through the surround panel with irradiance, in watts.

5.3 Determination of the net density of heat flow rate due to thermal transmission

The net density of heat flow rate through the test specimen due to thermal transmission without irradiance, $q_{\text{in}}(q_{\text{Solar}} = 0)$, shall be calculated using [Formula \(5\)](#):

$$q_{\text{in}}(q_{\text{Solar}} = 0) = \frac{\Phi_{\text{in}}(q_{\text{Solar}} = 0)}{A_{\text{sp}}} = U_{\text{N}} \times (\theta_{\text{ne}} - \theta_{\text{ni}}) \quad (5)$$

where

$\Phi_{\text{in}}(q_{\text{Solar}} = 0)$ is the net heat flow rate through the test specimen due to thermal transmission without irradiance when the temperature difference between internal side and external side is $(\theta_{\text{ne}} - \theta_{\text{ni}})$, in watts;

U_{N} is the thermal transmittance of the test specimen without irradiance, in $\text{W}/(\text{m}^2 \cdot \text{K})$;

θ_{ne} is the environmental external temperature with irradiance, in $^{\circ}\text{C}$;

θ_{ni} is the environmental internal temperature with irradiance, in $^{\circ}\text{C}$.

5.4 Measurement of heat flow rates without irradiance

The thermal transmittance of the test specimen without irradiance, U_{N} , shall be calculated using [Formula \(6\)](#):

$$U_{\text{N}} = \frac{q'_{\text{in}}(q_{\text{Solar}} = 0)}{\theta'_{\text{ne}} - \theta'_{\text{ni}}} \quad (6)$$

where

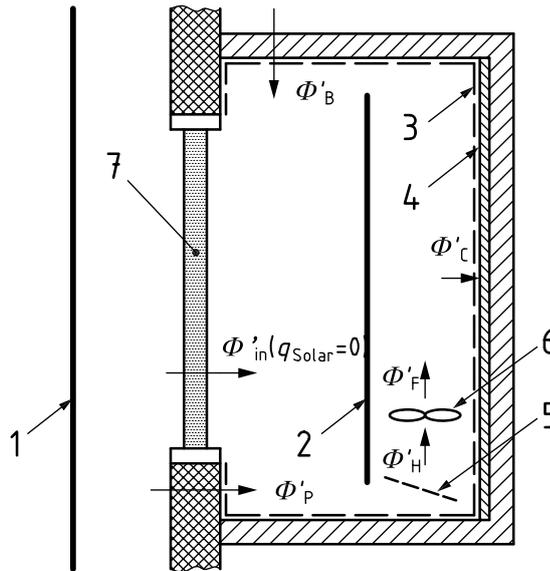
$q'_{\text{in}}(q_{\text{Solar}} = 0)$ is the net density of heat flow rate through the test specimen due to thermal transmission without irradiance when the temperature difference between internal side and external side is $(\theta'_{\text{ne}} - \theta'_{\text{ni}})$, in W/m^2 ;

θ'_{ne} is the environmental external temperature without irradiance, in $^{\circ}\text{C}$;

θ'_{ni} is the environmental internal temperature without irradiance, in $^{\circ}\text{C}$.

In the case when $(\theta'_{\text{ne}} - \theta'_{\text{ni}})$ is too small, U_{N} shall be estimated by means of [Annex B](#).

The heat flow rates without irradiance are shown in [Figure 2](#).


Key

1	external side baffle (optional)	Φ'_B	heat flow rate through the planes of peripheral wall of the metering box without irradiance
2	internal side baffle (optional)	Φ'_C	heat flow rate removed by the cooling device without irradiance
3	heat flow measuring device	Φ'_F	heat flow rate supplied by the one or more internal fans without irradiance (optional)
4	cooling device	Φ'_H	heat flow rate supplied by the heating device without irradiance (optional)
5	heating device (optional)	$\Phi'_{in}(q_{Solar}=0)$	net heat flow rate through the test specimen due to thermal transmission without irradiance when the temperature difference between internal side and external side is $(\theta'_{ne} - \theta'_{ni})$
6	one or more internal fans (optional)	Φ'_P	heat flow rate through the surround panel without irradiance
7	test specimen		

NOTE This figure shows the case of a condition when the environmental external temperature is higher than the environmental internal temperature. In the case of a reverse condition, the directions of the heat flow through the test specimen and the surround panel due to thermal transmission will be reversed.

Figure 2 — Heat flow rates without irradiance

The net density of heat flow rate through the test specimen due to thermal transmission without irradiance, $q'_{in}(q_{Solar} = 0)$, shall be calculated using [Formula \(7\)](#):

$$q'_{in}(q_{Solar} = 0) = \frac{\Phi'_{in}(q_{Solar} = 0)}{A_{sp}} = \frac{\Phi'_C - \Phi'_B - \Phi'_F - \Phi'_H - \Phi'_P}{A_{sp}} \quad (7)$$

where

$\Phi'_{in}(q_{Solar} = 0)$ is the net heat flow rate through the test specimen due to thermal transmission without irradiance when the temperature difference between internal side and external side is $(\theta'_{ne} - \theta'_{ni})$, in watts;

Φ'_C is the heat flow rate removed by the cooling device without irradiance, in watts;

Φ'_B is the heat flow rate through the planes of peripheral wall of the metering box without irradiance, in watts;

Φ'_F is the heat flow rate supplied by the one or more internal fans without irradiance (optional), in watts;

Φ'_H is the heat flow rate supplied by the heating device without irradiance (optional), in watts;

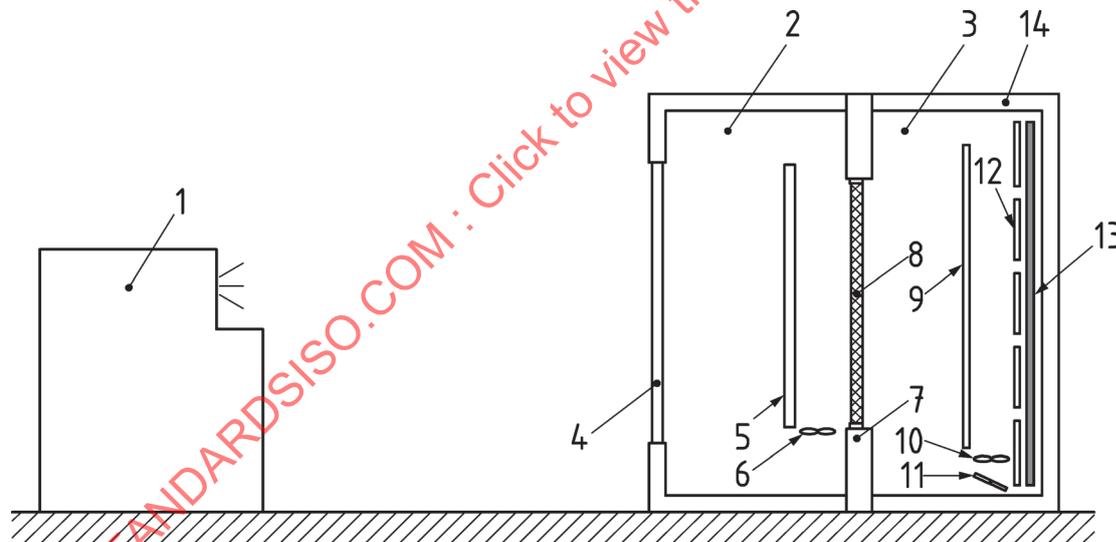
Φ'_P is the heat flow rate through the surround panel without irradiance, in watts.

6 Test apparatus and specimens

6.1 Construction and summary of the test apparatus

6.1.1 Construction of the test apparatus

The measuring apparatus consists of a solar simulator, a climatic chamber, and a metering box. The overall construction of the measuring apparatus is shown in Figure 3.



Key

- | | | | |
|---|---------------------------------|----|--------------------------------------|
| 1 | solar simulator | 8 | test specimen |
| 2 | climatic chamber | 9 | internal side baffle (optional) |
| 3 | metering box | 10 | one or more internal fans (optional) |
| 4 | transparent aperture | 11 | heating device (optional) |
| 5 | external side baffle (optional) | 12 | heat flow measuring device |
| 6 | external airflow generator | 13 | cooling device |
| 7 | surround panel | 14 | peripheral wall of the metering box |

Figure 3 — Construction of the test apparatus

6.1.2 Summary of the test apparatus

The measuring apparatus can be summarized as follows.

- a) Light emitted by the solar simulator passes through the transparent aperture and is then directed towards the test specimen. The light passing through the test specimen is absorbed by the cooling device.
- b) The transparent aperture is installed in the climatic chamber in order to allow the light from the solar simulator to pass through to the test specimen.
- c) The external airflow generator and the external side baffle with transparency may be installed in the climatic chamber in order to adjust the external surface coefficient of heat transfer and environmental external temperature.
- d) The cooling device is installed opposite the test specimen in the metering box in order to remove the solar heat gain and the thermal transmission that has entered the metering box.
- e) The heating device and the internal side baffle with transparency may be installed in the metering box in order to adjust the internal surface coefficient of heat transfer and environmental internal temperature.
- f) One or more internal fans may be installed in the metering box in order to stir the internal air to obtain a uniform temperature distribution and/or to adjust the internal surface coefficient of heat transfer.
- g) All of the heat flow rates passing through the metering box are measured by the heat flow measuring device in order to determine the net heat flow rate through the test specimen.
- h) All the walls and the floor shall be covered with the coating of solar reflectance of 0,05 or lower in order to avoid stray light.

6.2 Solar simulator

A steady-state solar simulator shall be used, which meets with the following requirements.

- a) Spectral match of the irradiance: The spectral match of the irradiance on the test plane is defined by the deviation from the global reference solar spectral irradiance for air mass 1,5 in accordance with ISO 9845-1. For nine wavelength ranges, the percentage of total irradiance is specified in [Table 1](#). The spectral match to all wavelength ranges specified in [Table 1](#) shall be measured in accordance with IEC 60904-9 and shall be within 0,55 to 1,45. Examples of spectral match of solar simulator are shown in [Table D.1](#).

Table 1 — Global reference solar spectral irradiance distribution given in ISO 9845-1

No.	Wavelength range nm	Percentage of total irradiance in the wavelength range 300 nm to 2 500 nm
1	300 to 400	4,6 %
2	400 to 500	14,1 %
3	500 to 600	15,4 %
4	600 to 700	14,0 %
5	700 to 800	11,3 %
6	800 to 900	9,4 %
7	900 to 1 100	12,2 %
8	1 100 to 1 700	14,1 %
9	1 700 to 2 500	4,8 %

- b) Non-uniformity of the irradiance: The non-uniformity of the irradiance on the test plane shall be measured in accordance with IEC 60904-9 and shall be within 5 %. However, the designated test area shall be divided into at least 16 points, alternatively.
- c) Temporal instability of the irradiance: Temporal instability of the irradiance on the test plane shall be measured by the procedure for long term instability (LTI) in accordance with IEC 60904-9 and shall be within 5 %.
- d) Maximum angle of irradiance: The maximum angle of irradiance to the test specimen shall be within 10°.
- e) Area of effective irradiance: The width and height of the area of effective irradiance shall be 100 % or greater than each dimension of the test specimen width, W_{sp} , and height, H_{sp} .

6.3 Climatic chamber

The climatic chamber is constructed of the following: a transparent aperture, an external airflow generator, an external side baffle (optional), and the surround panel aperture. It maintains the environmental external conditions (see [Figure 3](#)).

- a) Transparent aperture: The transparent aperture is installed in order to allow the light from the solar simulator to pass through the climatic chamber to the test specimen. The transparent aperture shall be made from high-transmittance glass specified as follows:
 - 1) the solar transmittance of each glass pane according to ISO 9050 shall be 88,0 % or higher;
 - 2) the difference between the maximum and minimum value of the spectrum transmittance according to ISO 9050:2003, Table 2 within a range of 380 nm to 2 100 nm shall be 0,050 or lower.
- b) External airflow generator: The external airflow generator is installed in order to maintain the external surface coefficient of heat transfer on the test specimen. The airflow shall be parallel to the test specimen and the surround panel. The appropriate air speed shall be set to maintain the external surface coefficient of heat transfer.
- c) External side baffle (optional): The external side baffle with transparency may be installed in order to form and maintain the environmental external conditions between the test specimen and the surround panel. The external side baffle is very useful to set up the environmental external conditions. More details are presented in ISO 12567-1. In this case, the environmental temperature may be considered as the air temperature. The external side baffle shall be made from high-transmittance glass.

