



DPC: 25/30507317 DC

BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000

Fax: +44 (0)20 8996 7400

www.bsigroup.com

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



DRAFT International Standard

ISO/DIS 9050

Glass in building — Determination of luminous and solar characteristics of glazing

ICS: 81.040.20

ISO/TC 160

Secretariat: **BSI**

Voting begins on:
2025-04-16

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2025-07-09

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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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 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 160, *Glass in building*.

This third edition cancels and replaces the second edition (ISO 9050:2003), which has been technically revised.

The main changes are as follows:

- changes to the calculation of the internal heat transfer coefficient;
- clarification provided that UV transmittance is determined only for the total range and not split into UVA and UVB;
- modification to normalized relative spectral distribution of global solar radiation based on 10nm wavelength intervals;
- ambiguity relating to the area-weighting procedure for screen printed glass has been clarified;
- introduction of a matrix method for non-scattering incoherent optical systems, including multiple layers;
- modifications to the formulae to permit calculation and declaration of the luminous and solar properties of BIPV glazing.

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

While this International Standard presents the formulae for the exact calculations of the spectral characteristics of glazing, it does not consider the uncertainty of the measurements necessary to determine the spectral parameters that are used in the calculations. It should be noted that, for simple glazing systems where few measurements are required, the uncertainty of the results will be satisfactory if correct measurements procedures have been followed. When the glazing systems become complex and a large number of measurements are required to determine the spectral parameters, the uncertainty is cumulative with the number of measurements and should be considered in the final results.

The term interface used in this International Standard, is considered to be a surface characterized by its transmission and reflections of light intensities. That is, the interaction with light is incoherent, all phase information being lost. In the case of thin films (not described in this International Standard), interfaces are characterized by transmission and reflections of light amplitudes, i.e. the interaction with light is coherent and phase information is available. Finally, for clarity, a coated interface can be described as having one or more thin films, but the entire stack of thin films is characterized by its resulting transmission and reflection of light intensities.

In [Annex B](#), the procedure for the calculation of spectral characteristics of laminated glass makes specific reference to coated glass. The same procedure can be adopted for filmed glass (e.g. adhesive backed polymeric film applied to glass).

Glass in building — Determination of luminous and solar characteristics of glazing

1 Scope

This document specifies methods of determining the luminous and solar characteristics of glazing in buildings. These characteristics can serve as a basis for lighting, heating and cooling calculations of rooms and permit comparison between different types of glazing.

This document applies both to conventional glazing and to absorbing or reflecting solar-control glazing, used as vertical or horizontal glazed apertures. The appropriate formulae for single, double and triple glazing are given. A matrix method is provided as an alternative calculation method.

This document introduces a method to determine the luminous and solar properties of Building-Integrated Photovoltaic (BIPV) glazing.

This document is accordingly applicable to all transparent materials except those which show significant transmission in the wavelength region 5 μm to 50 μm of ambient temperature radiation, such as certain plastic materials.

Materials with light-scattering properties for incident radiation are dealt with as conventional transparent materials subject to certain conditions (see [5.3](#)).

Angular light and solar properties of glass in building are excluded from this document. However, research work in this area is summarised in [\[1\]](#), [\[2\]](#) and [\[3\]](#).

Guidance on the measurement of luminous and spectral properties of glass can be found in [\[4\]](#).

Vacuum Insulating Glass (VIG) is excluded from the scope of this document. For determination of the g value of VIG, please refer to ISO 19916-1.

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 10291:1994, *Glass in building — Determination of steady-state U values (thermal transmittance) of multiple glazing — Guarded hot plate method*

ISO 10292:1994, *Glass in building — Calculation of steady-state U values (thermal transmittance) of multiple glazing*

ISO 10293:1997, *Glass in building — Determination of steady-state U values (thermal transmittance) of multiple glazing — Heat flow meter method*

ISO 20589¹⁾, *Glass in building — Determination of the emissivity*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

1) Under preparation. Stage at the time of publication: ISO/DIS 20589:2024

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

light transmittance

fraction of the incident light that is transmitted by the glass

3.2

light reflectance

fraction of the incident light that is reflected by the glass

3.3

total solar energy transmittance (solar factor)

fraction of the incident solar radiation that is totally transmitted by the glass

3.4

solar direct transmittance

fraction of incident solar radiation that is directly transmitted by the glass

3.5

normal emissivity

ratio, in a direction normal to the surface, of the emissive power of the surface of the glass to the emissive power of a black body

Note 1 to entry: Normal emissivity is determined in accordance with ISO 20589.

