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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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Foreword

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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]).

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 52022-3[1)], *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	$W/(m^2 \cdot K)$
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	$W/(m^2 \cdot K)$
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:

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

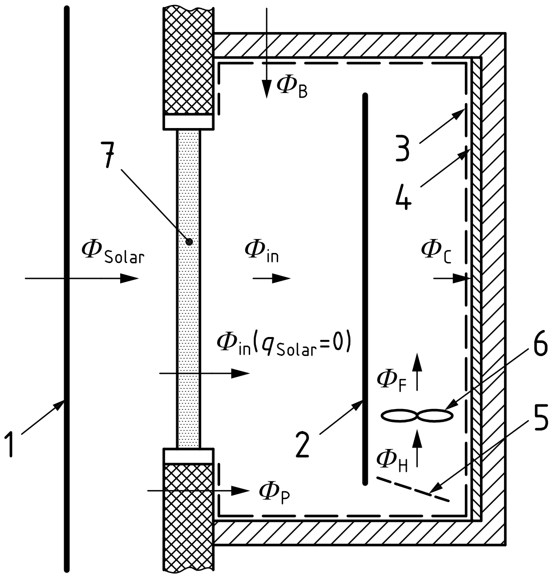
where

q_{Solar}	is the net density of heat flow rate of incident radiation, in W/m²;
q_{in}	is the net density of heat flow rate through the test specimen with irradiance, in W/m²;
$q_{in}(q_{Solar} = 0)$	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/m².

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/m^2;

A_{sp} is the projected area of the test specimen, in m^2;

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/m^2;

A_g is the glazing area of the test specimen, in m^2.

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.

$$q_{Solar} = \frac{\Phi_{Solar}}{A_{sp}} = I_{Solar} \tag{3}$$

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):

$$q_{in} = \frac{\Phi_{in}}{A_{sp}} = \frac{\Phi_C - \Phi_B - \Phi_F - \Phi_H - \Phi_P}{A_{sp}} \tag{4}$$

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, $q_{in}(q_{Solar} = 0)$, shall be calculated using Formula (5):

$$q_{in}\left(q_{Solar} = 0\right) = \frac{\Phi_{in}\left(q_{Solar} = 0\right)}{A_{sp}} = U_N \times \left(\theta_{ne} - \theta_{ni}\right) \tag{5}$$

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;

U_N is the thermal transmittance of the test specimen without irradiance, in $W/(m^2 \cdot K)$;

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

θ_{ni} is the environmental internal temperature with irradiance, in °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):

$$U_N = \frac{q'_{in}\left(q_{Solar} = 0\right)}{\theta'_{ne} - \theta'_{ni}} \quad (6)$$

where

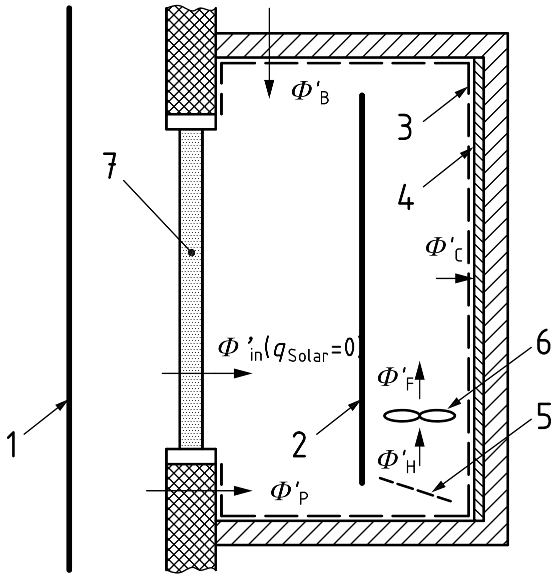
$q'_{in}(q_{Solar} = 0)$ is the net density of heat flow rate through the test specimen due to thermal transmission without irradiance when the temperature difference between internal side and external side is $(\theta'_{ne} - \theta'_{ni})$, in W/m^2;

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

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

In the case when $(\theta'_{ne} - \theta'_{ni})$ 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):

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

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;

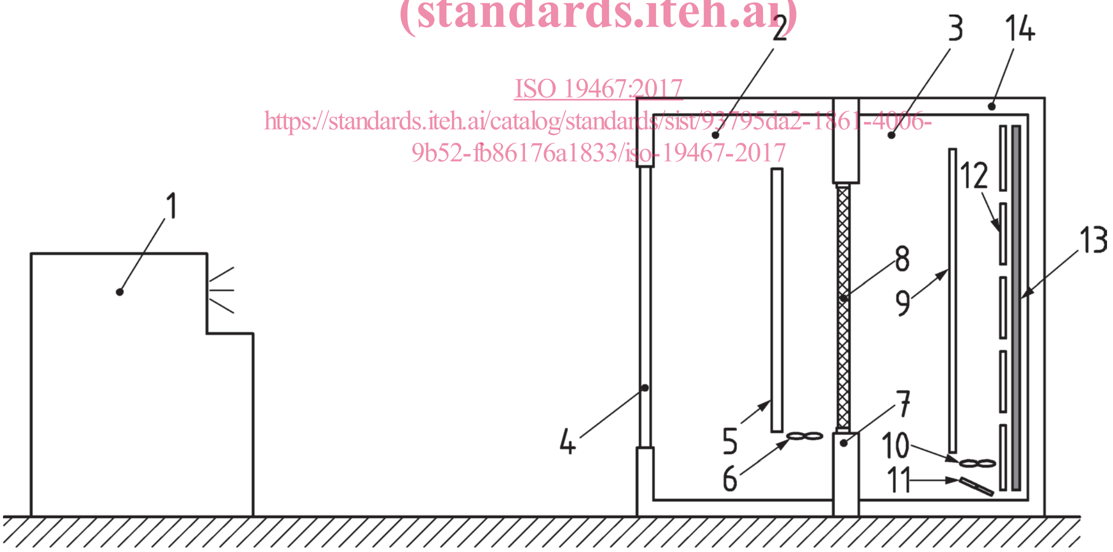
Φ'_P is the heat flow rate through the surround panel without irradiance, in watts.

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
2 climatic chamber
3 metering box
4 transparent aperture
5 external side baffle (optional)
6 external airflow generator
7 surround panel
8 test specimen
9 internal side baffle (optional)
10 one or more internal fans (optional)
11 heating device (optional)
12 heat flow measuring device
13 cooling device
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 %