6.4 Metering box

The metering box is constructed from the following: a cooling device, an internal side baffle (optional), one or more internal fans (optional), and a heating device (optional). It maintains the environmental internal conditions (see [Figure 3](#)).

The appropriate heat flow measuring devices such as heat flow meter and so forth shall be used in order to measure all of the heat flow rates passing through the metering box.

- a) Cooling device: The cooling device is installed opposite to the test specimen in order to remove all the heat entering the metering box. The surface of the cooling device shall have a solar absorptance of 0,90 or greater and have a matte finished to maximize heat absorption. The heat flow meters or the calorimeter may be used as the heat flow measuring device. The refrigerant set a temperature lower than environmental internal temperature, is circulated over the rear surface of the cooling device. Environmental internal temperature is controlled by either the heating device, the inlet temperature of the refrigerant or the volumetric flow rate of the refrigerant or by a combination of these three.

- b) Internal side baffle (optional): The internal side baffle with transparency may be installed in order to form and maintain the environmental internal conditions between the test specimen and the surround panel. The internal side baffle is very useful to set up the environmental internal conditions. More details are presented in ISO 12567-1. In this case, the environmental temperature may be considered as the air temperature. The internal side baffle shall be made from high-transmittance glass.
- c) Heating device (optional): The heating device may be installed in the metering box to control environmental internal temperature. The electrical power used for heating shall be measured.
- d) One or more internal fans: The one or more internal fans may be installed in the metering box in order to stir the internal air to obtain a uniform temperature distribution and/or to adjust the internal surface coefficient of heat transfer. The electrical power used for stirring the air shall be measured.

6.5 Surround panels

The surround panels shall be used to hold the test specimen in the correct position and to separate the climatic chamber side from the metering box side.

The heat flow rate through the surround panels shall be determined, for example, by measuring it with heat flow measuring devices that are attached to the surface of the surround panel on the metering box side and/or climatic chamber side or by calculating it based on the temperature difference between the surface of the surround panel on the metering box side and climatic chamber side.

NOTE An example of the design of the surround panel is shown in [Annex D](#).

6.6 Calibration panels

The calibration panels shall be of a size similar to the test specimen. They are used to set up the measuring conditions of the surface coefficients of heat transfer.

The calibration panel conforms to ISO 12567-1.

6.7 Metering location of temperatures and irradiance

Metering location of temperatures and irradiance shall be as follows.

- a) The surface temperatures of the calibration panels shall be measured on the climatic chamber side and the metering box side. Temperatures shall be measured by appropriate methods at appropriate locations.
- b) The air temperatures and the baffle surface temperatures of the metering box side shall be measured using the same layout of the surface temperatures grid on the calibration panel. Examples of the temperature measurement are shown in [Annex E](#).
- c) The distance between the air temperature sensors and the surfaces of the surround panel of both the climatic chamber and metering box sides shall be approximately 100 mm.
- d) The net density of heat flow rate of the incident radiation, q_{Solar} , shall be measured by a radiometer installed on the climatic chamber side directly facing the light source. The position of the radiometer shall be near the centre of the test specimen and not cast a shadow on the temperature sensor. The distance between the radiometer and the surface of the surround panel shall be approximately 50 mm.
- e) The temperature sensors shall have the mechanism to eliminate the effects due to irradiance as much as possible.

6.8 Test specimens

The test specimen shall fill the surround panel aperture, in accordance with the actual construction.

The clearance between the surround panel and the test specimen frame shall be 5 mm or less, and the perimeter joints between the surround panel and the specimen shall be sealed with tape, caulking or mastic material.

7 Measurement procedure

7.1 Measurement

Measurements shall be performed in each case with and without irradiance. Recommended environmental conditions are shown in [Table 2](#).

The environmental conditions may be decided according to local standards, national standards or regulations. Alternate environmental conditions shall be reported in [8.1 d](#)).

Table 2 — Recommended environmental conditions

Element		Conditions according to ISO 15099		Conditions according to ISO 52022-3	
		Summer	Winter	Summer	Reference
Internal temperature, θ_{in}	°C	25	20	25	20
External temperature, θ_{ex}	°C	30	0	25	5
Internal surface coefficient of heat transfer ^a , h_{si}	W/(m ² ·K)	8	8	8	8
External surface coefficient of heat transfer ^a , h_{se}	W/(m ² ·K)	14	24	14	23
Density of heat flow rate of incident radiation ^b , q_{Solar}	W/m ²	500	300	500	300

NOTE 1 The performance requirements of windows and doors are the solar shading in summer and the solar heat gain in winter. Therefore, this document specifies each of the environmental conditions.

NOTE 2 Whether the heat flow rate due to thermal transmission is negligible or not should be decided according to [Annex B](#).

^a Internal and external surface coefficients of heat transfer shall be determined as specified in [Annex A](#).

^b Irradiance shall be normal incidence to the test plane. If the solar simulator cannot meet the density of heat flow rate of the incident radiation, q_{Solar} , under summer conditions, the value may be 400 W/m² or higher and the maximum density of heat flow rate.

The tolerance for the air temperature or environmental temperature difference between internal side and external side during measurements shall be ±2 °C or ±5 °C, respectively, of the set value. The difference between the environmental temperatures and the reference temperatures shall be less than 5 K.

The metering location of the metering box side shall be used the same layout of the air temperatures grid in the case when the surface temperatures of the test specimen and baffle are measured. Examples of the temperature measurement are shown in [Annex E](#).

The relative humidity in the climatic chamber and metering box shall be kept at low enough levels to avoid condensation or other factors.

The heat flow rate pass through the test specimen and others are as shown in [Clause 5](#).

The measurement set-up shall reach thermally stable conditions before valid measurements with or without irradiation can be performed. The required time to reach stability for steady-state tests depends upon such factors as irradiance, thermal resistance and thermal capacity of the specimen, surface coefficients of heat transfer, presence of mass transfer and/or moisture redistribution within the specimen, type and performance of automatic controllers of the apparatus. Due to variation of these factors, it is impossible to give a single criterion for steady-state. An example of a requirement for steady-state is the following: In order to check the stability of the measurement set-up, the thermal

transmittance (for measurements without irradiation) or solar heat gain coefficient (for measurements with irradiation) can be averaged over three disjoint time intervals of minimum 10 min each. The frequency of the measurement for each quantity (e.g. for the heat flow rate) can be 30 s or less. When the solar heat gain coefficients or thermal transmittances deviate less than 1 % from the average of the three values, thermally stable conditions can be assumed. In order to determine the valid final result, the measurement can then be continued for at least 30 min and the average over that time period shall be used.

7.2 Expression of results for reference conditions

The solar heat gain coefficient depends on several environmental conditions (e.g. the external airflow and the spectrum of the irradiance). The goal of the measurements is to determine standardized solar heat gain coefficient, g_{st} , for a certain set of reference environmental conditions. These measurement reference environmental conditions can be national or international reference conditions for product comparisons or product ratings or special conditions.

During the measurements, the measuring conditions should be close to the reference environmental conditions. However, it is difficult to realize exactly the reference environmental conditions. Therefore, the measured solar heat gain coefficient, g_m , is necessary either to prove that the difference between both conditions is negligible or to correct g_m to g_{st} . In following cases, it shall be checked and corrected according to the methods specified in [Annex C](#).

- a) Correction and sensitivity analysis of the effect of the non-ideal black absorber: This correction shall be done in the case when irradiation reflected back to the external side of the metering box, I_r , is not negligible. In the case of negligible level, it shall be proved.
- b) Correction and sensitivity analysis for a non-reference spectrum of the solar simulator.
- c) Correction and sensitivity analysis for non-reference external and internal convective heat transfer conditions: This correction may be used in the case to correct to specific surface coefficients of heat transfer.

8 Test report

8.1 Report contents

The test report shall contain the following information:

- a) number and title of this document, i.e. ISO 19467;
- b) identification of the organization performing the measurement;
- c) date of measurement;
- d) environmental conditions;
- e) all details necessary to identify the test specimen:
 - 1) specifications such as the name, type, width, height, thickness, material, colour, and other elements of the frame, glazing, shading device, opaque panel, or other components;
 - 2) the technical drawing (cross-sections) of the test specimen;
- f) results of measurement.

The results of measurement listed in [Table 3](#) shall be indicated. The results of the solar heat gain coefficient shall be accurate to two decimal places.

Table 3 — Indicated results of measurement

Element		With irradiance	Without irradiance
Standardized solar heat gain coefficient, g_{st}	—	0	—
Measured solar heat gain coefficient, g_m	—	0	—
Thermal transmittance, U_N	W/(m ² ·K)	—	✓
Projected width of test specimen, W_{sp}	m	0	
Projected height of test specimen, H_{sp}	m	0	
Projected area of test specimen, A_{sp}	m ²	0	
Ratio of glazing area, A_g/A_{sp}	—	0	
Net density of heat flow rate of incident radiation, q_{Solar}	W/m ²	✓	—
Net density of heat flow rate through the test specimen, q_{in}	W/m ²	✓	—
Net density of heat flow rate through the test specimen due to thermal transmission, $q_{in}(q_{Solar} = 0)$, $q'_{in}(q_{Solar} = 0)$	W/m ²	✓	✓
Mean environmental external temperature, θ_{ne} , θ'_{ne}	°C	0	0
Mean environmental internal temperature, θ_{ni} , θ'_{ni}	°C	0	0
NOTE Measured solar heat gain coefficient is obtained from measuring conditions. Standardized solar heat gain coefficient is the corrected value for effects of some difference between reference conditions and measuring conditions.			
0 Mandatory.			
✓ Recommended.			

8.2 Estimation of uncertainty

Estimation of the uncertainty of measurement should include the following contribution for uncertainty (standard uncertainty):

- uncertainties related to the measuring apparatus (including uncertainties in verification and characterization of the measuring apparatus);
- uncertainties related to the calibration of the measurement method (including uncertainties in thermal conductance of the calibration panels and settings on the internal and external surface coefficient of heat transfer);
- uncertainty related to the calibration of the measurement equipment and accuracy of the measurement equipment [radiometer, heat flow meter, thermocouple, thermopile, resistance temperature detector (RTD), temperature measurements, voltage measurements, electric power measurements, fluid flow rate measurements, etc.];
- uncertainties related to the irradiate conditions of solar simulator (temporal instability, non-uniformity, etc.);
- uncertainties related to the measurement method (measurement procedure, variations in the measurement conditions and additional uncertainties due to corrections made).

NOTE 1 The procedure for evaluating uncertainty is described in ISO/IEC Guide 98-3.

When describing uncertainty of measurement, the expanded uncertainty of approximately 95 % confidence level should be reported along with the results of measurement shown in [Table 3](#).

NOTE 2 The example of measurement and uncertainty analysis is shown in [Annex G](#).

Annex A (normative)

Determination of surface coefficient of heat transfer

A.1 General

The surface coefficient of heat transfer shall be set under the conditions without irradiance and using the calibration panel described in 6.6.

The settings for the value of the surface coefficient of heat transfer shall be evaluated through the method of using either environmental temperature or air temperature. The method for evaluating the surface coefficient of heat transfer with environmental temperature shall consist of ISO 12567-1:2010, Annex A. The method for evaluating the surface coefficient of heat transfer with air temperature is specified in this annex.

It shall be made sure that the heat balance is consistent. That is, a summation of the heat flow rate through the calibration panel and all of the heat flow rates pass through the surround panel and metering box.

The internal and external surface coefficients of heat transfer shall be adjusted to match the environmental conditions using the external airflow generator on the climatic chamber side and the one or more internal fans on the metering box side.

The tolerance between the set value for the surface coefficient of heat transfer and the environmental conditions shall be set at $\pm 10\%$. Thereafter, the operation of the adjusted external airflow generator and one or more internal fans shall remain constant for all subsequent measurements.

This means that the real surface coefficient of heat transfer may be higher than the reference value in case of samples with rough or structured surfaces.

A.2 Determination of surface coefficient of heat transfer with air temperature

Measurements without irradiance shall be used to determine the surface coefficient of heat transfer. The external surface coefficient of heat transfer, h_{se} , and the internal surface coefficient of heat transfer, h_{si} , shall be calculated using [Formula \(A.1\)](#) and [Formula \(A.2\)](#):

$$h_{se} = \frac{q_{cal}}{\theta_{ex} - \theta_{se}} \quad (A.1)$$

$$h_{si} = \frac{q_{cal}}{\theta_{si} - \theta_{in}} \quad (A.2)$$

where

h_{se} is the external surface coefficient of heat transfer, in $W/(m^2 \cdot K)$;

h_{si} is the internal surface coefficient of heat transfer, in $W/(m^2 \cdot K)$;

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

θ_{ex} is the external air temperature, in $^{\circ}C$;

θ_{in} is the internal air temperature, in °C;

θ_{se} is the external surface temperatures of the calibration panel, in °C;

θ_{si} is the internal surface temperatures of the calibration panel, in °C.

