INTERNATIONAL STANDARD

ISO 19467-2

First edition
2021-11

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

Part 2:
Centre of glazing

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

Partie 2: Centre du vitrage

COPYRIGHT PROTECTED DOCUMENT

Contents

Page

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of 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 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*.

A list of all parts in the ISO 19467 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is designed to provide solar heat gain coefficient values of the centre of glazing in fenestration systems by standardized measurement method. 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.

The solar heat gain coefficient of a complex fenestration system can depend on the direction of the incident radiation. It also might be influenced by other factors, e.g. window frame. In order to avoid the complexity and to enable the measurement of off-normal irradiation, this document focuses on the centre of glazing in fenestration systems.

This document specifies standardized apparatus and criteria. The solar heat gain coefficient measuring apparatus applied in this document includes solar simulator, climatic chamber and metering box. In some cases, solar heat gain coefficient of the centre of glazing can be determined most accurately by a combination of calculations and measurements.

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

Part 2: Centre of glazing

1 Scope

This document specifies a method to measure the solar heat gain coefficient for the centre of glazing in fenestration systems (e.g. complete windows, doors or curtain walls with or without shading devices) for normal and off-normal irradiation on the surface.

This document applies to the centre of glazing in fenestration systems which might consist of:

a) various types of glazing (e.g. glass or plastic; single or multiple glazing; with or without low emissivity coatings, and with spaces filled with air or other gases; opaque or transparent glazing);

b) various types of shading devices (e.g. blind, screen, film or any attachment with shading effects);

c) various types of active solar fenestration systems [e.g. building-integrated PV systems (BIPV) or building-integrated solar thermal collectors (BIST)].

This document does not include:

a) shading effects of building elements (e.g. eaves, sleeve wall, etc.);

b) shading effects of fenestration attachments with overhang structures (e.g., awning, etc.) or similar;

c) shading effects of non-glazing elements in fenestration systems (e.g. window frame, etc.);

d) heat transfer caused by air leakage between indoors and outdoors;

e) ventilation of air spaces in double and coupled windows;

f) thermal bridge effects at the joint between the glazing and the rest of the fenestration parts (e.g. window frame, etc.).

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 7345, *Thermal performance of buildings and building components — Physical quantities and definitions*

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

ISO 9288, *Thermal insulation — Heat transfer by radiation — Physical quantities and definitions*

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, *Thermal performance of windows, doors and shading devices — Detailed calculations*

ISO 19467:2017, *Thermal performance of windows and doors — Determination of solar heat gain coefficient using solar simulator*

ISO 52016-1, *Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 1: Calculation procedures*

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 9050, ISO 9288, ISO 12567-1, ISO 15099, ISO 19467, ISO 52016-1 and IEC 60904-9 and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
centre of glazing
central area of the glazing, undisturbed by edge and frame effects

3.2
off-normal irradiance
irradiation with altitude and/or azimuth angle not equal to 0°

3.3
projected area
area of the projection of the surface of the element on to a plane parallel to the transparent or translucent part of the element

Note 1 to entry: In the case of non-parallel condition, refer to Annex D.

3.4
simple fenestration system
fenestration products having non-ventilated glazing units made from glass and/or polymers and homogeneous specular and transparent properties in optical and thermal.

Note 1 to entry: In the case of non-parallel condition, refer to Annex D.

3.5
complex fenestration system
optically and/or thermally complex fenestration products that are not described as *simple fenestration systems* (3.4)

EXAMPLE   optically scattering glazing and/or shading devices and/or ventilated cavities and/or PV cells and/or solar collectors.

3.6
solar wavelength range
range of wavelengths for the incident radiation used for solar properties

Note 1 to entry: The range of wavelengths for the incident shall be as specified in ISO 9050.

4 Symbols

Symbol	Quantity	Unit
A	Area	m^2
f	Ratio of irradiation difference to distance difference	-
g	Solar heat gain coefficient (also known as total solar energy transmittance, solar factor or g-value)	—
h	Surface coefficient of heat transfer	$W/(m^2 \cdot K)$
H	Height	m
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
I	Irradiance, radiant flux (power) of incident radiation (energy per unit area per unit time resulting from incident radiation)	W/m^2
U	Thermal transmittance	$W/(m^2 \cdot K)$
W	Width	m
x	Distance or position	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
τ	Transmittance	-

Subscript	Meaning
B	Planes of peripheral wall of the metering box
C	Cooling device
cog	Centre of glazing
ex	External
F	Internal fan
H	Heating device
i	Number (Index)
in	Internal
INS	Insulation
N	Without irradiance
net	Net (Resulting quantity)
ne	Environmental external
ni	Environmental internal
P	Surround panel
r	Reflection
ref	Reference
scan	Scan
si	Internal surface
se	External surface

5 Principle

5.1 General

The solar heat gain coefficient for the centre of glazing in fenestration systems, g_{cog}, can be determined according to the same principle described in ISO 19467. Therefore, it shall be calculated using Formula (1) with or without shading devices.

$$g_{cog} = \frac{q_{in} - q_{in}\left(I_{net} = 0\right)}{I_{net}}$$ (1)

where

I_{net} is the net radiant flux (power) of incident radiation, in W/m2;

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

$q_{in}(I_{net} = 0)$ is the net density of heat flow rate through the test specimen in the centre of glazing 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.

Main differences between ISO 19467 and this document are as follows:

— this measurement deals with not the complete fenestration systems but the centre of glazing in fenestration systems;

— irradiance can be emitted also from off-normal incidence (see 5.2);

— not only "hot-box method" but also "cooled plate method" are adopted (see 5.3, 5.4, and 5.5).

5.2 Measurement of the irradiance

5.2.1 General

The determination of the net radiant flux (power) of incident radiation of the centre of glazing in fenestration systems involves three stages. The first stage is to scan the irradiation. The second stage is to take the irradiation divergence by distance between test specimen and lamp into account. The third stage is to calculate the net radiant flux (power) of the incident radiation in the solar wavelength range.

5.2.2 Determination of the net radiant flux (power) of incident radiation

Since the solar simulator cannot provide ideally parallel incident radiation to the test specimen, the irradiance depends on the distance between the solar simulator and each part of the test specimen and is not ideally homogeneous on the surface of the test specimen as shown in Figure 1. In order to take into account the inhomogeneity of the irradiance, net radiant flux (power) of incident radiation, I_{net}, shall be calculated using Formula (2), which is the area-weighted average irradiance at the external surface of the test specimen on which sensing position should be equally distributed.

$$I_{net} = \frac{\sum_{i=1}^{n} I_{net,i} \cdot A_{cog,i}}{A_{cog}}$$ (2)

where

$I_{net,i}$ is the corresponding net radiation flux (power) of incident radiation for each measurement point, i, along a vertical line in the plane of the test specimen, in W/m^2;

$A_{\text{cog},i}$ is the corresponding projected area for each measurement point, *i*, in the centre of glazing along a vertical line in the plane of the test specimen, in m^2;

A_{cog} is the projected area of the centre of glazing in the test specimen, in m^2.