3.6

solar direct reflectance

fraction of the incident solar radiation that is reflected by the glass

3.7

ultraviolet transmittance

fraction of the incident UV component of the solar radiation that is transmitted by the glass

3.8

colour rendering index (in transmission)

change in colour of an object as a result of the light being transmitted by the glass

3.9

shading coefficient

ratio of the solar factor of the glass to the solar factor of a reference glass (clear float)

3.10

planar PV module

planar device designed to convert solar radiation into electricity by the photovoltaic effect

Note 1 to entry: The glazing configuration of a planar PV module may be, but is not restricted to, a coated or uncoated pane of glass, a coated polymer film, a glass-polymer laminate or a glass-polymer-glass laminate. For the sake of brevity, the term PV module will be understood to mean a planar PV module in [Annex E](#).

3.11

building-integrated photovoltaic (BIPV) glazing

architectural glazing that incorporates a (planar) PV module as one of its panes

Note 1 to entry: In this context, architectural glazing refers to glazed apertures in buildings.

3.12**optically homogeneous**

attribute of glazing with optical properties, which, when determined using a spectrophotometer in accordance with this International Standard, are independent of the position selected for measurement

Note 1 to entry: Many thin-film PV modules are examples of optically homogeneous glazing.

3.13**optically inhomogeneous**

attribute of glazing with optical properties, which, when determined using a spectrophotometer in accordance with this International Standard, vary significantly (i.e. by an amount greater than measurement tolerances) on the position selected for measurement

Note 1 to entry: Typically, this refers to areas on a scale of cm^2 that have a visibly different appearance, e.g. crystalline PV cells surrounded by a transparent embedding material.

3.14**open circuit****OC**

with reference to a PV device, an electrical state in which the output electric current is zero (adapted from 3.4.57 of IEC TS 61836)

3.15**maximum power point****MPP**

point on a PV device's current-voltage characteristic where the product of electric current and voltage yields the maximum electrical power under specified operating conditions

[SOURCE: IEC TS 61836, 3.4.43.3]

3.16**standard test conditions****STC**

reference values of in-plane irradiance ($G_{\text{I,ref}} = 1\,000 \text{ W/m}^2$), photovoltaic cell junction temperature (25°C), and a reference spectral irradiance distribution calculated for air mass = 1,5 to be used during the testing of any photovoltaic device

[SOURCE: IEC TS 61836, 3.4.87]

3.17**conversion efficiency**

ratio of electric power generated by a PV device per unit area to its incident irradiance

[SOURCE: IEC TS 61836, 3.1.17]

4 Symbols

Symbol	Abbreviation
D65	standard illuminant D65
UV	ultraviolet radiation
τ_{UV}	ultraviolet transmittance
$\tau(\lambda)$	spectral transmittance
$\rho(\lambda)$	spectral reflectance
τ_{V}	light transmittance
ρ_{V}	light reflectance
τ_{e}	solar direct transmittance

Symbol	Abbreviation
ρ_e	solar direct reflectance
g	total solar energy transmittance (solar factor)
R_a	general colour rendering index
D_λ	relative spectral distribution of illuminant D65
$V(\lambda)$	spectral luminous efficiency
α_e	solar direct absorptance
Φ_e	incident solar radiant flux
q_i	secondary internal heat transfer factor
q_e	secondary external heat transfer factor
α_{elec}	proportion of total absorbed solar radiation that is extracted from the PV cell-covered area of a BIPV glazing unit as electricity
S_λ	relative spectral distribution of solar radiation
h_e	external heat transfer coefficient
h_i	internal heat transfer coefficient
ε	corrected emissivity
ε_n	normal emissivity
Λ	thermal conductance
λ	wavelength
$\Delta\lambda$	wavelength interval
U_λ	relative spectral distribution of UV in solar radiation
SC	shading coefficient
$I(\lambda)$	spectral normalised radiant flow
η_{mod}	photovoltaic conversion efficiency of a PV module
A	surface area
r	Reflectance on interface
CR	Coverage Ratio
$\eta_{cell,mod}$	power conversion efficiency of a hypothetical PV module with 100 % cell coverage ratio

5 Determination of characteristics

5.1 General

The characteristics are determined for quasi-parallel, near normal radiation incidence (see [4]) using the radiation distribution of illuminant D65 (see [Table 1](#)), solar radiation in accordance with [Table 2](#) and ultraviolet (UV) radiation in accordance with [Table 3](#).