The density of heat flow rate through the calibration panel, q_{cal} , shall be calculated using [Formula \(A.3\)](#):

$$q_{cal} = \frac{\theta_{se} - \theta_{si}}{R_{cal}} \quad (A.3)$$

where

R_{cal} is the thermal resistance of the calibration panel, in m²·K/W.

The thermal resistance of the calibration panel, R_{cal} , shall be calculated using [Formula \(A.4\)](#):

$$R_{cal} = \sum \frac{d_j}{\lambda_j} \quad (A.4)$$

where

d_j is the thickness of the calibration panel of layer j, in metres;

λ_j is the thermal conductivity of the calibration panel of layer j, in W/(m·K).

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Annex B (normative)

Determination of night time U -value in case of small temperature difference

B.1 General

The thermal transmittance of the test specimen without irradiance, U_N , shall be estimated by means of this annex if the temperature difference, $\Delta T' = (\theta'_{ne} - \theta'_{ni})$ is too small. [Formula \(6\)](#) shall not be used for the determination of U_N if the temperature difference, $\Delta T'$, is below ± 3 K.

B.2 Determination of U_N for the case of negligible temperature difference

The net density of heat flow rate due to thermal transmission, $q_{in}(q_{Solar} = 0)$, can be neglected if the ratio of the net density of heat flow rate due to thermal transmission, $q_{in}(q_{Solar} = 0)$, to the net density of heat flow rate of incident radiation, q_{Solar} , is below 0,5 %.

B.3 Determination of U_N for the case of small temperature difference

In the case of small temperature difference except for negligible temperature difference, two U_N -value measurements shall be done. For both measurements, the average of the external and internal temperature, θ_{av} , shall be the same as for the measurements with irradiance. The maximum allowable difference for the average temperature is ± 1 K. This means that $|\theta_{av}(q_{Solar} = 0) - \theta_{av}(q_{Solar} \neq 0)| \leq 1$ K. The first U_N -value measurement shall be done with $\Delta T_1 = (10 \pm 1)$ K. The second U_N -value measurement shall be done with $\Delta T_2 = (15 \pm 1)$ K. The results shall then be extrapolated linearly to $\Delta T = \Delta T'$ as shown in [Figure B.1](#).

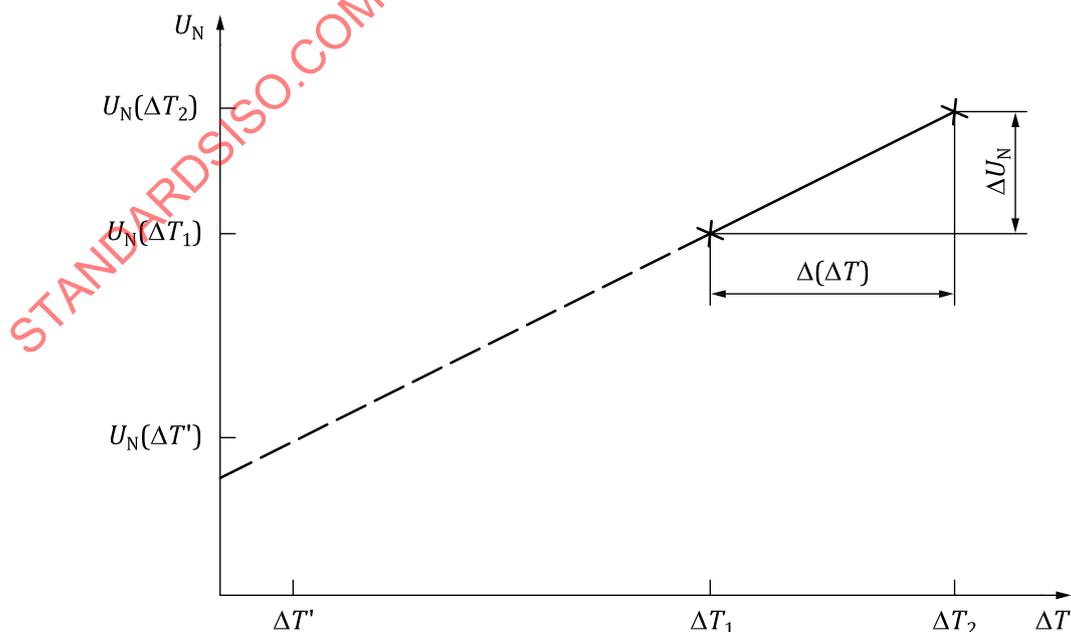


Figure B.1 — Thermal transmittance, U_N , for the case of small temperature difference

Annex C (normative)

Correction of measured solar heat gain coefficient to reference conditions

C.1 General

Measuring conditions and reference conditions should be equal, but practically, it is difficult to reach a perfect match. It is therefore essential to be able to evaluate the impact of non-reference measurement conditions and to correct the measured solar heat gain coefficient, g_m , to the standardized solar heat gain coefficient, g_{st} , if necessary. This annex provides methods for the correction and sensitivity analysis in following cases:

- a) non-ideal black absorbers (case1);
- b) non-reference spectrum of the solar simulator (case2);
- c) non-reference surface coefficients of heat transfer (case3).

If combined corrections are considered, the correction Δg for each case should be determined first. The combined effect shall be calculated using [Formula \(C.1\)](#):

$$g_{ref} = g_{exp} + \Delta g_{case1} + \Delta g_{case2} + \Delta g_{case3} \quad (C.1)$$

where

g_{ref} is the solar heat gain coefficient for the reference samples according to [Table C.1](#) under the reference condition;

g_{exp} is the solar heat gain coefficient for the reference samples according to [Table C.1](#) under the measuring condition;

Δg_{case1} is the difference of the solar heat gain coefficients between the reference condition and the measuring condition in the case of non-ideal black absorbers;

Δg_{case2} is the difference of the solar heat gain coefficients between the reference condition and the measuring condition in the case of non-reference spectrum of the solar simulator;

Δg_{case3} is the difference of the solar heat gain coefficients between the reference condition and the measuring condition in the case of non-reference surface coefficients of heat transfer.

In order to evaluate the necessities for the correction, the absolute errors, e , shall be calculated using [Formula \(C.2\)](#). If e is greater than 0,05, g_m shall be corrected to g_{st} :

$$e = |g_{exp} - g_{ref}| \quad (C.2)$$

where

e is the absolute error of the solar heat gain coefficient.

The solar heat gain coefficients under both the measuring conditions and the reference conditions shall be calculated according to procedure of ISO 9050 and calculated by reference samples as shown

in [Table C.1](#) in each correction. Optical characteristic parameters of reference samples are shown in [Table C.2](#).

Table C.1 — Reference samples to evaluate the necessities for the correction

Correction case	Reference sample		
	A	B	C
Non-ideal black absorbers	0	—	—
Non-reference spectrum of the solar simulator	0	0	0
Non-reference surface coefficients of heat transfer	—	0	—

Table C.2 — Optical characteristic parameters of reference samples

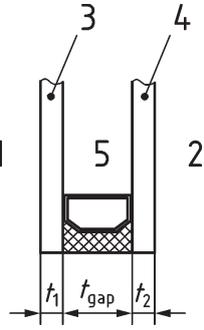
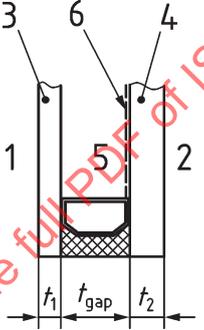
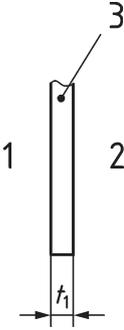
Element	Reference sample		
	A	B	C
Construction			
	Key 1 external 2 internal 3 first pane 4 second pane 5 air	Key 1 external 2 internal 3 first pane 4 second pane 5 air 6 low emissivity coating	Key 1 external 2 internal 3 first pane
Spectral transmittance of the first pane, $\tau_1(\lambda)$	Table C.3	Table C.4	Table C.5
Spectral reflectance of the first pane measured in the direction of incident radiation, $\rho_1(\lambda)$	Table C.3	Table C.4	Table C.5
Spectral reflectance of the first pane measured in the opposite direction of incident radiation, $\rho'_1(\lambda)$	Table C.3	Table C.4	Table C.5
Corrected emissivity of the first pane in the direction of incident radiation, ε_1	0,837	0,837	0,900
Corrected emissivity of the first pane in the opposite direction of incident radiation, ε'_1	0,837	0,837	0,900
Thickness of the first pane, t_1 , in metres	0,004	0,004	0,003
Width of the gap, t_{gap} , in metres	0,012	0,016	—
Spectral transmittance of the second pane, $\tau_2(\lambda)$	Table C.3	Table C.4	—

Table C.2 (continued)

Spectral reflectance of the second pane measured in the direction of incident radiation, $\rho_2(\lambda)$	Table C.3	Table C.4	—
Spectral reflectance of the second pane measured in the opposite direction of incident radiation, $\rho'_2(\lambda)$	Table C.3	Table C.4	—
Corrected emissivity of the second pane in the direction of incident radiation, ε_2	0,837	0,037	—
Corrected emissivity of the second pane in the opposite direction of incident radiation, ε'_2	0,837	0,837	—
Thickness of the second pane, t_2 , in metres	0,004	0,006	—

Table C.3 — Spectral characteristic parameters of the reference sample A

λ nm	$\tau_1(\lambda)$	$\rho_1(\lambda)$	$\rho'_1(\lambda)$	$\tau_2(\lambda)$	$\rho_2(\lambda)$	$\rho'_2(\lambda)$	λ nm	$\tau_1(\lambda)$	$\rho_1(\lambda)$	$\rho'_1(\lambda)$	$\tau_2(\lambda)$	$\rho_2(\lambda)$	$\rho'_2(\lambda)$
300	0,005	0,047	0,047	0,005	0,047	0,047	680	0,873	0,078	0,078	0,873	0,078	0,078
305	0,017	0,047	0,047	0,017	0,047	0,047	690	0,870	0,078	0,078	0,870	0,078	0,078
310	0,043	0,047	0,047	0,043	0,047	0,047	700	0,867	0,077	0,077	0,867	0,077	0,077
315	0,095	0,047	0,047	0,095	0,047	0,047	710	0,863	0,077	0,077	0,863	0,077	0,077
320	0,178	0,048	0,048	0,178	0,048	0,048	720	0,860	0,077	0,077	0,860	0,077	0,077
325	0,292	0,051	0,051	0,292	0,051	0,051	730	0,856	0,076	0,076	0,856	0,076	0,076
330	0,421	0,055	0,055	0,421	0,055	0,055	740	0,853	0,076	0,076	0,853	0,076	0,076
335	0,545	0,061	0,061	0,545	0,061	0,061	750	0,849	0,075	0,075	0,849	0,075	0,075
340	0,651	0,067	0,067	0,651	0,067	0,067	760	0,845	0,075	0,075	0,845	0,075	0,075
345	0,732	0,073	0,073	0,732	0,073	0,073	770	0,842	0,075	0,075	0,842	0,075	0,075
350	0,789	0,077	0,077	0,789	0,077	0,077	780	0,838	0,075	0,075	0,838	0,075	0,075
355	0,827	0,080	0,080	0,827	0,080	0,080	790	0,835	0,074	0,074	0,835	0,074	0,074
360	0,851	0,082	0,082	0,851	0,082	0,082	800	0,831	0,074	0,074	0,831	0,074	0,074
365	0,866	0,083	0,083	0,866	0,083	0,083	850	0,816	0,072	0,072	0,816	0,072	0,072
370	0,873	0,083	0,083	0,873	0,083	0,083	900	0,805	0,071	0,071	0,805	0,071	0,071
375	0,871	0,083	0,083	0,871	0,083	0,083	950	0,798	0,071	0,071	0,798	0,071	0,071
380	0,868	0,082	0,082	0,868	0,082	0,082	1 000	0,794	0,070	0,070	0,794	0,070	0,070
385	0,876	0,083	0,083	0,876	0,083	0,083	1 050	0,793	0,070	0,070	0,793	0,070	0,070
390	0,886	0,084	0,084	0,886	0,084	0,084	1 100	0,793	0,070	0,070	0,793	0,070	0,070
395	0,893	0,084	0,084	0,893	0,084	0,084	1 150	0,794	0,070	0,070	0,794	0,070	0,070
400	0,896	0,084	0,084	0,896	0,084	0,084	1 200	0,796	0,070	0,070	0,796	0,070	0,070
410	0,896	0,084	0,084	0,896	0,084	0,084	1 250	0,801	0,070	0,070	0,801	0,070	0,070
420	0,894	0,083	0,083	0,894	0,083	0,083	1 300	0,807	0,070	0,070	0,807	0,070	0,070
430	0,894	0,083	0,083	0,894	0,083	0,083	1 350	0,815	0,071	0,071	0,815	0,071	0,071
440	0,895	0,083	0,083	0,895	0,083	0,083	1 400	0,822	0,071	0,071	0,822	0,071	0,071
450	0,898	0,083	0,083	0,898	0,083	0,083	1 450	0,832	0,072	0,072	0,832	0,072	0,072
460	0,900	0,083	0,083	0,900	0,083	0,083	1 500	0,841	0,072	0,072	0,841	0,072	0,072