The projected area of the centre of glazing in the test specimen, A_{cog}, shall be identical to the sum of the projected area for each measurement point, $A_{\text{cog},i}$, as shown in Formula (3).

$$A_{\text{cog}} = \sum\nolimits_{i=1}^{n} A_{\text{cog},i} \tag{3}$$

Sensors shall be in the centre of each divided area. More information is given in Annex B. The projected area of the centre of glazing in the test specimen, A_{cog}, for both the cooled plate method and the hot box method can be determined according to Annex A and Annex D, respectively.
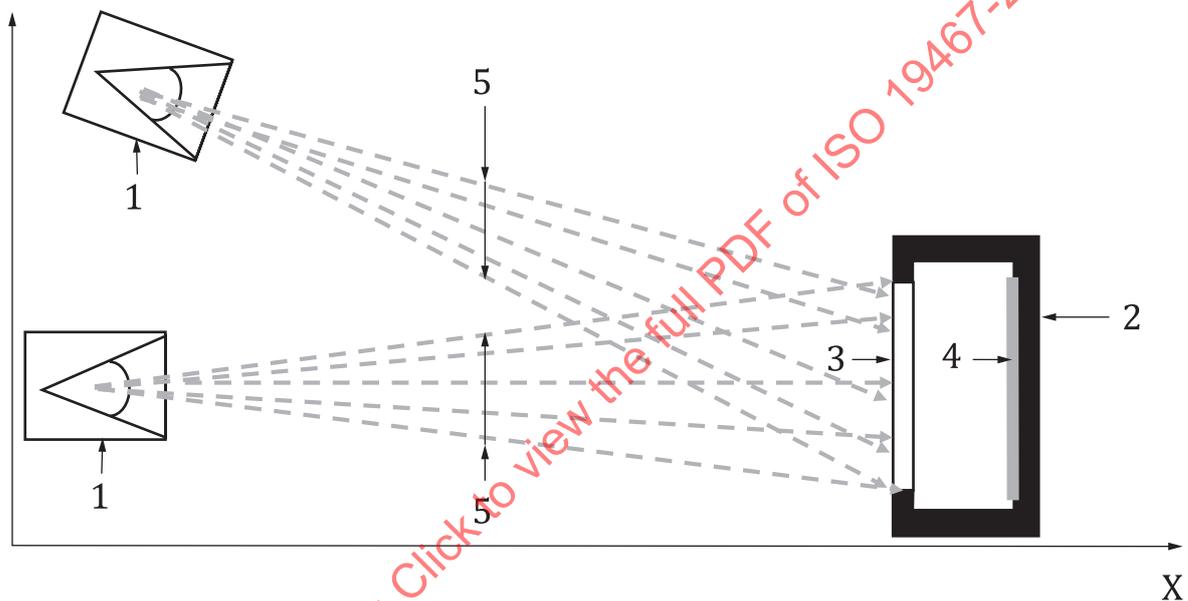
Key

X	x-axis	3	test specimen
1	solar simulator (normal and off-normal)	4	cooling device or absorber
2	metering box or insulation box	5	lighting generated by solar simulator

Figure 1 — Influence of beam divergence of the incident irradiation

Solar simulators do not provide ideally parallel radiation, therefore the irradiance depends on the distance from the solar simulator. The individual layers of the test specimen and the absorber in the case of cooled plate method are thus irradiated with slightly different irradiance values as shown in Figure 2.

The irradiance may also be determined in a different plane in front of the test specimen. In this case, $I_{\text{net},i}$ shall be calculated using Formula (4). The influence of divergent irradiation on the position of X_{ref} should be taken into account according to Annex C for the cooled plate method.

$$I_{\text{net},i} = I_{\text{scan},i}\left(1 + f\left(x_{\text{scan}} - x_{\text{ref}}\right)\right) \tag{4}$$

where

$I_{\text{scan},i}$ is the corresponding net radiant flux (power) of incident radiation for each measurement point, *i*, at the position x_{scan}, in W/m^2;

f is the variation ratio of the irradiance, in m^{-1};

x_{scan} is the distance between the solar simulator and the scanning radiometer, in m;

x_{ref} is the distance between the solar simulator and reference plane for the irradiance measurement, in m.

NOTE   Directions of x_{scan} and x_{ref} are normal to the test specimen.

Key
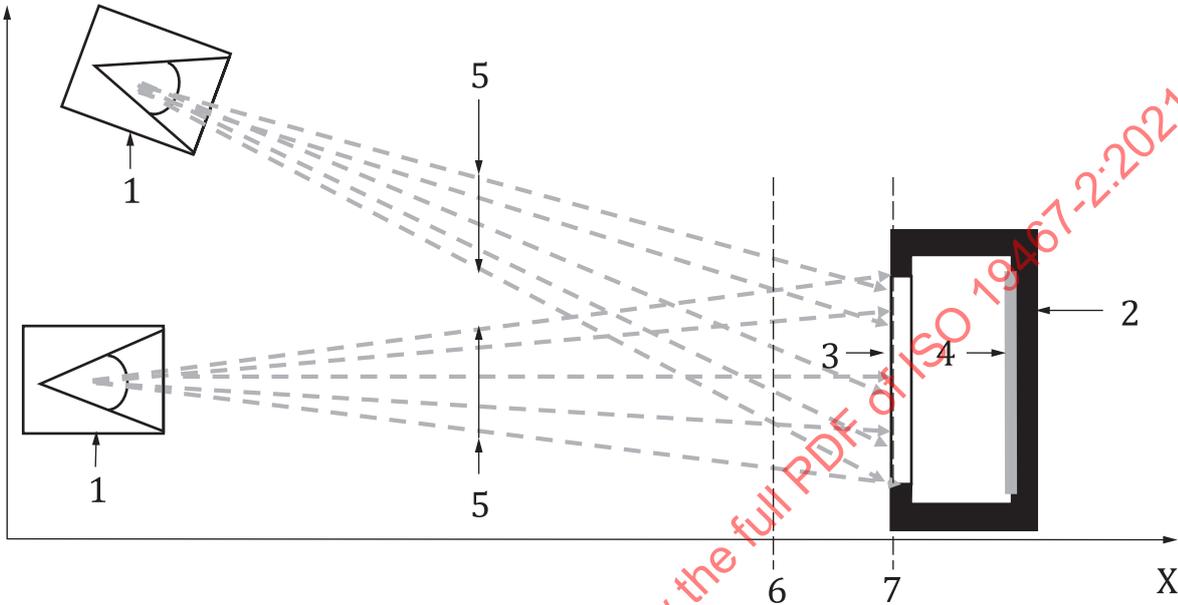
X	x-axis	4	cooling device or absorber
1	solar simulator (normal and off-normal)	5	lighting projected by solar simulator
2	metering box or insulation box	6	measuring plane of irradiance scan (x_{scan})
3	test specimen	7	plane of reference irradiance (x_{ref})

Figure 2 — Determination of reference irradiance when the sensor cannot be put in the plane of reference irradiance

In order to take into evaluate the variation of the irradiance level from the distance of the absorber, the criterion f might be used according to Formula (5).

$$f = \frac{\dfrac{I_{scan,1}}{I_{scan,2}} - 1}{x_{scan,2} - x_{scan,1}} \tag{5}$$

where

$x_{scan,1}$ is the measuring plane1 of irradiance scan in m (key 7 in Figure 3);

$x_{scan,2}$ is the measuring plane 2 of irradiance scan in m (key 8 in Figure 3);

$I_{scan,1}$ is the irradiance on the measuring plane 1, in W/m^2 (key 7 in Figure 3);

$I_{scan,2}$ is the irradiance on the measuring plane2, in W/m^2 (key 8 in Figure 3).

If the irradiance sensor cannot be put in the reference plane and f is greater than 0,07 %/mm, f should be taken into account to analyse the additional uncertainty of the irradiance level due to divergence

effects as shown in Figure 3 and the correction of the reference plane as described in Annex C as already mentioned before Formula (4). This additional systematic (non-statistical) error should be taken into account in the determination of the uncertainty of the *g*-value measurement.