The characteristics are as follows:

- the spectral transmittance $\tau(\lambda)$ and the spectral reflectance $\rho(\lambda)$ in the wavelength range from 300 nm to 2 500 nm;
- the light transmittance τ_v and the light reflectance ρ_v for illuminant D65;
- the solar direct transmittance τ_e and the solar direct reflectance ρ_e ;
- the total solar energy transmittance (solar factor) g ;
- the UV-transmittance τ_{UV} ;

- the general colour rendering index R_a ;
- the total shading coefficient, SC .

To characterize glazing, the principal parameters are τ_v and g ; the other parameters are optional to provide additional information.

If the value of a given characteristic is required for different glass thicknesses (in the case of uncoated glass) or for the same coating applied to different substrates, it can be obtained by calculation (in accordance with [Annex A](#)).

A procedure for the calculation of the spectral characteristics of laminated glass is given in [Annex B](#).

Guidelines on determining the spectral characteristics of screen-printed glass are given in [Annex C](#).

A modified matrix method is provided as an alternative calculation method is given in [Annex D](#).

Modifications to the formulae to permit calculation and declaration of the luminous and solar properties of BIPV glazing are given in [Annex E](#).

The convention adopted in this document is for the incident radiation to be from left to right. The left side is also referred to as outside or outdoors, whereas the right side is also referred to as inside or indoors.

5.2 Multiple-layer optical calculation

In the case of multiple-pane glazing, the spectral transmittance $\tau(\lambda)$, the spectral reflectance $\rho(\lambda)$ and the spectral absorptance $\alpha_j^T(\lambda)$ of the j th pane in the glazing unit are calculated from the spectral transmittances and reflectances of the individual components as follows:

For double glazing:

$$\tau(\lambda) = \frac{\tau_1(\lambda) \cdot \tau_2(\lambda)}{1 - \rho_1'(\lambda) \cdot \rho_2(\lambda)} \quad (1)$$

$$\rho(\lambda) = \rho_1(\lambda) + \frac{\tau_1^2(\lambda) \cdot \rho_2(\lambda)}{1 - \rho_1'(\lambda) \cdot \rho_2(\lambda)} \quad (2)$$

$$\rho'(\lambda) = \rho_2'(\lambda) + \frac{\tau_2^2(\lambda) \cdot \rho_1'(\lambda)}{1 - \rho_1'(\lambda) \cdot \rho_2(\lambda)} \quad (3)$$

$$\alpha_1^T(\lambda) = \alpha_1(\lambda) + \frac{\tau_1(\lambda) \cdot \rho_2(\lambda) \cdot \alpha_1'(\lambda)}{1 - \rho_1'(\lambda) \cdot \rho_2(\lambda)} \quad (4)$$

$$\alpha_2^T(\lambda) = \frac{\tau_1(\lambda) \cdot \alpha_2(\lambda)}{1 - \rho_1'(\lambda) \cdot \rho_2(\lambda)} \quad (5)$$

Where

- $\tau(\lambda)$ is the spectral transmittance of the double glazing;
- $\rho(\lambda)$ is the spectral reflectance of the double glazing for external incident radiation;
- $\rho'(\lambda)$ is the spectral reflectance of the double glazing for internal incident radiation;
- $\alpha_1^T(\lambda)$ is the spectral absorptance of the first (outer) pane in the double glazing for external incident radiation;

$\alpha_2^T(\lambda)$ is the spectral absorptance of the second (inner) pane in the double glazing for external incident radiation;

$\tau_1(\lambda)$ is the spectral transmittance of the first (outer) pane;

$\rho_1(\lambda)$ is the spectral reflectance of the first (outer) pane, measured in the direction of incident radiation;

$\rho_1'(\lambda)$ is the spectral reflectance of the first (outer) pane, measured in the direction opposite to the incident radiation;

$\tau_2(\lambda)$ is the spectral transmittance of the second pane;

$\rho_2(\lambda)$ is the spectral reflectance of the second pane, measured in the direction of the incident radiation;

$\rho_2'(\lambda)$ is the spectral reflectance of the second pane, measured in the direction opposite to the incident radiation;