Table C.3 (continued)

λ nm	$\tau_1(\lambda)$	$\rho_1(\lambda)$	$\rho'_1(\lambda)$	$\tau_2(\lambda)$	$\rho_2(\lambda)$	$\rho'_2(\lambda)$	λ nm	$\tau_1(\lambda)$	$\rho_1(\lambda)$	$\rho'_1(\lambda)$	$\tau_2(\lambda)$	$\rho_2(\lambda)$	$\rho'_2(\lambda)$
470	0,901	0,083	0,083	0,901	0,083	0,083	1 550	0,849	0,073	0,073	0,849	0,073	0,073
480	0,903	0,083	0,083	0,903	0,083	0,083	1 600	0,854	0,073	0,073	0,854	0,073	0,073
490	0,904	0,083	0,083	0,904	0,083	0,083	1 650	0,857	0,073	0,073	0,857	0,073	0,073
500	0,905	0,083	0,083	0,905	0,083	0,083	1 700	0,858	0,073	0,073	0,858	0,073	0,073
510	0,905	0,082	0,082	0,905	0,082	0,082	1 750	0,858	0,073	0,073	0,858	0,073	0,073
520	0,905	0,082	0,082	0,905	0,082	0,082	1 800	0,858	0,073	0,073	0,858	0,073	0,073
530	0,905	0,082	0,082	0,905	0,082	0,082	1 850	0,857	0,072	0,072	0,857	0,072	0,072
540	0,905	0,082	0,082	0,905	0,082	0,082	1 900	0,856	0,072	0,072	0,856	0,072	0,072
550	0,904	0,082	0,082	0,904	0,082	0,082	1 950	0,854	0,072	0,072	0,854	0,072	0,072
560	0,903	0,082	0,082	0,903	0,082	0,082	2 000	0,854	0,072	0,072	0,854	0,072	0,072
570	0,902	0,081	0,081	0,902	0,081	0,081	2 050	0,855	0,072	0,072	0,855	0,072	0,072
580	0,900	0,081	0,081	0,900	0,081	0,081	2 100	0,855	0,072	0,072	0,855	0,072	0,072
590	0,898	0,081	0,081	0,898	0,081	0,081	2 150	0,852	0,071	0,071	0,852	0,071	0,071
600	0,896	0,081	0,081	0,896	0,081	0,081	2 200	0,839	0,070	0,070	0,839	0,070	0,070
610	0,893	0,080	0,080	0,893	0,080	0,080	2 250	0,838	0,070	0,070	0,838	0,070	0,070
620	0,891	0,080	0,080	0,891	0,080	0,080	2 300	0,844	0,070	0,070	0,844	0,070	0,070
630	0,888	0,080	0,080	0,888	0,080	0,080	2 350	0,846	0,070	0,070	0,846	0,070	0,070
640	0,885	0,079	0,079	0,885	0,079	0,079	2 400	0,843	0,070	0,070	0,843	0,070	0,070
650	0,882	0,079	0,079	0,882	0,079	0,079	2 450	0,834	0,069	0,069	0,834	0,069	0,069
660	0,880	0,079	0,079	0,880	0,079	0,079	2 500	0,829	0,068	0,068	0,829	0,068	0,068
670	0,877	0,078	0,078	0,877	0,078	0,078	—	—	—	—	—	—	—

Table C.4 — Spectral characteristic parameters of the reference sample B

λ nm	$\tau_1(\lambda)$	$\rho_1(\lambda)$	$\rho'_1(\lambda)$	$\tau_2(\lambda)$	$\rho_2(\lambda)$	$\rho'_2(\lambda)$	λ nm	$\tau_1(\lambda)$	$\rho_1(\lambda)$	$\rho'_1(\lambda)$	$\tau_2(\lambda)$	$\rho_2(\lambda)$	$\rho'_2(\lambda)$
300	0,005	0,047	0,047	0,000	0,212	0,058	680	0,873	0,078	0,078	0,424	0,213	0,190
305	0,017	0,047	0,047	0,001	0,229	0,057	690	0,870	0,078	0,078	0,369	0,279	0,244
310	0,043	0,047	0,047	0,003	0,255	0,057	700	0,867	0,077	0,077	0,316	0,346	0,299
315	0,095	0,047	0,047	0,008	0,289	0,059	710	0,863	0,077	0,077	0,267	0,413	0,353
320	0,178	0,048	0,048	0,016	0,316	0,067	720	0,860	0,077	0,077	0,224	0,477	0,403
325	0,292	0,051	0,051	0,029	0,338	0,084	730	0,856	0,076	0,076	0,187	0,535	0,448
330	0,421	0,055	0,055	0,046	0,352	0,112	740	0,853	0,076	0,076	0,155	0,587	0,487
335	0,545	0,061	0,061	0,064	0,360	0,151	750	0,849	0,075	0,075	0,129	0,632	0,522
340	0,651	0,067	0,067	0,084	0,363	0,193	760	0,845	0,075	0,075	0,108	0,673	0,550
345	0,732	0,073	0,073	0,104	0,364	0,234	770	0,842	0,075	0,075	0,090	0,707	0,574
350	0,789	0,077	0,077	0,124	0,364	0,267	780	0,838	0,075	0,075	0,075	0,737	0,594
355	0,827	0,080	0,080	0,148	0,365	0,292	790	0,835	0,074	0,074	0,064	0,763	0,611
360	0,851	0,082	0,082	0,176	0,364	0,310	800	0,831	0,074	0,074	0,054	0,785	0,624
365	0,866	0,083	0,083	0,205	0,362	0,319	850	0,816	0,072	0,072	0,025	0,855	0,659
370	0,873	0,083	0,083	0,234	0,358	0,322	900	0,805	0,071	0,071	0,013	0,893	0,675
375	0,871	0,083	0,083	0,259	0,350	0,316	950	0,798	0,071	0,071	0,008	0,914	0,682
380	0,868	0,082	0,082	0,285	0,338	0,307	1 000	0,794	0,070	0,070	0,005	0,927	0,688
385	0,876	0,083	0,083	0,316	0,321	0,298	1 050	0,793	0,070	0,070	0,004	0,935	0,694

Table C.4 (continued)

λ nm	$\tau_1(\lambda)$	$\rho_1(\lambda)$	$\rho'_1(\lambda)$	$\tau_2(\lambda)$	$\rho_2(\lambda)$	$\rho'_2(\lambda)$	λ nm	$\tau_1(\lambda)$	$\rho_1(\lambda)$	$\rho'_1(\lambda)$	$\tau_2(\lambda)$	$\rho_2(\lambda)$	$\rho'_2(\lambda)$
390	0,886	0,084	0,084	0,350	0,299	0,286	1 100	0,793	0,070	0,070	0,002	0,943	0,700
395	0,893	0,084	0,084	0,388	0,272	0,267	1 150	0,794	0,070	0,070	0,002	0,948	0,707
400	0,896	0,084	0,084	0,427	0,241	0,244	1 200	0,796	0,070	0,070	0,002	0,953	0,715
410	0,896	0,084	0,084	0,502	0,180	0,193	1 250	0,801	0,070	0,070	0,002	0,956	0,724
420	0,894	0,083	0,083	0,561	0,135	0,154	1 300	0,807	0,070	0,070	0,001	0,958	0,736
430	0,894	0,083	0,083	0,596	0,112	0,134	1 350	0,815	0,071	0,071	0,001	0,959	0,748
440	0,895	0,083	0,083	0,617	0,102	0,128	1 400	0,822	0,071	0,071	0,001	0,962	0,759
450	0,898	0,083	0,083	0,631	0,097	0,126	1 450	0,832	0,072	0,072	0,001	0,964	0,775
460	0,900	0,083	0,083	0,644	0,093	0,124	1 500	0,841	0,072	0,072	0,000	0,965	0,792
470	0,901	0,083	0,083	0,655	0,088	0,121	1 550	0,849	0,073	0,073	0,001	0,967	0,805
480	0,903	0,083	0,083	0,667	0,083	0,116	1 600	0,854	0,073	0,073	0,000	0,967	0,813
490	0,904	0,083	0,083	0,676	0,079	0,111	1 650	0,857	0,073	0,073	0,001	0,969	0,818
500	0,905	0,083	0,083	0,685	0,076	0,106	1 700	0,858	0,073	0,073	0,000	0,969	0,819
510	0,905	0,082	0,082	0,690	0,075	0,103	1 750	0,858	0,073	0,073	0,001	0,971	0,818
520	0,905	0,082	0,082	0,693	0,077	0,101	1 800	0,858	0,073	0,073	0,001	0,973	0,812
530	0,905	0,082	0,082	0,693	0,079	0,100	1 850	0,857	0,072	0,072	0,000	0,971	0,807
540	0,905	0,082	0,082	0,693	0,082	0,099	1 900	0,856	0,072	0,072	0,001	0,973	0,804
550	0,904	0,082	0,082	0,690	0,084	0,098	1 950	0,854	0,072	0,072	0,000	0,977	0,800
560	0,903	0,082	0,082	0,687	0,085	0,096	2 000	0,854	0,072	0,072	0,001	0,975	0,797
570	0,902	0,081	0,081	0,686	0,084	0,092	2 050	0,855	0,072	0,072	0,000	0,974	0,795
580	0,900	0,081	0,081	0,681	0,079	0,086	2 100	0,855	0,072	0,072	0,001	0,979	0,796
590	0,898	0,081	0,081	0,677	0,072	0,079	2 150	0,852	0,071	0,071	0,000	0,974	0,790
600	0,896	0,081	0,081	0,672	0,063	0,070	2 200	0,839	0,070	0,070	0,000	0,976	0,736
610	0,893	0,080	0,080	0,665	0,054	0,061	2 250	0,838	0,070	0,070	0,002	0,980	0,739
620	0,891	0,080	0,080	0,653	0,047	0,054	2 300	0,844	0,070	0,070	0,000	0,977	0,752
630	0,888	0,080	0,080	0,634	0,045	0,053	2 350	0,846	0,070	0,070	0,001	0,979	0,756
640	0,885	0,079	0,079	0,608	0,053	0,059	2 400	0,843	0,070	0,070	0,000	0,976	0,747
650	0,882	0,079	0,079	0,573	0,074	0,075	2 450	0,834	0,069	0,069	0,001	0,978	0,724
660	0,880	0,079	0,079	0,529	0,108	0,103	2 500	0,829	0,068	0,068	0,000	0,984	0,707
670	0,877	0,078	0,078	0,479	0,155	0,142	—	—	—	—	—	—	—

Table C.5 — Spectral characteristic parameters of the reference sample C

λ nm	$\tau_1(\lambda)$	$\rho_1(\lambda)$	$\rho'_1(\lambda)$	$\tau_2(\lambda)$	$\rho_2(\lambda)$	$\rho'_2(\lambda)$	λ nm	$\tau_1(\lambda)$	$\rho_1(\lambda)$	$\rho'_1(\lambda)$	$\tau_2(\lambda)$	$\rho_2(\lambda)$	$\rho'_2(\lambda)$
300	0,000	0,071	0,071	—	—	—	680	0,901	0,099	0,099	—	—	—
305	0,000	0,070	0,070	—	—	—	690	0,902	0,098	0,098	—	—	—
310	0,000	0,069	0,069	—	—	—	700	0,902	0,098	0,098	—	—	—
315	0,000	0,068	0,068	—	—	—	710	0,902	0,098	0,098	—	—	—
320	0,000	0,068	0,068	—	—	—	720	0,903	0,097	0,097	—	—	—
325	0,000	0,067	0,067	—	—	—	730	0,903	0,097	0,097	—	—	—
330	0,000	0,067	0,067	—	—	—	740	0,903	0,097	0,097	—	—	—
335	0,000	0,067	0,067	—	—	—	750	0,903	0,097	0,097	—	—	—
340	0,000	0,066	0,066	—	—	—	760	0,904	0,096	0,096	—	—	—