Key
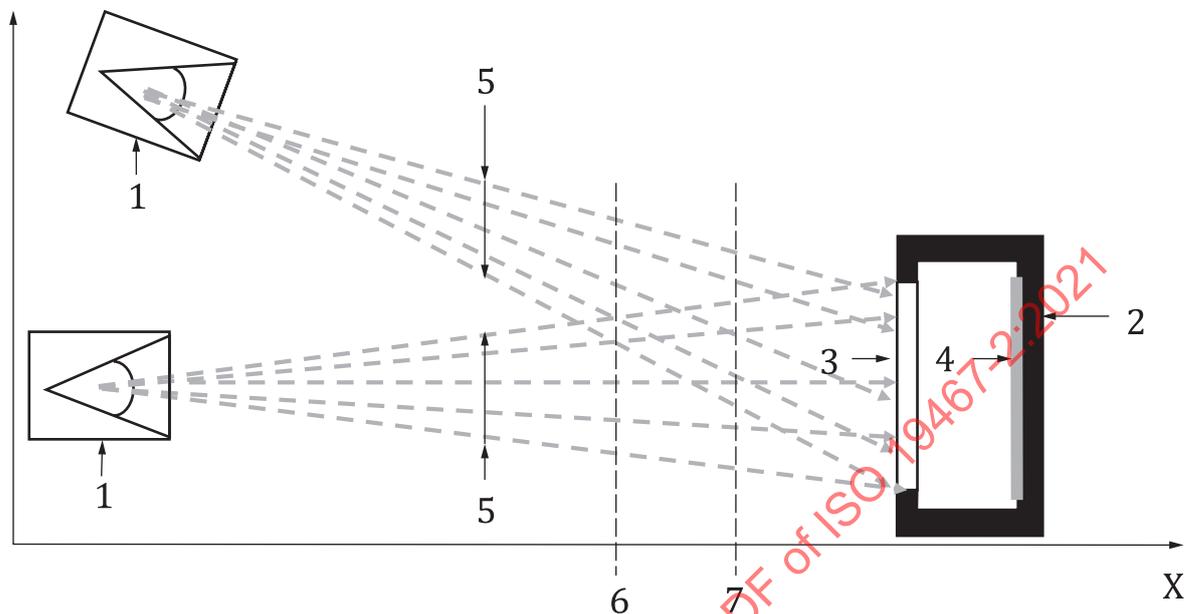
X	x-axis	4	cooling device or absorber
1	solar simulator (normal and off-normal)	5	lighting generated by solar simulator
2	metering box or insulation box	6	measuring plane 1 of irradiance scan ($x_{scan,1}$)
3	test specimen	7	measuring plane 2 of irradiance scan ($x_{scan,2}$)

Figure 3 — Determination of irradiance in different planes in front of the test specimen

5.2.3 Calculation of I_{net} with correction of reflected by the absorber

The net density of the heat flow rate of the incident radiation, $I_{net,i}$, shall be calculated using Formula (6).

$$I_{net,i} = I_{scan,i} - I_r \tag{6}$$

where I_r is the density of heat flow rate of the incident radiation that is transmitted to the external side of the metering box/plate after being reflected the internal side of the metering box/plate, in W/m^2.

If I_r is proved to be negligible (I_r approximately 0), the net radiant flux (power) of incident radiation, I_{net}, shall be calculated using Formula (7), which results in the second term on the right side of Formula (6) to become 0.
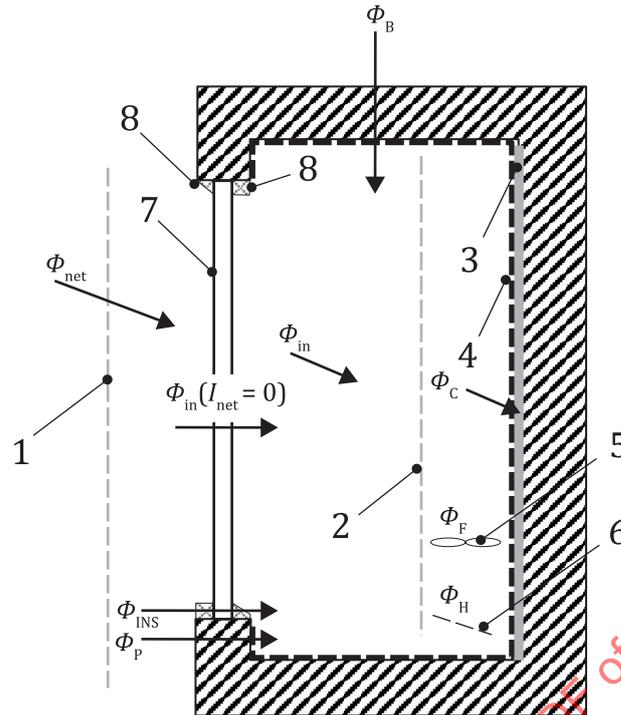
$$I_{net,i} = I_{scan,i} \tag{7}$$

Whether I_r is negligible or not shall be evaluated based on the criteria stated in ISO 19467.

5.3 Measurement of heat flow rates with irradiance

5.3.1 Hot box method

The heat flow rates with irradiance for the hot box method are shown in Figure 4.

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	cooling device	Φ_F	heat flow rate supplied by the one or more internal fans with irradiance (optional)
4	heat flow measuring device	Φ_H	heat flow rate supplied by the heating device with irradiance (optional)
5	internal fan(optional)	Φ_{in}	net heat flow rate through the test specimen with irradiance
6	heating device(optional)	$\Phi_{in}(I_{net} = 0)$	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
8	insulation of glazing edge	Φ_{net}	net radiant flux (power) of incident radiation
		Φ_{INS}	heat flow rate through the insulation of the glazing edge with irradiance

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. If the internal baffle is not present, the difference between air temperature and radiative temperature should be minimized.

Figure 4 — Heat flow rates with irradiance for the hot box method

The net density of heat flow rate through the test specimen with irradiance, q_{in}, for the hot box method shall be calculated using Formula (8). In the formula, Φ_{INS} should be estimated by the two-dimensional calculation.

$$q_{in} = \frac{\Phi_C - \Phi_B - \Phi_F - \Phi_H - \Phi_P - \Phi_{INS}}{A_{cog}}$$ (8)

where

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;

Φ_{INS} is the heat flow rate through the insulation of the glazing edge with irradiance, in watts.

A_{cog} is the projected area of the centre of glazing in the test specimen, in m^2.

5.3.2 Cooled plate method

The heat flow rates with irradiance for the cooled plate method are shown in Figure 5.
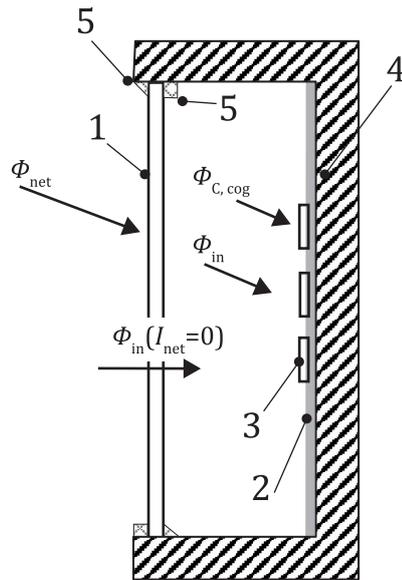
Key

1	test specimen	$\Phi_{C,cog}$	heat flow rate removed by the cooled plate for the centre of glazing with irradiance, in watts
2	cooling device	Φ_{in}	net heat flow rate through the test specimen with irradiance
3	heat flow measuring device	$\Phi_{in}(I_{net} = 0)$	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 $(\theta_{ne} - \theta_{ni})$
4	insulation	Φ_{net}	net radiant flux (power) of incident radiation
5	insulation of the glazing edge		

Figure 5 — Heat flow rates with irradiance for the cooled plate method

The test specimen is mounted in front of a cooled flat plate absorber with an air gap between the internal surface of the test specimen and the cooled plate. The convective-radiative heat transfer coefficient between this air gap is set by choosing the width of the gap. The evaluation of the measurement is based on a local energy balance at the centre of the test specimen, directly resulting in the centre of glazing value. Edge effects can be analysed with the heat flows of edge of glazing. Therefore, the net density of heat flow rate through the test specimen with irradiance, q_{in}, for the cooled plate method shall be calculated using Formula (9).

$$q_{in} = \frac{\Phi_{C, cog}}{A_{cog}} \tag{9}$$

where $\Phi_{C,cog}$ is the heat flow rate removed by the cooled plate for the centre of glazing with irradiance, in watts.