$\alpha_1(\lambda)$ is the spectral direct absorptance of the outer pane, measured in the direction of the incident radiation, given by the formula:

$$\alpha_1(\lambda) = 1 - \tau_1(\lambda) - \rho_1(\lambda) \quad (6)$$

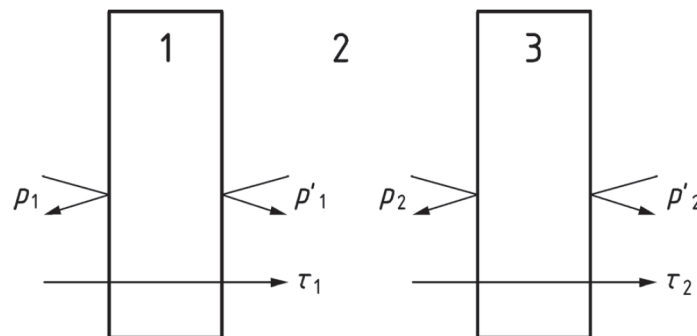
$\alpha_1'(\lambda)$ is the spectral direct absorptance of the outer pane, measured in the opposite direction to the incident radiation, given by the formula:

$$\alpha_1'(\lambda) = 1 - \tau_1(\lambda) - \rho_1'(\lambda) \quad (7)$$

$\alpha_2(\lambda)$ is the spectral direct absorptance of the second pane, measured in the direction of the incident radiation, given by the formula:

$$\alpha_2(\lambda) = 1 - \tau_2(\lambda) - \rho_2(\lambda) \quad (8)$$

The above is illustrated in [Figure 1](#).



Key

- 1 pane 1
- 2 cavity
- 3 pane 2

Figure 1 — Transmittance and reflectance in a double glazing insulating glass unit

For triple glazing:

$$\tau(\lambda) = \frac{\tau_1(\lambda) \cdot \tau_2(\lambda) \cdot \tau_3(\lambda)}{\left[1 - \rho'_1(\lambda) \cdot \rho_2(\lambda)\right] \cdot \left[1 - \rho'_2(\lambda) \cdot \rho_3(\lambda)\right] - \tau_2^2(\lambda) \cdot \rho'_1(\lambda) \cdot \rho_3(\lambda)} \quad (9)$$

$$\rho(\lambda) = \rho_1(\lambda) + \frac{\tau_1^2(\lambda) \cdot \rho_2(\lambda) \cdot \left[1 - \rho'_2(\lambda) \cdot \rho_3(\lambda)\right] + \tau_1^2(\lambda) \cdot \tau_2^2(\lambda) \cdot \rho_3(\lambda)}{\left[1 - \rho'_1(\lambda) \cdot \rho_2(\lambda)\right] \cdot \left[1 - \rho'_2(\lambda) \cdot \rho_3(\lambda)\right] - \tau_2^2(\lambda) \cdot \rho'_1(\lambda) \cdot \rho_3(\lambda)} \quad (10)$$

$$\rho'(\lambda) = \rho'_3(\lambda) + \frac{\tau_3^2(\lambda) \cdot \rho'_2(\lambda) \cdot \left[1 - \rho'_1(\lambda) \cdot \rho_2(\lambda)\right] + \tau_3^2(\lambda) \cdot \tau_2^2(\lambda) \cdot \rho'_1(\lambda)}{\left[1 - \rho'_1(\lambda) \cdot \rho_2(\lambda)\right] \cdot \left[1 - \rho'_2(\lambda) \cdot \rho_3(\lambda)\right] - \tau_2^2(\lambda) \cdot \rho'_1(\lambda) \cdot \rho_3(\lambda)} \quad (11)$$

$$\alpha_1^T(\lambda) = \alpha_1(\lambda) + \frac{\tau_1(\lambda) \cdot \alpha'_1(\lambda) \cdot \rho_2(\lambda) \cdot \left[1 - \rho'_2(\lambda) \cdot \rho_3(\lambda)\right] + \tau_1(\lambda) \cdot \tau_2^2(\lambda) \cdot \alpha'_1(\lambda) \cdot \rho_3(\lambda)}{\left[1 - \rho'_1(\lambda) \cdot \rho_2(\lambda)\right] \cdot \left[1 - \rho'_2(\lambda) \cdot \rho_3(\lambda)\right] - \tau_2^2(\lambda) \cdot \rho'_1(\lambda) \cdot \rho_3(\lambda)} \quad (12)$$

$$\alpha_2^T(\lambda) = \frac{\tau_1(\lambda) \cdot \alpha_2(\lambda) \cdot \left[1 - \rho'_2(\lambda) \cdot \rho_3(\lambda)\right] + \tau_1(\lambda) \cdot \tau_2(\lambda) \cdot \alpha'_2(\lambda) \cdot \rho_3(\lambda)}{\left[1 - \rho'_1(\lambda) \cdot \rho_2(\lambda)\right] \cdot \left[1 - \rho'_2(\lambda) \cdot \rho_3(\lambda)\right] - \tau_2^2(\lambda) \cdot \rho'_1(\lambda) \cdot \rho_3(\lambda)} \quad (13)$$