Table C.5 (continued)

λ nm	$\tau_1(\lambda)$	$\rho_1(\lambda)$	$\rho'_1(\lambda)$	$\tau_2(\lambda)$	$\rho_2(\lambda)$	$\rho'_2(\lambda)$	λ nm	$\tau_1(\lambda)$	$\rho_1(\lambda)$	$\rho'_1(\lambda)$	$\tau_2(\lambda)$	$\rho_2(\lambda)$	$\rho'_2(\lambda)$
345	0,000	0,067	0,067	—	—	—	770	0,904	0,096	0,096	—	—	—
350	0,000	0,067	0,067	—	—	—	780	0,904	0,096	0,096	—	—	—
355	0,000	0,067	0,067	—	—	—	790	0,903	0,097	0,097	—	—	—
360	0,000	0,067	0,067	—	—	—	800	0,904	0,096	0,096	—	—	—
365	0,000	0,068	0,068	—	—	—	850	0,907	0,093	0,093	—	—	—
370	0,000	0,069	0,069	—	—	—	900	0,904	0,096	0,096	—	—	—
375	0,000	0,071	0,071	—	—	—	950	0,913	0,087	0,087	—	—	—
380	0,000	0,072	0,072	—	—	—	1 000	0,912	0,088	0,088	—	—	—
385	0,001	0,072	0,072	—	—	—	1 050	0,916	0,084	0,084	—	—	—
390	0,014	0,073	0,073	—	—	—	1 100	0,910	0,090	0,090	—	—	—
395	0,094	0,075	0,075	—	—	—	1 150	0,838	0,087	0,087	—	—	—
400	0,268	0,080	0,080	—	—	—	1 200	0,884	0,091	0,091	—	—	—
410	0,645	0,094	0,094	—	—	—	1 250	0,916	0,084	0,084	—	—	—
420	0,821	0,103	0,103	—	—	—	1 300	0,913	0,087	0,087	—	—	—
430	0,858	0,106	0,106	—	—	—	1 350	0,862	0,090	0,090	—	—	—
440	0,869	0,106	0,106	—	—	—	1 400	0,791	0,084	0,084	—	—	—
450	0,874	0,105	0,105	—	—	—	1 450	0,856	0,089	0,089	—	—	—
460	0,876	0,105	0,105	—	—	—	1 500	0,883	0,092	0,092	—	—	—
470	0,878	0,104	0,104	—	—	—	1 550	0,894	0,093	0,093	—	—	—
480	0,879	0,104	0,104	—	—	—	1 600	0,842	0,087	0,087	—	—	—
490	0,879	0,103	0,103	—	—	—	1 650	0,318	0,057	0,057	—	—	—
500	0,880	0,103	0,103	—	—	—	1 700	0,281	0,053	0,053	—	—	—
510	0,879	0,102	0,102	—	—	—	1 750	0,622	0,064	0,064	—	—	—
520	0,878	0,102	0,102	—	—	—	1 800	0,692	0,075	0,075	—	—	—
530	0,876	0,101	0,101	—	—	—	1 850	0,691	0,075	0,075	—	—	—
540	0,874	0,100	0,100	—	—	—	1 900	0,490	0,069	0,069	—	—	—
550	0,873	0,100	0,100	—	—	—	1 950	0,732	0,075	0,075	—	—	—
560	0,873	0,099	0,099	—	—	—	2 000	0,709	0,075	0,075	—	—	—
570	0,872	0,099	0,099	—	—	—	2 050	0,582	0,067	0,067	—	—	—
580	0,870	0,098	0,098	—	—	—	2 100	0,453	0,059	0,059	—	—	—
590	0,872	0,098	0,098	—	—	—	2 150	0,044	0,044	0,044	—	—	—
600	0,876	0,098	0,098	—	—	—	2 200	0,292	0,050	0,050	—	—	—
610	0,879	0,099	0,099	—	—	—	2 250	0,089	0,049	0,049	—	—	—
620	0,880	0,099	0,099	—	—	—	2 300	0,004	0,046	0,046	—	—	—
630	0,880	0,098	0,098	—	—	—	2 350	0,017	0,046	0,046	—	—	—
640	0,884	0,099	0,099	—	—	—	2 400	0,007	0,044	0,044	—	—	—
650	0,890	0,099	0,099	—	—	—	2 450	0,001	0,045	0,045	—	—	—
660	0,895	0,099	0,099	—	—	—	2 500	0,023	0,047	0,047	—	—	—
670	0,899	0,100	0,100	—	—	—	—	—	—	—	—	—	—

C.2 Correction of the effect of the non-ideal black absorber

C.2.1 Correction procedure

g_m is not equal to g_{st} if some of the transmitted radiation is reflected back to the external environment and is therefore not absorbed by the measurement system behind the test specimen. If only the absorptance of the absorber is not equal to reference conditions, the relationship between g_{st} and g_m can be established using [Formula \(C.3\)](#), [Formula \(C.4\)](#) and [Formula \(C.5\)](#):

$$g_{st} = \tau_{st,sp} + q_{i,st,sp} \quad (C.3)$$

$$g_m = \tau_{st,sp} \times \frac{\alpha_{m,abs}}{1 - \rho_{st,abs} \times \rho'_{st,sp}} + q_{i,st,sp} \times \frac{\alpha_{m,sp}}{\alpha_{st,sp}} \quad (C.4)$$

$$\alpha_{m,sp} = \alpha_{st,sp} \times \left(1 + \frac{\alpha'_{st,sp}}{\alpha_{st,sp}} \times \tau_{st,sp} \times \rho_{st,abs} \times \frac{1}{1 - \rho_{st,abs} \times \rho'_{st,sp}} \right) \quad (C.5)$$

where

$\tau_{st,sp}$ is the solar transmittance of the test specimen for incident radiation coming from the external side in the case of reference condition;

$q_{i,st,sp}$ is the secondary heat transfer factor of the test specimen towards the internal side in the case of reference condition;

$\alpha_{m,abs}$ is the solar absorptance of the absorber for incident radiation coming from the external side in the case of measuring condition;

$\alpha_{m,sp}$ is the solar absorptance of the test specimen for incident radiation coming from the external side in the case of measuring condition;

$\alpha_{st,sp}$ is the solar absorptance of the test specimen for incident radiation coming from the external side in the case of reference condition;

$\alpha'_{st,sp}$ is the solar absorptance of the test specimen for incident radiation coming from the internal side in the case of reference condition;

$\rho_{st,abs}$ is the solar reflectance of the absorber for incident radiation coming from the external side in the case of reference condition;

$\rho'_{st,sp}$ is the solar reflectance of the test specimen for incident radiation coming from the internal side in the case of reference condition.

α_{sp} can be determined using [Formula \(C.6\)](#):

$$\alpha_{sp} = \frac{\int \alpha_{\lambda,sp} S_{\lambda} d\lambda}{\int S_{\lambda} d\lambda} \quad (C.6)$$

where

$\alpha_{\lambda,sp}$ is the spectral absorptance of the test specimen for radiation coming from the external side;

S_{λ} is the spectral distribution of the solar simulator.

$\alpha_{\lambda,sp}$ can be determined using [Formula \(C.7\)](#):

$$\alpha_{\lambda,sp} = 1 - \rho_{\lambda,sp} - \tau_{\lambda,sp} - \eta \quad (C.7)$$

where

$\rho_{\lambda,sp}$ is the spectral reflectance of the test specimen for incident radiation coming from the external side. This value can be measured according to ISO 9050 in the case of uniform samples (e.g. glass pane) and can be measured according to EN 14500[7], EN 14501[8] or CIE 130[10] in the case of complex samples (e.g. venetian blind);

$\tau_{\lambda,sp}$ is the spectral transmittance of the test specimen for incident radiation coming from the external side. This value can be measured according to ISO 9050 in the case of uniform samples (e.g. glass pane) and can be measured according to EN 14500[7], EN 14501[8] or CIE 130[10] in the case of complex samples (e.g. venetian blind);

η is the efficiency of solar energy conversion for the measuring conditions in order to take into account that some of the incident radiation is converted into useful energy forms and extracted from the test specimen. This is only necessary in the case of active renewable energy harvesting components, such as building-integrated PV (BIPV) or building-solar thermal collectors (BIST), integrated into the test specimen (see [Annex F](#)). This specifically means that η should be set to zero when collectors are not operated (stagnation condition) or when a PV system is in the open circuit state.

α'_{sp} can be determined using [Formula \(C.8\)](#) and [Formula \(C.9\)](#), analogously whereby it is clear that $\rho_{\lambda,sp}$ is not equal to $\rho'_{\lambda,sp}$ in general. It should also be noted that, in general, $\tau_{\lambda,sp}$ is not equal to $\tau'_{\lambda,sp}$ in the case of complex fenestration systems. Only in the case of clear samples it is generally true that $\tau_{\lambda,sp}$ and $\tau'_{\lambda,sp}$ are equal because of the reversibility principle for light rays.

$$\alpha'_{sp} = \frac{\int a'_{\lambda,sp} S_{\lambda} d\lambda}{\int S_{\lambda} d\lambda} \quad (C.8)$$

$$\alpha'_{\lambda,sp} = 1 - \rho'_{\lambda,sp} - \tau'_{\lambda,sp} - \eta \quad (C.9)$$

where

$\alpha'_{\lambda,sp}$ is the spectral absorptance of the test specimen for radiation coming from the internal side;

$\rho'_{\lambda,sp}$ is the spectral reflectance of the test specimen for incident radiation coming from the internal side. This value can be measured according to ISO 9050 in the case of uniform samples (e.g. glass pane) and can be measured according to EN 14500[7], EN 14501[8] or CIE 130[10] in the case of complex samples (e.g. venetian blind);

$\tau'_{\lambda,sp}$ is the spectral transmittance of the test specimen for incident radiation coming from the internal side. This value can be measured according to ISO 9050: in the case of uniform samples (e.g. glass pane) and can be measured according to EN 14500[7], EN 14501[8] or CIE 130[10] in the case of complex samples (e.g. venetian blind).

Practical line of action:

- a) measure g_m ;
- b) determine the properties needed in [Formula \(C.4\)](#) for the correction of g_m ;
- c) correct g_m to g_{st} ;

- d) if no measured values are available, the properties should be varied in the maximum physically meaningful range in order to determine the maximum possible impact on g_m by varying the parameters within these ranges.

C.2.2 I_r measurement

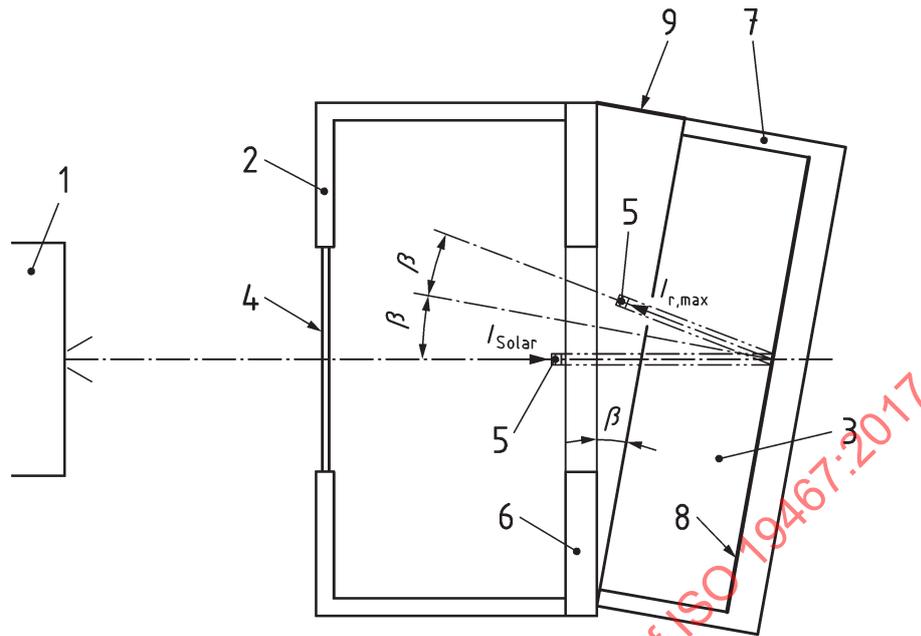
This procedure may be used in order to check whether I_r can be negligible or not. The metering box and the radiometer are set as shown in [Figure C.1](#). I_r should be measured in the state without the test specimen in order to measure the maximum reflected irradiation, $I_{r,max}$. The angle from normal incidence of the irradiation, β , should not exceed 10° and the self-shading of the radiometer should be avoided. If there is any gap between the surround panel and the metering box caused by this inclination, the gap should be closed by the gap closing device (e.g. thick screen with same optical properties as internal surface of the metering box). If the maximum solar reflectance from the metering box, $\rho_{box,max}$ that is calculated by [Formula \(C.10\)](#) is lower than 0,05, I_r can be negligible:

$$\rho_{box,max} = \frac{I_{r,max}}{I_{Solar}} \quad (C.10)$$

where

$\rho_{box,max}$ is the maximum solar reflectance from the metering box.