More information is presented in Annex A.

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

The net density of heat flow rate through the area of the centre of glazing due to thermal transmission without irradiance, $q_{in}(I_{net}=0)$, shall be calculated using Formula (10) in the case of both hot box method and cooled plate method.

$$q_{in}\left(I_{net}=0\right)=U_N \cdot \left(\theta_{ne} - \theta_{ni}\right) \tag{10}$$

where

U_N is the thermal transmittance of the test specimen without irradiance, in W/(m²·K);

θ_{ne} is the environmental external temperature with irradiance, in °C;

θ_{ni} is the environmental internal temperature with irradiance, in °C.

5.5 Measurement of heat flow rates without irradiance

5.5.1 Thermal transmittance

The thermal transmittance of the test specimen without irradiance, U_N, shall be calculated using Formula (11).

$$U_N = \frac{q'_{in}\left(I_{net}=0\right)}{\left(\theta'_{ne}-\theta'_{ni}\right)} \tag{11}$$

where

$q'_{in}(I_{net}=0)$ is the net density of heat flow rate of 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/m²;

θ'_{ne} is the environmental external temperature without irradiance, in °C;

θ'_{ni} is the environmental internal temperature without irradiance, in °C.

5.5.2 Hot box method

The heat flow rates without irradiance for hot box method are shown in Figure 6.

Key

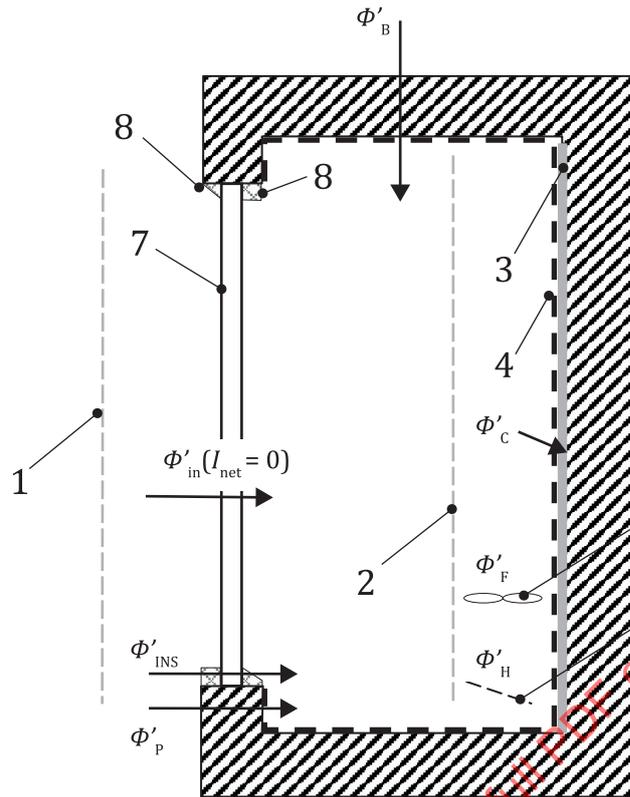|			
1	external side baffle(optional)	Φ'_B	heat flow rate through the planes of peripheral wall of the metering box without irradiance
2	internal side baffle (optional)	Φ'_C	heat flow rate removed by the cooling device without irradiance
3	cooling device	Φ'_F	heat flow rate supplied by the one or more internal fans without irradiance (optional)
4	heat flow measuring device	Φ'_H	heat flow rate supplied by the heating device without irradiance (optional)
5	internal fan (optional)	$\Phi'_{in}(I_{net} = 0)$	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	heating device (optional)	Φ'_P	heat flow rate through the surround panel without irradiance
7	test specimen	Φ'_{INS}	heat flow rate through the insulation of the glazing edge without irradiance
8	insulation of the glazing edge		

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. If the internal baffle is not present, the difference between air temperature and radiative temperature should be minimized.

Figure 6 — Heat flow rates without irradiance for hot box method

The net density of heat flow rate through the test specimen due to thermal transmission without irradiance, $q'_{in}(I_{net}=0)$, shall be calculated using Formula (12).
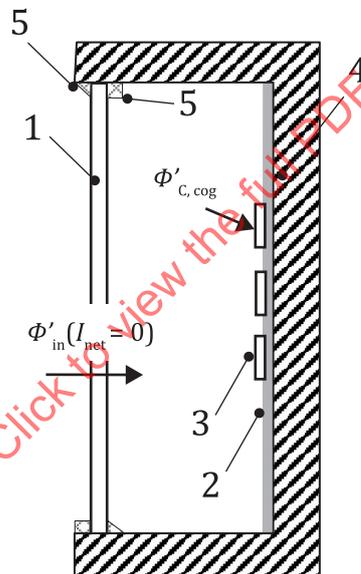
$$q'_{in} \left(I_{net} = 0 \right) = \frac{\Phi'_C - \Phi'_B - \Phi'_F - \Phi'_H - \Phi'_P - \Phi'_{INS}}{A_{cog}} \tag{12}$$

where

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;

Φ'_{INS} is the heat flow rate through the insulation of the glazing edge without irradiance, in watts.

5.5.3 Cooled plate method

The heat flow rates without irradiance for cooled plate method are shown in Figure 7.

Key

1   test specimen

2   cooling device

3   heat flow measuring device

4   insulation

5   insulation of the glazing edge

$\Phi'_{C,cog}$ heat flow rate removed by the cooling device without irradiance

$\Phi'_{in}(I_{net} = 0)$ 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 $(\theta'_{ne} - \theta'_{ni})$

Figure 7 — Heat flow rates without irradiance for cooled plate method

The net density of heat flow rate through the test specimen without irradiance, $q'_{in}(I_{net}=0)$ for the cooled plate method shall be calculated using Formula (13).

$$q'_{in}\left(I_{net}=0\right)=\frac{\Phi'_{C,cog}}{A_{cog}}$$ (13)