$$\alpha_3^T(\lambda) = \frac{\tau_1(\lambda) \cdot \tau_2(\lambda) \cdot \alpha_3(\lambda)}{\left[1 - \rho'_1(\lambda) \cdot \rho_2(\lambda)\right] \cdot \left[1 - \rho'_2(\lambda) \cdot \rho_3(\lambda)\right] - \tau_2^2(\lambda) \cdot \rho'_1(\lambda) \cdot \rho_3(\lambda)} \quad (14)$$

where

$\tau(\lambda)$ is the spectral transmittance of the triple glazing;

$\rho(\lambda)$ is the spectral reflectance of the triple glazing for external incident radiation;

$\rho'(\lambda)$ is the spectral reflectance of the triple glazing for internal incident radiation;

$\alpha_1^T(\lambda)$ is the spectral absorptance of the first (outer) pane in the triple glazing for external incident radiation;

$\alpha_2^T(\lambda)$ is the spectral absorptance of the second (middle) pane in the triple glazing for external incident radiation;

$\alpha_3^T(\lambda)$ is the spectral absorptance of the third (inner) pane in the triple glazing for external incident radiation;

$\tau_1(\lambda)$, $\rho_1(\lambda)$, $\rho'_1(\lambda)$, $\tau_2(\lambda)$, $\rho_2(\lambda)$, $\rho'_2(\lambda)$, $\alpha_1(\lambda)$, $\alpha'_1(\lambda)$ and $\alpha_2(\lambda)$ are explained in [Formula \(1\)](#) to [Formula \(5\)](#);

$\tau_3(\lambda)$ is the spectral transmittance of the third pane;

$\rho_3(\lambda)$ is the spectral reflectance of the third pane, measured in the direction of the incident radiation;

$\rho'_3(\lambda)$ is the spectral reflectance of the third pane, measured in the direction opposite to the incident radiation;

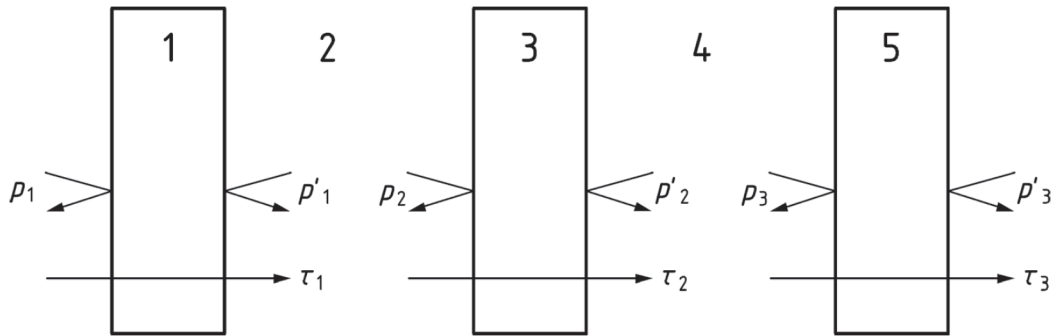
$\alpha'_2(\lambda)$ is the spectral direct absorptance of the second pane, measured in the opposite direction to the incident radiation, given by the formula:

$$\alpha'_2(\lambda) = 1 - \tau_2(\lambda) - \rho'_2(\lambda) \quad (15)$$

$\alpha_3(\lambda)$ is the spectral direct absorptance of the third pane, measured in the direction of the incident radiation, given by the formula:

$$\alpha_3(\lambda) = 1 - \tau_3(\lambda) - \rho_3(\lambda) \quad (16)$$

The above is illustrated in [Figure 2](#).



Key

1	pane 1	4	cavity 2
2	cavity 1	5	pane 3
3	pane 2		

Figure 2 — Transmittance and reflectance in a triple glazing insulating glass unit

For glazing with more than three components, formulae similar to [Formula \(1\)](#) to [Formula \(5\)](#) and [Formula \(9\)](#) to [Formula \(14\)](#) are found to calculate $\tau(\lambda)$ of such glazing from the spectral coefficients of the individual components. As an example, glazing composed of five components may be treated as follows:

- first consider the first three components as triple glazing and calculate the spectral characteristics of this combination;
- next, run the same procedure for the next two components as double glazing;
- then calculate $\tau(\lambda)$ for the five-component glazing, considering it as double glazing consisting of the preceding triple and double glazing (or, alternatively, the methodology in [Annex D](#) could be followed).