$I_{r,max}$ is the maximum density of heat flow rate of the incident radiation that is transmitted to the external side of the metering box after being reflected in the internal side of the metering box, in W/m^2 .


Key

- | | | | |
|---|----------------------|---|-------------------------------------|
| 1 | solar simulator | 6 | surround panel |
| 2 | climatic chamber | 7 | peripheral wall of the metering box |
| 3 | metering box | 8 | cooling device |
| 4 | transparent aperture | 9 | gap closing device |
| 5 | radiometer | | |

Figure C.1 — Example of horizontal cross-section of I_r measurement
C.3 Correction for the non-reference spectrum of the solar simulator

The spectrum of the irradiation of a solar simulator depends mainly on the type of the illuminant and the age of the illuminant. The relationship between g_{st} and g_m can be established using [Formula \(C.11\)](#). Therefore, the impact of a non-reference spectrum can be evaluated or corrected using [Formula \(C.12\)](#):

$$g_m = \tau_{sim,sp} + q_{i,sim,sp} \approx g_{st} + (\tau_{sim,sp} - \tau_{st,sp}) + q_{i,sim,sp} \times \left(1 - \frac{\alpha_{st,sp}}{\alpha_{sim,sp}} \right) \quad (C.11)$$

$$g_{st} \approx g_m - (\tau_{sim,sp} - \tau_{st,sp}) - q_{i,sim,sp} \times \left(1 - \frac{\alpha_{st,sp}}{\alpha_{sim,sp}} \right) \quad (C.12)$$

where

- $\tau_{\text{sim,sp}}$ is the solar transmittance of the test specimen for incident radiation coming from the external side calculated using the spectrum of the solar simulator (detailed calculation procedure is described in [Annex H](#));
- $q_{\text{i,sim,sp}}$ is the secondary heat transfer factor of the test specimen towards the internal side calculated using the spectrum of the solar simulator;
- $\alpha_{\text{sim,sp}}$ is the solar absorptance of the test specimen for incident radiation coming from the external side calculated using the spectrum of the solar simulator (detailed calculation procedure is described in [Annex H](#));
- $\tau_{\text{st,sp}}$ is the solar transmittance of the test specimen for incident radiation coming from the external side calculated using the reference spectrum as shown in ISO 9050:2003, Table 2;
- $\alpha_{\text{st,sp}}$ is the solar absorptance of the test specimen for incident radiation coming from the external side calculated using the reference spectrum as shown in ISO 9050:2003, Table 2.

For the spectral correction in the case of test specimens with $(g_m - \tau_{\text{sim,sp}})/g_m < 0,1$, only the spectral transmittance, τ_λ , is needed in addition to the solar heat gain coefficient, g_m and [Formula \(C.12\)](#) can be simplified to [Formula \(C.13\)](#):

$$g_{\text{st}} \approx g_m - (\tau_{\text{sim,sp}} - \tau_{\text{st,sp}}) \quad (\text{C.13})$$

C.4 Correction for non-reference external and internal convective heat transfer conditions

Convective and radiative heat transfer conditions on the internal and external sides of the test specimen affect only the secondary heat transfer factor of the test specimen towards the internal side, q_i . Both, the assessment of the impact of non-reference heat transfer conditions and the correction to reference conditions can be done using the γ - formalism (see Reference [13]). First of all, the parameter $\gamma \in [0,1]$ is determined using [Formula \(C.14\)](#):

$$q_{\text{i,m}} = \frac{(R_{\text{se,m}} + \gamma \times R_{\text{sp}}) \times \alpha_{\text{sp}}}{R_{\text{se,m}} + R_{\text{sp}} + R_{\text{si,m}}} \quad (\text{C.14})$$

where

- $q_{\text{i,m}}$ is the measured secondary heat transfer factor of the test specimen towards the internal side;
- $R_{\text{se,m}}$ is the measured external surface thermal resistance, in $\text{m}^2 \cdot \text{K}/\text{W}$;
- $R_{\text{si,m}}$ is the measured internal surface thermal resistance, in $\text{m}^2 \cdot \text{K}/\text{W}$;
- R_{sp} is the thermal resistance of the test specimen, in $\text{m}^2 \cdot \text{K}/\text{W}$;
- α_{sp} is the solar absorptance of the test specimen.

The term " $\gamma \times R_{\text{sp}}$ " can be interpreted as a sliding variable resistor where γ determines the location of the absorptance in the test specimen. The standardized secondary heat transfer factor towards the internal side, $q_{\text{i,st}}$ can then be corrected to reference heat transfer conditions R_{se} and R_{si} are determined using [Formula \(C.15\)](#):

$$q_{\text{i,st}} = \frac{(R_{\text{se,st}} + \gamma \times R_{\text{sp}}) \times \alpha_{\text{sp}}}{R_{\text{se,st}} + R_{\text{sp}} + R_{\text{si,st}}} \quad (\text{C.15})$$

where

$q_{i,st}$ is the standardized secondary heat transfer factor of the test specimen towards the internal side;

$R_{se,st}$ is the standardized external surface thermal resistance, in $m^2 \cdot K/W$;

$R_{si,st}$ is the standardized internal surface thermal resistance, in $m^2 \cdot K/W$.

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Annex D (informative)

Examples of design of measuring apparatus

D.1 General

The measuring apparatuses described in this annex are designed to determine the solar heat gain coefficient by different ways as follows: hot box method and cool box method. There are many differences not only the design of the measuring apparatus but also the definition of the boundary conditions.

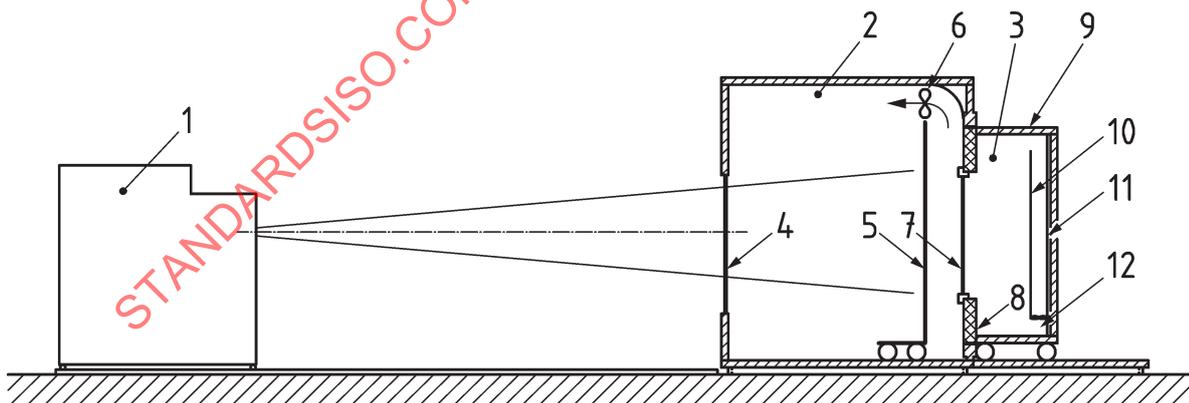
D.2 Design A

D.2.1 General

The apparatus described in this subclause is designed to determine the solar heat gain coefficient based on the definition of ISO 15099 and on the measurement by the hot box method specified in ISO 8990 and ISO 12567-1. Therefore, the apparatus is designed so that can be measured continuously for the two boundary conditions: with irradiance and without irradiance (see Reference [14]).

The condition “without irradiance” is used because all effects on the thermal resistances due to irradiance are incorporated in the solar heat gain coefficient and the environmental temperatures, as defined in ISO 15099 (all of the effects, such as changes in the surface coefficient of heat transfer caused by irradiance, shall be included in the solar heat gain coefficient).

In the case of this method, it is recommended to set up the environmental conditions according to ISO 15099 shown in Table 4. The overall construction for the measuring apparatus is shown in [Figure D.1](#).



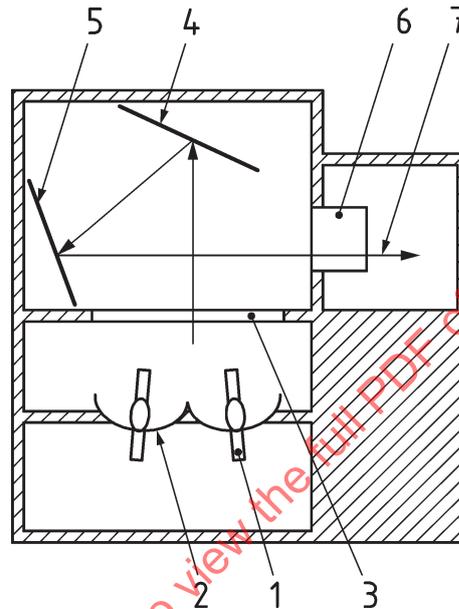
Key

- | | | | |
|---|----------------------------|----|-------------------------------------|
| 1 | solar simulator | 7 | test specimen |
| 2 | climatic chamber | 8 | surround panel |
| 3 | metering box | 9 | peripheral wall of the metering box |
| 4 | transparent aperture | 10 | internal side baffle |
| 5 | external side baffle | 11 | cooling plate |
| 6 | external airflow generator | 12 | internal fans and heater |

Figure D.1 — Construction for apparatus in case of hot box method

D.2.2 Design of solar simulator

The steady-state solar simulator made of xenon lamp is used in this apparatus. The example of the cross-section of the lamp house of the solar simulator is shown in Figure D.2. Light irradiated short-arc xenon lamps (6,5 kW × 4 lamps) in the bottom of the apparatus are reflected by the ellipsoidal reflector or directly through an air mass filter (AM1,5G), subsequently reflected by the primary mirror and the secondary mirror. Finally, the light is irradiated to the test specimen through via the integrator lens. Three lamps are at a constant current control and only one lamp is a feedback current control by detecting the light quantity after passing through the integrator lens. The integrator lens is critical optical components in order to form the light with uniform distribution on the irradiated surface.



Key

- 1 short-arc xenon lamps (6,5 kW × 4 lamps)
- 2 ellipsoidal reflector
- 3 air mass filter (AM1,5G)
- 4 primary mirror
- 5 secondary mirror
- 6 integrator lens
- 7 incident radiation

Figure D.2 — Example of cross-section of lamp house of solar simulator

Table D.1 — Example of spectral match of solar simulator

No.	Wavelength range nm	Percentage of total irradiance in the wavelength range 300 nm to 2 500 nm		Spectral match
		Solar simulator	Table 1	
1	300 to 400	4,0 %	4,6 %	0,85
2	400 to 500	15,2 %	14,1 %	1,07
3	500 to 600	15,2 %	15,4 %	0,99
4	600 to 700	13,3 %	14,0 %	0,95
5	700 to 800	10,1 %	11,3 %	0,89
6	800 to 900	9,4 %	9,4 %	1,00

Table D.1 (continued)

7	900 to 1 100	13,8 %	12,2 %	1,12
8	1 100 to 1 700	14,3 %	14,1 %	1,02
9	1 700 to 2 500	4,7 %	4,8 %	0,99

D.2.3 Design and determination of heat flow rate of metering box

The hot box based on ISO 8990 and ISO 12567-1 is used as the metering box in this apparatus.

The heat flow meters are attached to the internal side surfaces of the metering box in order to measure the heat flow rates for the entire metering box. The heat flow meters should be the solar absorptance of 0,90 or greater and be matte finished.

The information regarding the heat flow meters may be referred to ISO 8301:1991, 2.3, 2.4, 2.5 and Annex B.

D.2.4 Design and determination of heat flow rate of surround panel

D.2.4.1 Design of surround panel

The example of the cross-sections and internal elevation of the surround panel specified in 6.5 in the case of hot box method are shown in Figure D.3. Other design of surround panels can also be used as alternatives.