where $\Phi'_{C,cog}$ is the heat flow rate removed by the cooled plate for the centre of glazing 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 overall constructions of the measuring apparatus for hot box method and for cooled plate method are shown in Figure 8 and Figure 9, respectively.
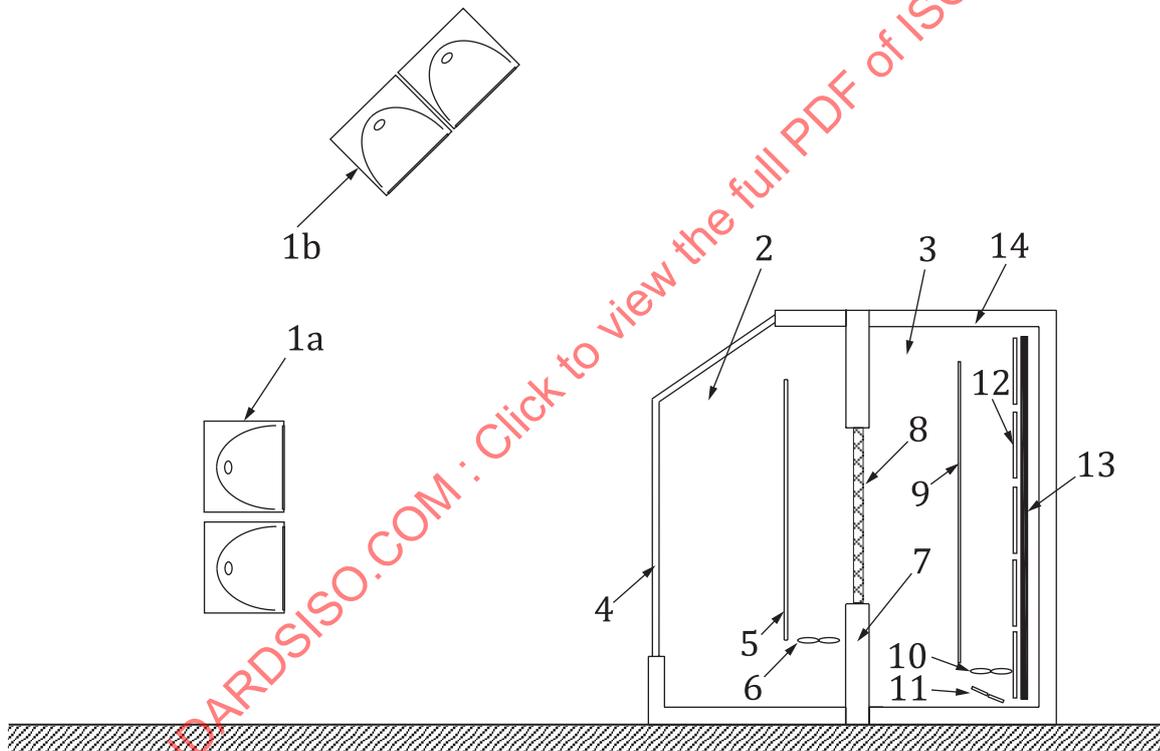
Key

1a	solar simulator in the case of normal irradiance	8	test specimen
1b	solar simulator in the case of off-normal irradiance		
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 8 — Construction of the test apparatus for hot box method
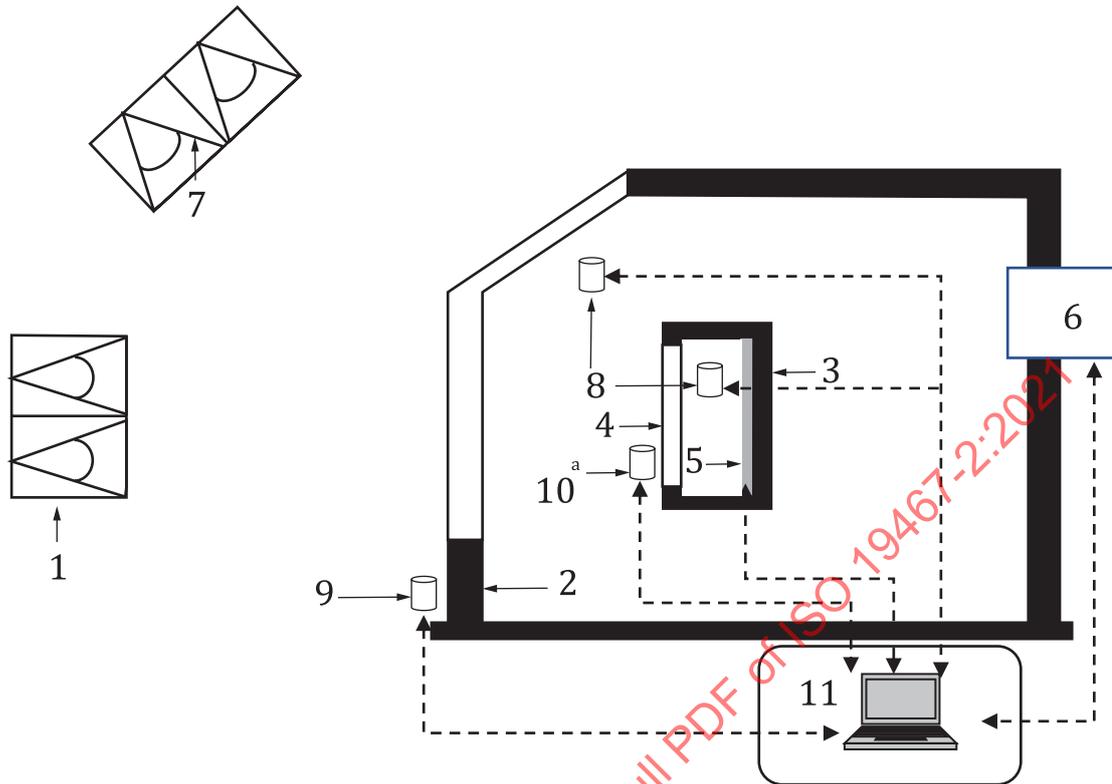
Key

1	solar simulator in case of normal irradiance	7	solar simulator in case of off-normal irradiance
2	climatic chamber	8	air temperature sensors
3	metering box	9	radiometer for monitoring the stability of the solar simulator
4	test specimen	10	radiometer in front of test specimen [a]
5	cooling device	11	data acquisition and control system
6	air conditioner	[a]	The Radiometer in front of test specimen should be removed before the actual measurement.

Figure 9 — Construction of the test apparatus for cooled plate method

6.1.2 Summary of the test apparatus

The details of measuring apparatus are described in ISO 19467:2017 and the subsequent sections.

6.2 Solar simulator

A steady-state solar simulator whose quality of the irradiance for normal condition meets the requirement of ISO 19467:2017, 6.2 shall be used. For off-normal condition, it should allow off-normal irradiation by tilting light source or by rotating test specimen around a vertical axis, i.e., varying the azimuth. But it should have separate requirements for quality of irradiation. In addition to the list of requirements for normal condition, the requirement should also include requirements on unpolarization of incident irradiation. For off-normal irradiance, altitude angle and azimuth angle shall be specified.

6.3 Climatic chamber

The climatic chamber is basically same as specified in ISO 19467:2017, 6.3 except for following specifications:

a) Transparent aperture: The transparent aperture should be devised to transmit off-normal irradiation from solar simulator as much as possible. Angle of incidence on the transparent aperture of the climatic chamber shall not exceed 35°;

b) Rotatable device (optional): Rotatable device that is able to change azimuth angle of the test specimen to the solar simulator can be installed in the climatic chamber.

6.4 Metering box

The metering box is same as specified in ISO 19467:2017, 6.4. More information is presented in Annex A for cooled plate method and ISO 19467:2017, Annex D for hot box method.

6.5 Surround panel

The surround panel is same as specified in ISO 19467:2017, 6.5.

6.6 Calibration panels

The calibration panel is same as specified in ISO 19467:2017, 6.6.

6.7 Metering location of temperatures

Metering location of temperatures is same as specified in ISO 19467:2017 except for ISO 19467:2017, 6.7, d).

6.8 Test specimens

The projected area of the test specimen shall be equal to or greater than 0,8 m in width and 0,8 m in height to minimize the influence of edge effects. Furthermore, the area should be larger than the inhomogeneities of complex fenestration systems. The maximum size of the test specimen might depend on the distance between the solar simulator and the test specimen and should be considered for each test facility condition. Therefore, this document does not set the maximum size of the test specimen that can be applied to all the test facilities due to the fact that it depends on many factors and set-up condition of each test facility.

The test specimen shall fill the surround panel aperture using additional insulation of glazing edge according to 6.9. The clearance between the surround panel and the test specimen with the additional insulation of glazing edge shall be 5 mm or less, and the perimeter joints between the surround panel and the test specimen with additional insulation of glazing edge shall be sealed with tape, caulking or mastic material.

NOTE   If applicable, the position of the coating, can be checked before the measurement.