NOTE 1 The use of an integrating sphere is necessary when light scattering materials are tested. In this case the size of the sphere and its aperture shall be large enough to collect all possible scattered light and to obtain fair average values when surface patterns are irregularly distributed.

NOTE 2 Measurement of light scattering glass products is the subject of a round robin test programme under the responsibility of International Commission on Glass Technical Committee 10. The results of this programme are expected to include suggestions for improvements in measurement and prediction techniques.

5.3 Light transmittance and reflectance

The light transmittance τ_v and reflectance ρ_v of the glazing are calculated using the following formula:

$$\tau_v = \frac{\sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} D_\lambda \cdot \tau(\lambda) \cdot V(\lambda) \cdot \Delta\lambda}{\sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} D_\lambda \cdot V(\lambda) \cdot \Delta\lambda} \quad (17)$$

$$\rho_v = \frac{\sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} D_\lambda \cdot \rho(\lambda) \cdot V(\lambda) \cdot \Delta\lambda}{\sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} D_\lambda \cdot V(\lambda) \cdot \Delta\lambda} \quad (18)$$

where

D_λ is the relative spectral distribution of illuminant D65 (see [5]);

$\tau(\lambda)$ is the spectral transmittance of the glazing;

$\rho(\lambda)$ is the spectral reflectance of the glazing;

$V(\lambda)$ is the spectral luminous efficiency for photopic vision defining the standard observer for photometry (see [5]);

$\Delta\lambda$ is the wavelength interval.

Table 1 indicates the values for $D_\lambda \cdot V(\lambda) \cdot \Delta\lambda$ for wavelength intervals of 10 nm. The table has been drawn up in such a way that $\sum D_\lambda \cdot V(\lambda) \cdot \Delta\lambda = 1$.

For calculating the internal light reflectance $\rho'(\lambda)$ is used instead of $\rho(\lambda)$ in Formula (18).

5.4 Solar direct transmittance, reflectance and absorptance

The solar direct transmittance τ_e , the solar direct reflectance ρ_e and the solar direct absorptance $\alpha_{e,j}$ of the glazing is calculated using the following formula:

$$\tau_e = \frac{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_\lambda \cdot \tau(\lambda) \cdot \Delta\lambda}{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_\lambda \cdot \Delta\lambda} \quad (19)$$

$$\rho_e = \frac{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_\lambda \cdot \rho(\lambda) \cdot \Delta\lambda}{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_\lambda \cdot \Delta\lambda} \quad (20)$$

$$\alpha_{e,j} = \frac{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_\lambda \cdot \alpha_j^T(\lambda) \cdot \Delta\lambda}{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_\lambda \cdot \Delta\lambda} \quad (21)$$

where

S_λ is the relative spectral distribution of the solar radiation (see Table 2);

$\tau(\lambda)$ is the spectral transmittance of the glazing;

$\rho(\lambda)$ is the spectral reflectance of the glazing;

$\alpha_j^T(\lambda)$ is the spectral absorptance of the j -th pane from the outside in the glazing consisting of n glass panes;

$\Delta\lambda$ is the wavelength interval.

In the case of multiple glazing, the spectral transmittance $\tau(\lambda)$, the spectral reflectance $\rho(\lambda)$ and the spectral absorptance $\alpha_j^T(\lambda)$ are calculated in accordance with 5.2.

The relative spectral distribution, S_λ , used to calculate the solar direct transmittance is derived from CIE 85.[6] The corresponding values $S_\lambda \Delta\lambda$ are given in Table 2. The table was drawn up in such a way that $\sum S_\lambda \Delta\lambda = 1$.

NOTE 1 For measurements previously undertaken in accordance with ISO 9050:2003, Table 2, where there is no transmittance or reflectance data at a given wavelength in Table 2 of this document, the missing values can be obtained by linear interpolation.

NOTE 2 Contrary to real situations, it is always assumed, for simplification, that the spectral distribution of the solar radiation (see [Table 2](#)) is not dependent upon atmospheric conditions (e.g. dust, mist, moisture content) and that the solar radiation strikes the glazing as a collimated beam and at normal incidence. The resulting errors are very small.