The shield plate is installed on the surface of the surround panel on the climatic chamber side in order to avoid the reflection of irradiated light. The shield plate should be the solar absorptance of 0,90 or greater and be matte finished. In addition, the rear surface of the shield plate should have the ventilation layers for discharging the absorbed heat in order to reduce the heat flow rate into the metering box. The shield plate should be in the same state of the construction as the normal external wall. Therefore, it is necessary to cover the area of the frame that is not irradiating the irradiance.

The heat flow meters are attached to the entire surface of the surround panel on the metering box side in order to measure the passing heat flow rate. The heat flow meters should be the solar absorptance of 0,90 or greater and be matte finished. It should be made sure that there are no gaps between the heat flow meters attached on the entire surround panel within the internal dimensions of the metering box. However, depending on the dimensions of the surround panel aperture, it can be difficult to attach the heat flow meters without any gaps. In such cases, the heat flow meters are attached to be equal with respect to the area of the surround panel. Since the core of the surround panel using the insulating materials takes time to stabilize the heat transfer, the materials with relatively high thermal resistance and small heat capacity, such as honeycomb core should be selected, in order to stabilize the heat transfer in a short period of time. The wooden trims that are usually constructed on the internal side of the frame are installed.

D.2.4.3 Determination of heat flow rate of surround panel

If there are gaps between the heat flow meters attached on the surround panel, the heat flow rate measured by the heat flow meters is the part of heat flow rate of the surround panel. Therefore, the heat flow rate of the surround panel is corrected by [Formula \(D.1\)](#) and [Formula \(D.2\)](#) on the assumption that the uniform heat flow is generated through the entire surround panel:

$$A_p = W_{ps} \times H_{ps} - A_{sp} \quad (D.1)$$

$$\Phi_p = \frac{A_p \times \sum \Phi_t}{\sum A_t} \quad (D.2)$$

where

A_p is the area of the surround panel on the internal dimensions of the metering box, in m²;

A_{sp} is the projected area, in m²;

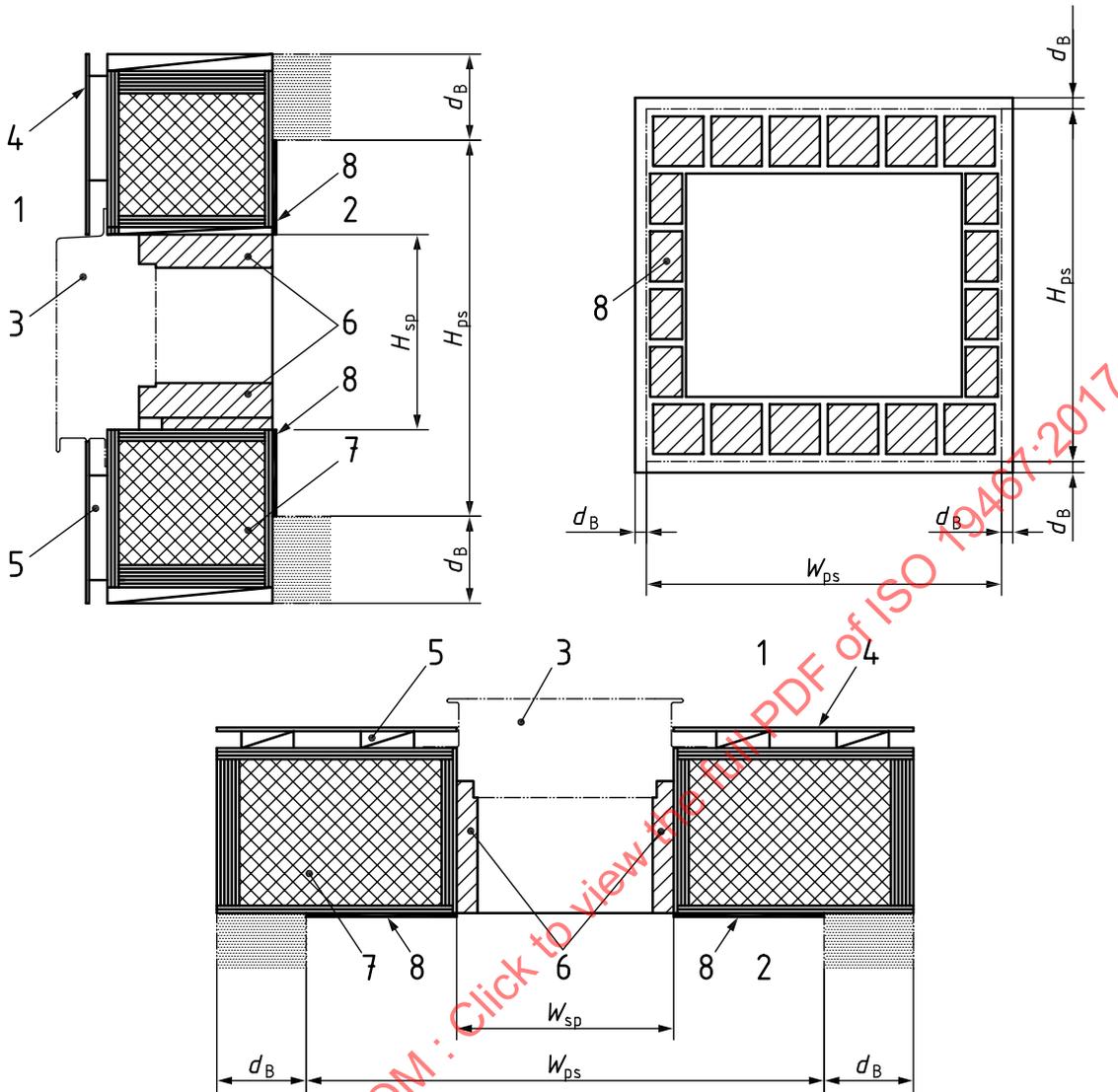
A_t is the area of heat flow meters, in m²;

W_{ps} is the internal width of the metering box, in metres;

H_{ps} is the internal height of the metering box, in metres;

Φ_p is the heat flow rate through the entire surround panel, in watts;

Φ_t is the heat flow rate to be measured by the heat flow meters, in watts.



Key

- | | | | |
|---|----------------------------------|----------|--|
| 1 | external (climatic chamber) side | W_{sp} | projected width of test specimen |
| 2 | internal (metering box) side | H_{sp} | projected height of test specimen |
| 3 | test specimen | W_{ps} | internal width of metering box |
| 4 | shield plate | H_{ps} | internal height of metering box |
| 5 | furring strip for ventilation | d_B | thickness of planes of peripheral wall of metering box |
| 6 | wooden trim | | |
| 7 | core (honeycomb core) | | |
| 8 | heat flow meter | | |

Figure D.3 — Example of cross-sections and internal elevation of surround panel

D.3 Design B

D.3.1 General

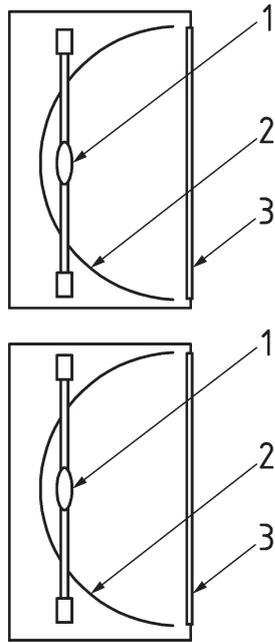
The metering box simulates the internal side and can be constructed either as a guarded hot box or as a calibrated hot box. The construction should comply with the requirements specified in ISO 8990 except where modified by this document.

To control climatic steady-state conditions in the metering box, the transmitted energy should be absorbed and removed by a heat removal system. The heat flow Φ_C removed by the cooling device can either be measured with a heat flow meter or with a fluid calorimeter. In both cases, the stationary climate condition of the metering chamber can be maintained by several control parameters. These are the inlet temperature of the cooling fluid, the fluid volumetric flow rate and an additional internal heating.

If the climatic stationary conditions of the metering side are controlled by the inlet fluid temperature and the interchange of heat exchanger to the air is adequate, the resultant surface temperature of the heat exchanger will be close to the ambient temperature of the metering side. Therefore, internal side baffles are optional.

D.3.2 Design of solar simulator

The steady-state solar simulator with metal halide lamps can be used to create a uniform irradiance on the test specimen. Due to the composition of the illuminant with rare earth metals the lamps create a solar spectral distribution which is very close to the global radiation according to Reference [9]. The solar simulator can be constructed with one or more lamps. The configuration of four lamps in square with a connection power of 4 kW of each lamp has been proven as suitable. The light path of the radiation can be directed with parabolic reflectors. The surface of the reflector can be fine structured and should have a not selective high reflectance. If it is necessary, special filter glasses in front of the lamps can be used to meet the requirement on the spectral distribution and the uniformity. The example of the cross-section of the lamp house of the solar simulator is shown in [Figure D.4](#).



Key

- 1 metal halide lamps
- 2 parabolic reflectors
- 3 air mass filter

Figure D.4 — Example of cross-section of lamp house of solar simulator

D.3.3 Design and determination of heat flow rate of metering box

The metering box with fluid calorimeter is constructed of the following:

- a) Interior heat removal system: The heat exchanging system with a chilled fluid flow is installed behind the test specimen in order to remove heat flow due to solar radiation and thermal transmission. The absorber system can be a freestanding air-to-fluid (rippled) heat exchanger which removes heat by direct conduction from the solar absorption and by an air to fluid heat exchange. The transmitted solar radiation should be absorbed entirely on the heat exchanging system. Stray light on the metering box walls should be avoided. The absorption of the heat exchanging system should be not less than 0,90 in the spectral bandwidth of 300 nm to 2 500 nm.

The heat flow rate Φ_C , in watts, can be given by [Formula \(D.3\)](#):

$$\Phi_C = \rho \times C_p \times V \times (T_{in} - T_{out}) \tag{D.3}$$

where

- Φ_C is the heat flow rate removed by the heat exchanger, in watts;
- ρ is the density of cooling fluid, in kg/m³;
- C_p is the specific heat capacity, in J/(kg·K);
- V is the fluid volumetric flow rate, in m³/s;
- T_{in} is the inlet fluid thermodynamic temperature, in kelvins;
- T_{out} is the outlet fluid thermodynamic temperature, in kelvins.

- b) Temperature difference measuring device: Temperature sensors to measure the temperature difference of inlet fluid temperature and outlet fluid temperature of the heat exchanger should be located inside the metering box near to the chamber wall in the middle of the fluid stream. Suitable temperature measurement devices are the following:
 - 1) PT 100 high precision resistance thermometer;
 - 2) matched type T thermocouple sensors;
 - 3) type T thermopile sensors.
- c) Volumetric fluid flow rate measuring device: The volumetric fluid flow rate should be measured with an electromagnetic flow meter.
- d) Internal heating system: An internal heating system can be installed in the metering chamber to enable an additional heat flux into the metering box to increase the heat flow rate, Φ_C , of the cooling device. This can be necessary when the transmitted energy is too small to achieve a sufficient resolution of the measurement signal. The heat flow rate, Φ_H , supplied by the heater should be measured with a true RMS measurement of the electrical power and current.
- e) Calorimeter wall: Heat flux from the metering box into the guarded box should be determined from the outside-inside temperature difference and the thermal conductivity of wall material, or by equivalent instrumentation. Therefore, the metering box walls can be equipped with a multi junction thermopile system. The junction's pairs should be connected in series and each junction pair should be located directly opposite across the wall thickness. The temperature sensor should be uniformly distributed with a density of at least one pair of junctions per 0,25 m² surface.

D.3.4 Design and determination of heat flow rate of surround panel

D.3.4.1 Design of surround panel

The construction should comply with the requirements specified in ISO 12567-1 except where modified by this document. The surround panel acts as an idealized wall with high thermal resistance and holds the window or door in the correct position and separates the warm box from the cold box. The surround panel should be large enough to cover the open face of the guard box in the case of a guarded hot-box apparatus or the open face of the hot box in the case of a calibrated hot-box apparatus.

The surround panel should be made of homogeneous material of long time stable low thermal conductivity. The thermal conductivity of the core material should be determined with a guarded hot plate measurement device and should be not greater than 0,04 W/(m·K). The surround panel should be uniform and should have at least the maximum thickness of the test specimen but not less than 100 mm. The aperture area should be significantly smaller than the area of the heat exchanging system to avoid direct radiation on the chamber walls of the metering box.

The heat flow through the surround should be determined from the temperature difference between climatic side and metering side and from the thermal conductivity of surround panel. Therefore, the surround panel can be equipped with the following:

- a) Multi junction thermopile system. The junction's pairs should be connected in series and each junction pair should be located directly opposite across the wall thickness. The temperature sensor should be uniformly distributed with a density of at least four temperature sensors on each side of the wall surface.
- b) As individual thermocouples of at least four temperature sensors on each side of the surround panel.