6.9 Insulation of glazing edge

The additional insulation of glazing edge shall be used on both internal side and external side of the edge of the test specimen to hold the test specimen and to avoid disturbing heat transfer by shadow and reflectance by the joint edge between the frame and test specimen. More information is presented in Annex D.

In order to keep the absorption and the additional heat flux through the edge zone low and to reflect radiation onto the absorber surface, the surfaces of the insulation of glazing edge should be coated with a highly reflective material.

NOTE   When the surfaces of the insulation of glazing edge are coated with a highly reflective material, it helps to keep the absorption and the additional heat flux through the edge zone low. The inclination and the gloss level of the surfaces of the edge insulation material determines the fraction of incident radiation that is reflected onto the absorber surface for a certain direction of the incident radiation.

7 Measurement procedure

7.1 Determination of surface coefficient of heat transfer

The surface coefficient of heat transfer shall be determined as specified in ISO 19467:2017, Annex A.

The settings for the value of the surface coefficient of heat transfer shall be evaluated through the method of using environmental temperature.

NOTE   As described in ISO 19467:2017, Annex A, the real surface coefficient of heat transfer can be higher in case of samples with rough or structured surfaces.

7.2 Measurement

Measurements shall be performed in each case with and without irradiance. Recommended environmental conditions are shown in Table 1.

The environmental conditions are decided according to local standards, national standards or regulations. Alternate environmental conditions shall be reported in 8.1 d).

Table 1 — Recommended environmental conditions

Element		Conditions based on ISO 15099		Conditions based on 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, h_{si}	W/(m²·K)	8	8	8	8
External surface coefficient of heat transfer, h_{se}	W/(m²·K)	14	24	14	23
Net radiation flux (power) of incident radiation for the case of normal incidence[a], I_{net}	W/m²	500	300	500	300

[a]   If the solar simulator cannot meet the density of heat flow rate of the incident radiation, I_{net}, under summer conditions, the value may be 400 W/m² or higher.

NOTE 1 The performance requirements of fenestration systems 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 is determined according to ISO 19467:2017, Annex B.

NOTE 3 The relative humidity in the climatic chamber and metering box is kept at low enough levels to avoid condensation.

NOTE 4 Off-normal condition is specified according to national standards.

NOTE 5 There are different International Standards with different reference conditions (e.g. ISO 9050, ISO 15099 and ISO 52022-3).

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.

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.

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 19467-2:2021;

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 glazing, shading device, opaque panel, or other components;

2)   the technical drawing (cross-sections) of the test specimen;

f)   results of measurement (Table 2);

The results of measurement listed in Clause 4. Symbols shall be indicated. The results of the solar heat gain coefficient shall be accurate to two decimal places.

Table 2 — Indicated results of measurement

Element		With irradiation	Without irradiation
Solar heat gain coefficient, g_{cog}	—	O	—
Thermal transmittance, U_N	W/(m²·K)	—	✓
Projected width of test specimen, W_{cog}	m	O	
Projected height of test specimen, H_{cog}	m	O	
Projected area of test specimen, A_{cog}	m²	O	
Net radiant flux (power) of incident radiation, I_{net}	W/m²	✓	—
Profile angle of incident radiation	°	O	—
O Mandatory			
✓ Recommended			

Table 2 *(continued)*

Element		With irradiation	Without irradiation
Azimuth angle of incident radiation	°	O	—
Net density of heat flow rate through the test specimen, q_{in}	W/m²	✓	—
Net density of heat flow rate through the test specimen due to thermal transmission, $q_{in}(I_{net} = 0)$, $q'_{in}(I_{net} = 0)$	W/m²	✓	✓
Environmental external temperature, θ_{ne}, θ'_{ne}	°C	O	O
Environmental internal temperature, θ_{ni}, θ'_{ni}	°C	O	O
O Mandatory			
✓ Recommended			

8.2 Estimation of uncertainty

The uncertainty of measurement should be estimated as specified in ISO 19467:2017.

Annex A
(informative)

Cooled plate method for SHGC measuring for the centre of glazing

A.1 General

The overall construction for the measuring apparatus for the cooled plate method is shown in Figure 9. The modification of the angle of incidence can be realized in two different ways: Either the lamps remain in normal position (0°) with the sample is rotated around a vertical axis or the height angle of the lamp is changed by moving the lamps. The combination of both movements is necessary to realize combined non-zero facade azimuth angle and non-zero height angle.

The test sample is irradiated with a solar simulator. The external environment in front of the sample is temperature-controlled and the external surface of the test sample is exposed to artificial wind conditions. The test sample is mounted in front of a cooled flat-plate absorber with an air gap between the inner surface of the sample and the cooled plate. The purpose of the absorber is to remove the energy that passes through the test sample. The convective-radiative heat transfer coefficient between the absorber and the indoor surface of the sample is set by choosing the width of this air gap. The evaluation of the measurement is based on a local energy balance at the centre of the sample, directly resulting in the centre of glazing value. For very small samples there can be an influence of the edges also at the centre of the sample. Test samples therefore shall be sufficiently large [e.g. at least with external dimensions, b is greater than 0,8 m as shown in Figure A.1 a)] when a generally valid centre of glazing value g is to be determined. The distance from edge, a, should be greater than 0,19 m as shown in Figure A.1 a). The centre of glazing can be analysed with the heat flux sensors No. 5, 6, 9, 10, 11, 14, and 15 for Figure A.1 b).
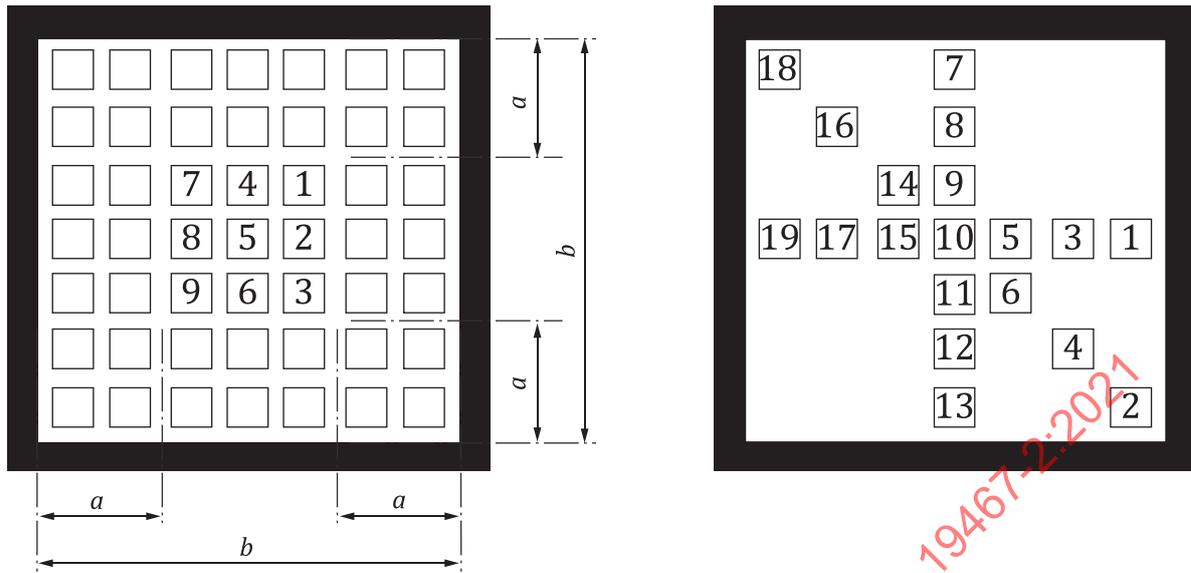
a) Centre of glazing on the absorber   **b) Centre of glazing and edge on the absorber**

Key

1 to 19   heat flux sensor

a   distance from edge

b   external dimensions

Figure A.1 — Example of the position of heat flow meters

A.2   Configuration on room side to define h_i

For the case of the cooled plate method, the test sample is mounted such that there is an air gap of 10 mm between the indoor pane and the absorber surface (see also Note in this subclause). The absorber surface should have an emissivity of $\varepsilon_{abs} = 0{,}97 \pm 0{,}03$. The convective-radiative heat transfer coefficient between the absorber and the indoor surface of the sample is then $h_i = 8 \pm 1$ W/(m²K)

NOTE   In such a narrow gap with a width of 10 mm and a typical height of more than 800 mm, the convective heat transfer coefficient is clearly defined, because the air flow is laminar for the prevailing temperatures. The radiative heat transfer coefficient could be obtained from the well-known analytical solution for infrared heat transport between flat, parallel plates.