5.5 Total solar energy transmittance (solar factor)

5.5.1 Calculation

The total solar energy transmittance g is calculated as the sum of the solar direct transmittance τ_e and the secondary heat transfer factor q_i of the glazing towards the inside (see [5.4](#) and [5.5.3](#)), the latter resulting from heat transfer by convection and longwave IR-radiation of that part of the incident solar radiation which has been absorbed by the glazing:

$$g = \tau_e + q_i \quad (22)$$

5.5.2 Division of incident solar radiant flux

The incident solar radiant flux Φ_e is divided into the following three parts (see [Figure 3](#)):

- a) the transmitted part, $\tau_e \Phi_e$;
- b) the reflected part, $\rho_e \Phi_e$;
- c) the absorbed part, $\alpha_e \Phi_e$;

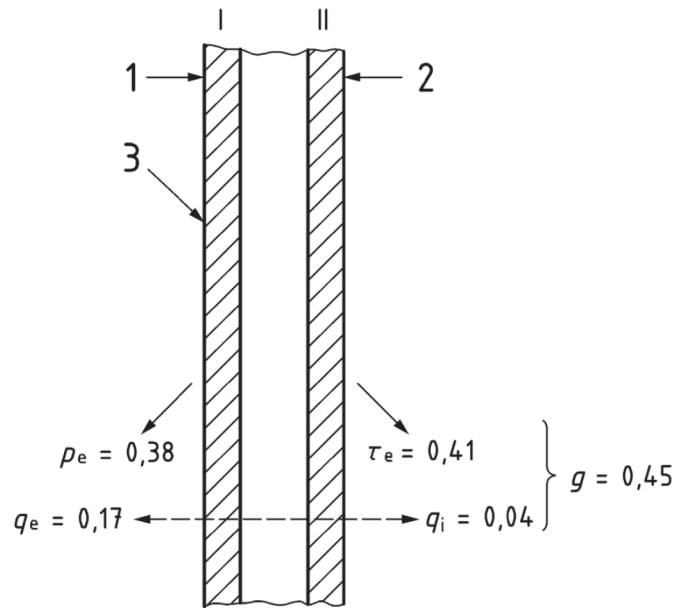
where

τ_e is the solar direct transmittance (see [5.4](#));

ρ_e is the solar direct reflectance (see [5.4](#));

α_e is the solar direct absorptance (see [5.4](#)).

$$\alpha_e = \sum_{j=1}^n \alpha_{e,j} \quad (23)$$

**Key**

- 1 outer pane
- 2 inner pane
- 3 unit incident radiant flux

Figure 3 — Example of division of the incident radiant flux

The relation between the three characteristics is:

$$\tau_e + \rho_e + \alpha_e = 1 \quad (24)$$

The absorbed part $\alpha_e \Phi_e$ is subsequently split into two parts $q_i \Phi_e$ and $q_e \Phi_e$ which are energy transferred to the inside and outside respectively:

$$\alpha_e = q_i + q_e \quad (25)$$

where

- q_i is the secondary heat transfer factor of the glazing towards the inside;
- q_e is the secondary heat transfer factor of the glazing towards the outside.

5.5.3 Secondary heat transfer factor towards the inside**5.5.3.1 Boundary conditions**

For the calculation of the secondary heat transfer factor towards the inside, q_i , the heat transfer coefficients of the glazing towards the outside, h_e , and towards the inside, h_i are needed. These values mainly depend on the position of the glazing, wind velocity, inside and outside temperatures and furthermore on the temperature of the two external glazing surfaces.

As the purpose of this document is to provide basic information on the performance of glazing, conventional conditions have been stated for simplicity:

- a) position of the glazing: vertical;

- b) outside surface: wind velocity: approximately 4 m/s, corrected emissivity = 0,837;
- c) inside surface: natural convection, emissivity optional;
- d) air spaces are unventilated.

Under these conventional, average conditions, standard values for h_e and h_i are obtained:

$$h_e = 25 \text{ W / (m}^2 \cdot \text{K)}$$

$$h_i = h_r + h_c \quad (26)$$

where

h_r is the internal radiative heat transfer coefficient;

h_c is the internal convective heat transfer coefficient.

For the purposes of this document, the internal radiative heat transfer coefficient for uncoated soda lime glass surfaces is $4,8 \text{ W/(m}^2 \cdot \text{K)}$, rounded to one decimal place.

If the internal surface of the glass has a lower emissivity the internal radiative heat transfer coefficient is given by:

$$h_r = 4 \cdot \varepsilon \cdot \sigma \cdot T_s^3 \quad (27)$$

where

ε is the corrected emissivity of the coated surface;

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

T_s is the mean temperature of the internal surface of the glass (K).