The surface of the surround panel facing the solar simulator should have an opaque thin coating with an absorbance $\alpha < 0,2$ and an emissivity $\varepsilon > 0,8$. The surface temperature sensors should be embedded behind the coating.

D.3.4.2 Determination of heat flow rate of surround panel

The heat flow rate through the surround panel, Φ_P , can be given by [Formula \(D.4\)](#):

$$\Phi_P = \frac{A_{SP} \times \theta_{SP}}{R_P} \quad (D.4)$$

where

Φ_P is the heat flow rate through the surround panel for the conditions with irradiance, in watts;

A_{SP} is the projected area of the surround panel, in m²;

θ_{SP} is the difference between the average surface temperatures of the surround panel, in kelvins;

R_P is the thermal resistance of the surround panel, in m²·K/W.

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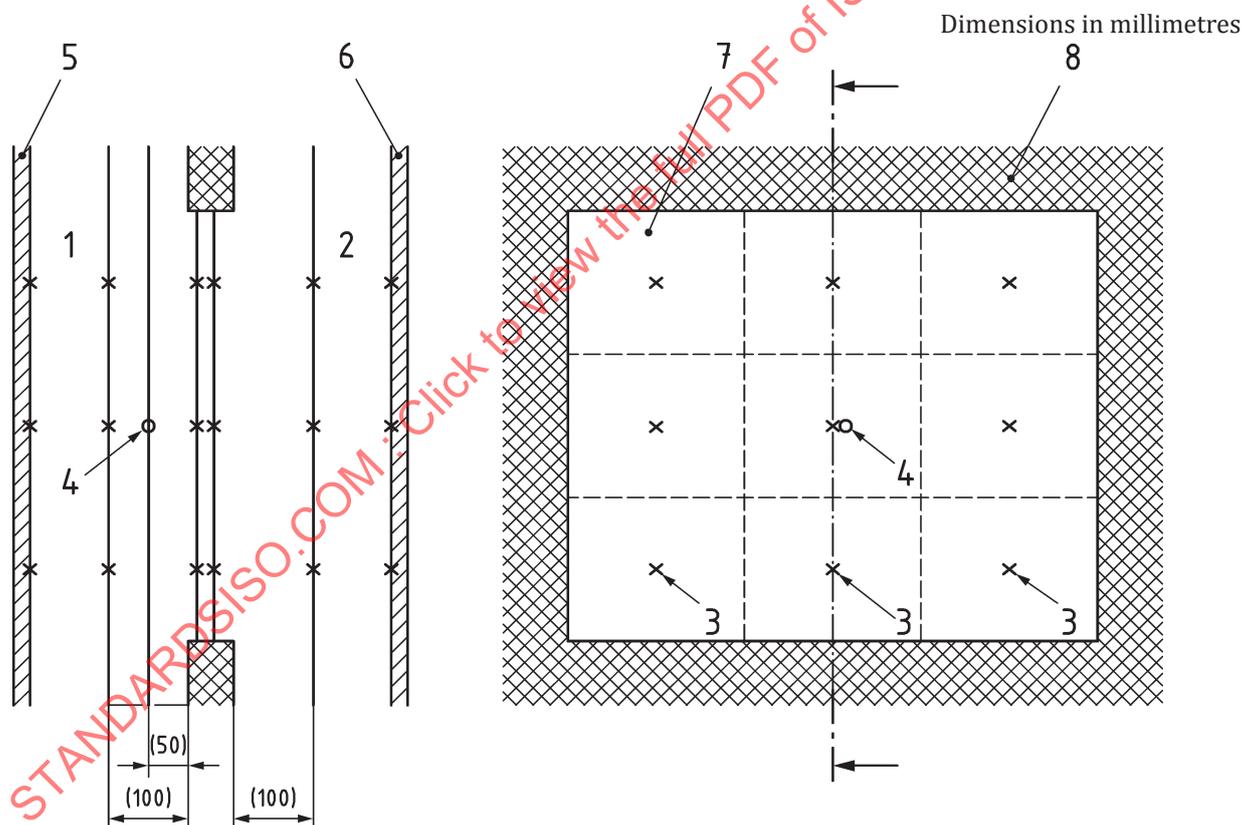
Annex E (informative)

Example of temperature measurement

E.1 General

This annex describes the examples of temperature measurement in the case of the determination of the solar heat gain coefficient. When the temperature sensors receive the irradiance, the temperature sensors should have the mechanism to eliminate the effects for casting a shadow of the sensors on the specimen and heating up the temperature of the sensors by the solar absorption as much as possible.

E.2 Example of temperature measurement by the thin sensors



Key

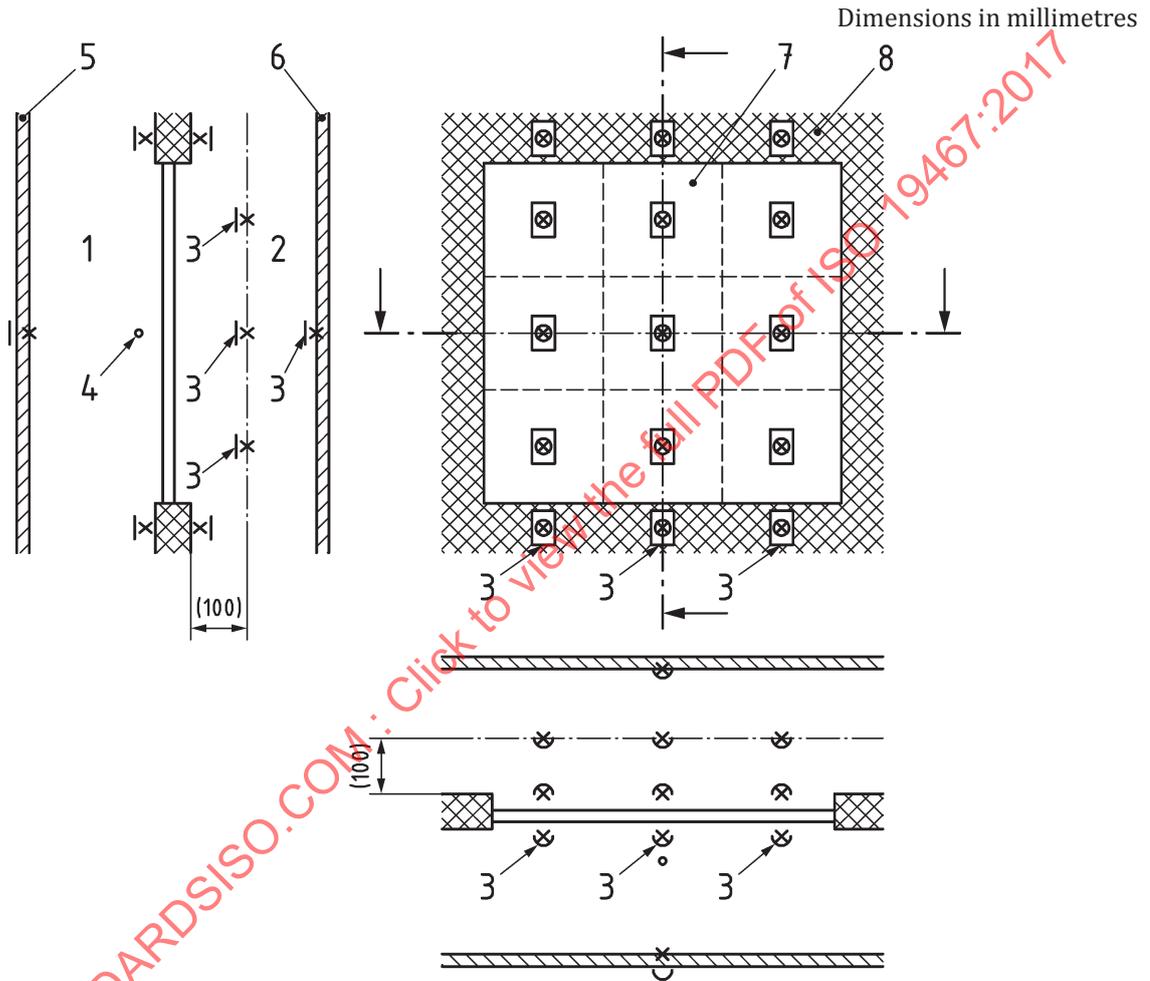
- | | | | |
|---|----------------------------------|---|--|
| 1 | external (climatic chamber) side | 5 | external side baffle or transparent aperture |
| 2 | internal (metering box) side | 6 | internal side baffle or absorber of cooling device |
| 3 | temperature sensors | 7 | test specimen |
| 4 | radiometer | 8 | surround panel |

Figure E.1 — Metering location of temperatures in the case of thin sensors

When the thin thermocouples (e.g. type T or type E, etc.) in accordance with IEC 60584-1 made from wire with diameter not greater than 0,1 mm are used as the temperature sensor, the effect for casting a shadow of the sensors on the specimen and heating up the temperature of the sensors by the solar absorption should be eliminated as much as possible.

solar absorption can be extremely small. Therefore, the temperatures can be measured in the directly irradiated condition without a shield. For this reason, the surface and air temperatures can be measured at the same position according to ISO 12567-1 with or without irradiance (see [Figure E.1](#)). Then, the position of the radiometer should not cast a shadow on the temperature sensors. In the case of surface temperature measurement, the temperature sensors should be fixed to the surface using adhesive or transparent adhesive tape (e.g. transparent polypropylene tape, etc.) with an outer surface of high emissivity greater than 0,8.

E.3 Example of temperature measurement by the thick sensors



Key

1	external (climatic chamber) side	5	external side baffle or transparent aperture
2	internal (metering box) side	6	internal side baffle or absorber of cooling device
3	temperature sensors	7	test specimen
4	radiometer	8	surround panel

Figure E.2 — Metering location of temperatures in the case of thick sensors

When a temperature sensor made from wire has a diameter thicker than 0,1 mm, the effect of the absorption of irradiation on the sensor cannot be neglected. In this case, the temperature sensors should be shaded from direct irradiation. The shading shields should have a high solar reflection (e.g. white painted) and the dimension should ensure a sufficient shading of the sensor. For the shields, thin aluminium with half round can be used. An adequate dimension is 50 mm by 80 mm.

Due to the effect of the shields on the solar heat gain coefficient, the air temperatures cannot be measured within the area of the test specimen on the external side. The temperature sensors should be located besides the test specimen (see [Figure E.2](#)).

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Annex F (informative)

Measuring method and example of measurement of active solar fenestration systems

F.1 General

Active solar fenestration systems convert solar energy in useful energy forms. They contain integrated PV-cells (for electricity generation) and/or solar collectors for heat generation. The extraction of useful energy lowers the solar heat gain coefficient in most cases and therefore should be considered in the measurements.

F.2 Guidelines for the measurement of active solar fenestration systems with solar thermal collectors

The extraction of heat lowers the temperature of the absorber of the solar thermal collector and therefore generally also lowers q_{in} and therefore, the solar heat gain coefficient. It is clear that this effect does not occur when the collector is not operated (in stagnation conditions). The key parameters that determine the effect on the solar heat gain coefficient are the inlet-temperature and the flow rate of the heat transfer fluid. The following solar heat gain coefficient measurements are recommended.

- a) Stagnation condition (no fluid flow).
- b) Without irradiation: No fluid flow in case of the dark measurement of U_N .
With irradiation:
 - 1) inlet temperature 40 °C (if lower than stagnation temperature);
 - 2) high fluid flow so that the temperature difference between inlet and outlet is ≤ 3 K.
- c) Without irradiation: No fluid flow in case of the dark measurement of U_N .
With irradiation:
 - 1) inlet temperature 65 °C (if lower than stagnation temperature);
 - 2) high fluid flow so that the temperature difference between inlet and outlet is ≤ 3 K.

NOTE 1 It is not relevant for the solar heat gain coefficient to determine the amount of extracted heat and the efficiency of the collector. The collector efficiency is nevertheless important for a proper characterization of the performance of such multifunctional facades.

NOTE 2 An example of a measurement setup for a window with a glazing integrated solar thermal collector with a conventional liquid cooled absorber between the outer and the inner glass pane and a water pipe connection in the framing system is the following: The window with the glazing integrated collector should be mounted in the solar heat gain coefficient measurement equipment in the same way as conventional glazing but with the only speciality, that the water pipe inlet and outlet connection can be accessed from the outside (not within the measurement chamber) and that it can be connected to a water thermostat. Temperature sensors at the water inlet and outlet are necessary in order to check the above-mentioned requirements.