Annex B
(informative)

Example of irradiation measurement

B.1 General

This annex describes example of irradiation measurement.

B.2 Determination of I_{net}

The measurement of irradiation should be satisfied with the following conditions;

a) The sensing area of the radiometers should be positioned on the plane of the irradiance measurement as shown in Figure B.1.

b) Grid should be fine enough to capture the in-homogeneity.

c) I_{net} should be re-determined whenever the irradiation conditions are changed. For example, it might have different irradiance-levels, angle of incidences or lamp or specimen changes.

Sufficient sensing position should be used so that the homogeneity of each test facility can be justified. In many cases a grid with 100 mm width might be sufficient.

When the configuration of the lamps has been changed, the reference or instant irradiation should be re-determined. The methodology described in 5.2.2 should be followed. In addition to that, the sensing area of the radiometers should be at the position of the reference area as shown in Figure B.1.
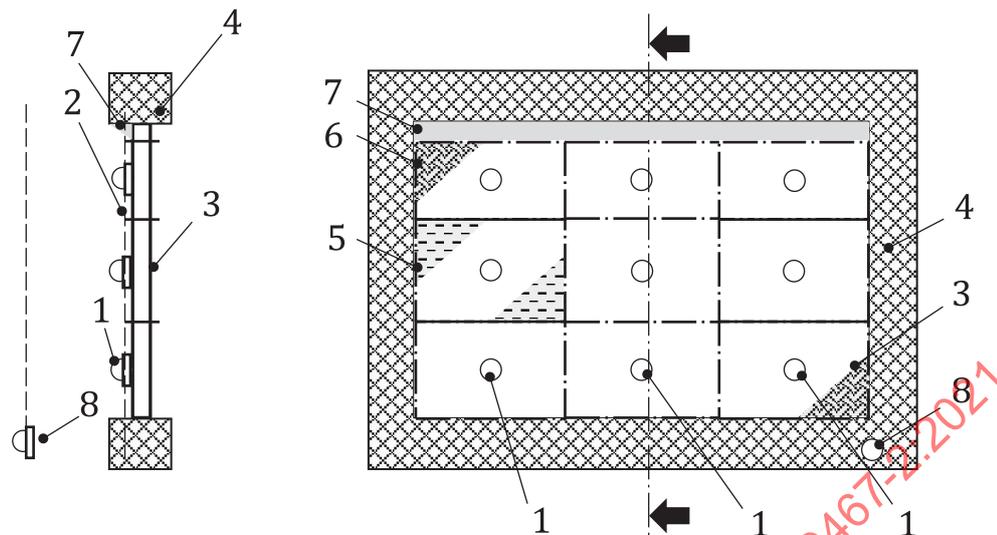
Key

1 reference radiometer
2 plane of the irradiance measurement
3 test specimen
4 surround panel

5 projected area for each measurement
6 projected area of the centre of glazing in the test
7 insulation of the glazing edge
8 radiometer to monitor instant irradiation during the measurement

NOTE   Definition of I_{net} is key 1 and I_{net} is reference irradiation. Key 8 is not used for the determination of SHGC but is used only for monitoring the stability of the lamps.

Figure B.1 — Example of metering location of irradiance on the test specimen

B.3   Monitoring of the stability of the solar simulator

It is impossible to determine the irradiation at many different positions in front of the sample during the actual calorimetric measurement. The main reason is, that the sensor would shield the sample from the irradiation and therefore would disturb the measurement. On the other hand it should be ensured, that the irradiation during the measurement remains the same as during the reference determination of irradiance distribution. It is therefore necessary to place an additional radiometer (see key 8 in Figure B.1) besides the test specimen (without causing shades or disturbance of the convection etc.) to monitor instant irradiation during the measurement. The comparison of the reading of this sensor with the sensor reading during the reference irradiance measurements allows to conclude, that there is no obvious difference in the irradiance conditions of the reference irradiance measurement and the actual calorimetric measurement. When the stability of the lamps is in question, it might be necessary to put more than one sensor for the monitoring of the irradiance distribution at different locations.

In any case, eventual fluctuations of the solar simulator should be taken into account when determining the measurement uncertainty.

Annex C
(informative)

Consideration of effects caused by the divergence of the incident light

C.1 General

The "reference plane" is the plane parallel to the surface of the sample in which the irradiance-level I_{net} has to be determined. None of the solar simulator emits perfectly parallel irradiation, the divergence of a solar simulator can lead to deviations of the experimentally determined g_{exp} compared with the reference value g for parallel light[6]:

a) The radiance of a divergent light source is spread over an area that depends on the distance to the light source. As a result, the measured irradiance along the normal to the light source depends on this distance. For the case of thick samples, e.g. composed of several layers, this effect leads to small deviations of the irradiance on the different sample layers. The methods that correct this effect for the case of the cooled plate method presented in Clause C.2 are based on Reference [4].

b) When g_{exp} is experimentally determined by means of a solar simulator for a specified direction of the incident light, the light received by the sample is not incident from this direction alone, but from a range of directions due to the divergence of the solar simulator. Since the g-value generally depends on the direction of incidence radiation, this can lead to differences between g_{exp} and the reference value g for parallel light coming from the desired direction. Moreover, the differing divergence of the solar simulators from different testing institutes can lead to a significant uncertainty when it comes to specifying the g-value as a product parameter. The methods that correct this effect presented in Clause C.3 are based on Reference [6].

C.2 Determination of the reference irradiance I_{net} for the cooled plate method when divergence effects on the irradiance-level are not negligible

Because of the aforementioned facts, different irradiation levels are received at the different layers in the sample when the incoming light is not parallel. For centre of glazing measurements with the cooled plate method, there is therefore no unique position of the reference plane for the determination of I_{net} which is valid for all types of test specimens. Nevertheless, it is possible in most cases to use one general reference plane x_{ref}, when the additional measurement uncertainty caused by divergence effects is included in the error bar of the irradiance measurement.

a) Method for the determination of a general reference plane for the case of divergent irradiation

The following examples are intended to explain the influence of the test specimen on the reference plane:

— For clear non-scattering and non-absorbing test specimens, g is equal to the solar transmittance of the test specimen. There is no secondary inward flowing fraction in this case and the reference plane for the determination of the irradiance is the surface of the absorber (cooling device).

— If the outer pane of a multiple-pane glazing unit consists of an opaque black panel, the surface of the black panel is the reference plane.

— For a non-absorbing test specimen, for which the outer pane is ideally diffusely and isotopically scattering, the reference pane is the plane of the outer pane as shown in Figure B.1.

The conclusion from the above examples is that there are different reference planes, which should be used for absorbing, scattering or clear samples to correct for divergence effects. Two conclusions can be drawn from this finding. First, the different planes can be used to determine a best guess for I_{net}. An exact determination of I_{net} is not possible, because in almost all cases neither sufficient information about the divergent irradiance nor about the optical and thermal effects is available. Second, in order to obtain a valid measured value for g, the additional measurement uncertainty caused by this estimation should therefore be determined and taken into account.

For the correction of these effects, the following can be used:

$$I'_{net} = I_{scan} \left[1 + f\, X'_{ref} \right]$$

$$X'_{ref} = \left[\left(\frac{q_i}{g} \left(x_{q_i} - x_{scan} \right) + \frac{\tau_{e,d\text{-}dif}}{g} \left(x_{diff} - x_{scan} \right) + \frac{\tau_{e,d\text{-}d}}{g} \left(x_{abs} - x_{scan} \right) \right) \right]$$

where,

$I_{scan,i}$	is the corresponding net radiant flux (power) of incident radiation for each measurement point, i, at the position x_{scan}, in W/m^2;
f	is the variation ratio of the irradiance, in m^{-1};
x_{scan}	is the distance between the solar simulator and the scanning radiometer, in m;
$x_{qi} - x_{scan}$	is the distance between the plane of the scanning radiometer and the absorbing plane in the test sample
$x_{diff} - x_{scan}$	is the distance between the plane of the scanning radiometer and the diffusing plane in the test sample
$x_{abs} - x_{scan}$	is the distance between the plane of the scanning radiometer and the surface of the absorber of the cooling device
$\tau_{e,d\text{-}d}$	is the solar direct direct transmittance
$\tau_{e,d\text{-}dif}$	is the solar direct diffuse transmittance

Direction of x_{scan} and x_{ref} should be normal to the test specimen. The determination of the best guess for I_{net} is therefore reduced to the determination of the best guess for $\tau_{e,d\text{-}d}$, $\tau_{e,d\text{-}dif}$ and q_i.

b) Determination of the additional measurement uncertainty

The uncertainty measurement results from the unknown exact position of the reference plane x_{ref}. The measurement uncertainty caused by this can be determined by determining the minimum possible value for I_{net} and the maximum possible value for I_{net}. The irradiance level at a certain distance from the solar simulator can be determined by using f, determined with Formula (5). The minimum value for the irradiance $I_{net,min}$ corresponds to the position $x'_{ref,min}$, which corresponds to the greatest possible distance between reference pane and solar simulator, so this is often the surface of the absorber of the cooling device. The maximum possible value for the irradiance $I_{net,max}$ corresponds to the minimum distance between x_{ref} and the solar simulator, which is usually given by the outer surface of the test sample. The additional uncertainty is therefore $\Delta I_{net} = \text{Max}[(I_{net,max} - I_{net}); (I_{net} - I_{net,min})]$, where for I_{net}, the best guess should be used.

For the determination of I_{net_min} and I_{net_max}, the following can be used:

$$I_{net,min} = I_{net} \left[1 + f\, \left(x'_{ref} - x'_{ref,min} \right) \right]$$

$$I_{net,max} = I_{net} \left[1 + f\, \left(x'_{ref} - x'_{ref,max} \right) \right]$$

C.3   Correction of divergence effects caused by the angular dependence of the *g*-value

C.3.1   General

This chapter applies to both, hot box and cooled plate method.[6] This section presents a methodology to quantify and correct the effect of divergent incident radiation on the experimentally determined SHGC value. Figure C.1 presents a schematic of the workflow. The different steps are described in detail in the following subsections.
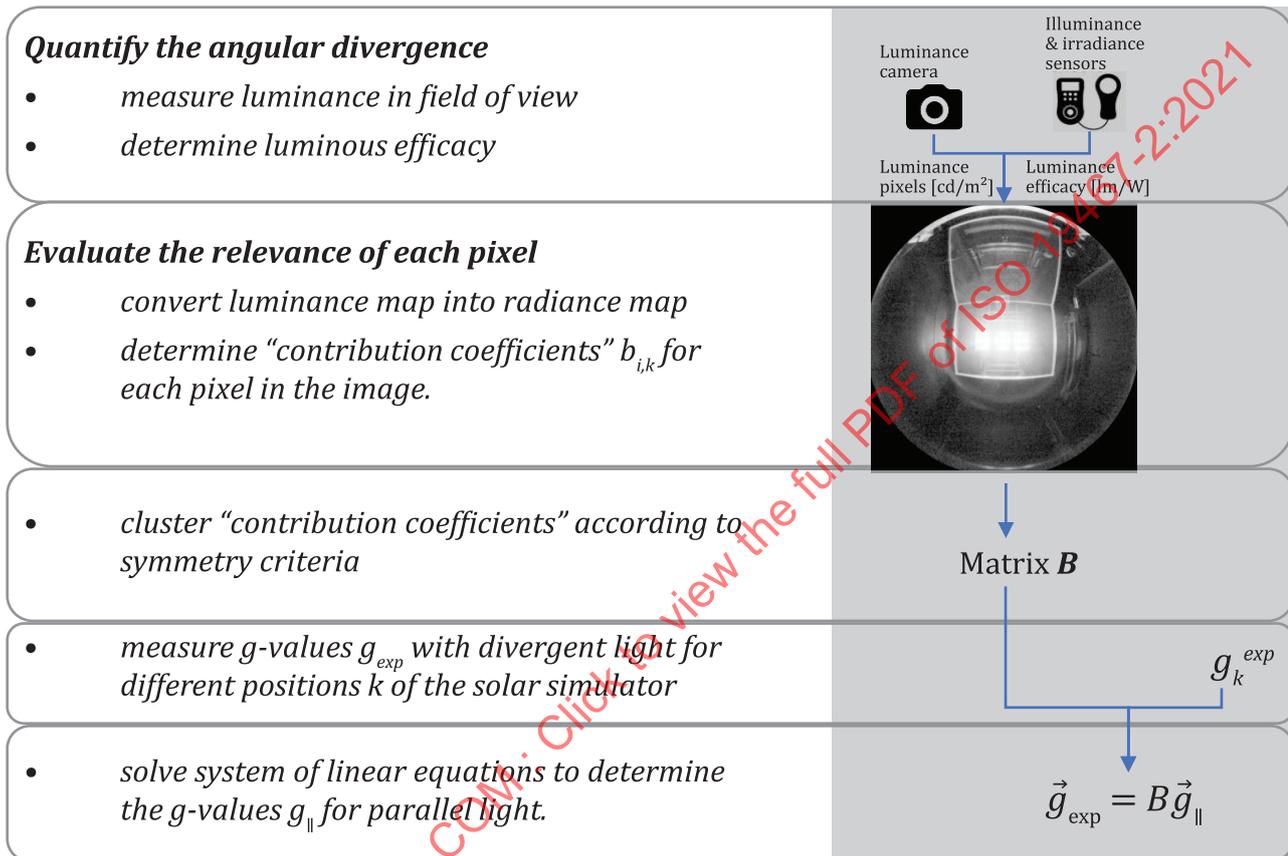

Figure C.1 — Overview of the workflow to correct the influence of angular divergence.

Assuming a discretization of a hemisphere centred at the test sample, the *g*-value that is experimentally obtained using divergent radiation (g_k^{exp}) for a specific position of the solar simulator with incident (desired) direction k is a combination of *g*-values $g_i^{\parallel}$ for parallel light from different regions i of the hemisphere, weighted by the projected solid angle ω_i of each region. This can be mathematically expressed as follows [Formula (C.1)].

$$g_k^{\text{exp}} = \frac{\sum_i g_i^{\parallel} L_{i,k} \cos(\alpha_i) \omega_i}{\sum_j L_{j,k} \cos(\alpha_j) \omega_j} = \sum_i g_i^{\parallel} b_{i,k} \, , \tag{C.1}$$

where,

$L_{i,k}$, is the radiance of the region *i*, in W/sr/m²;

$\alpha_i f$ is the incidence angle of the region *i*, in degree;