This is only applicable if there is no condensation on the coated surface. A procedure for determining the corrected emissivity of a coating is given in ISO 20589.

The value of h_c is $2,5 \text{ W/(m}^2 \cdot \text{K)}$ for free convection for horizontal heat flow.

For vertical soda lime glass surfaces and free convection

$$h_i = 4,8 + 2,5 = 7,3 \text{ W / (m}^2 \cdot \text{K)} \quad (28)$$

which is standardized for the purposes of comparison of U values.

For uncoated soda lime silicate glass, $\varepsilon = 0,837$ and $h_i = 7,3 \text{ W / (m}^2 \cdot \text{K)}$

NOTE 1 With reasonable confidence the same value may be used for uncoated borosilicate glass, alkaline earth silicate glass, alumino silicate glass and glass ceramics.

The corrected emissivity shall be defined and measured in accordance with ISO 20589.

NOTE 2 Values lower than 0,837 for ε (due to surface coatings with higher reflectance in the far infra-red) are only to be taken into account if condensation on the coated surface can be excluded.

5.5.3.2 Single glazing

The secondary internal heat transfer factor, q_i , of single glazing is calculated using the following formula:

$$q_i = \alpha_e \cdot \frac{h_i}{h_e + h_i} \quad (29)$$

where

α_e is the solar direct absorptance in accordance with [5.4](#);

h_e and h_i are the heat transfer coefficients towards the outside and inside respectively in accordance with [5.5.3.1](#).

5.5.3.3 Double glazing

The secondary internal heat transfer factor, q_i , of double glazing is calculated using the following formula:

$$q_i = \frac{\left[\frac{\alpha_{e,1} + \alpha_{e,2}}{h_e} + \frac{\alpha_{e,2}}{\Lambda} \right]}{\left[\frac{1}{h_i} + \frac{1}{h_e} + \frac{1}{\Lambda} \right]} \quad (30)$$

where

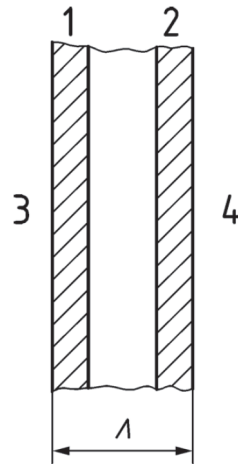
h_e and h_i are the heat transfer coefficients towards the outside and inside respectively in accordance with [5.5.3.1](#);

$\alpha_{e,1}$ is the solar direct absorptance of the outer pane within the double glazing in accordance with [5.4](#);

$\alpha_{e,2}$ is the solar direct absorptance of the second pane within the double glazing in accordance with [5.4](#);

Λ is the thermal conductance between the outer surface and the innermost surface of the double glazing (see [Figure 4](#)).

The thermal conductance Λ is determined by the calculation method in accordance with ISO 10292 whenever possible or by measuring methods in accordance with ISO 10291 or ISO 10293.

**Key**

- 1 pane 1
- 2 pane 2
- 3 outside
- 4 inside

Figure 4 — Illustration of the meaning of thermal conductance Λ **5.5.3.4 Triple glazing**

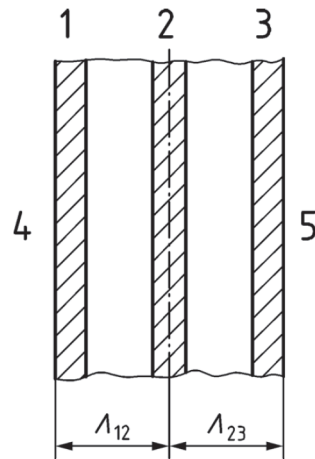
The secondary internal heat transfer factor of triple glazing, q_i , is calculated using the following formula:

$$q_i = \frac{\left[\frac{\alpha_{e,3}}{\Lambda_{23}} + \frac{\alpha_{e,3} + \alpha_{e,2}}{\Lambda_{12}} + \frac{\alpha_{e,3} + \alpha_{e,2} + \alpha_{e,1}}{h_e} \right]}{\left[\frac{1}{h_i} + \frac{1}{h_e} + \frac{1}{\Lambda_{12}} + \frac{1}{\Lambda_{23}} \right]} \quad (31)$$

where

- $\alpha_{e,1}$ is the solar direct absorptance of the outer pane within the triple glazing in accordance with 5.4;
- $\alpha_{e,2}$ is the solar direct absorptance of the second pane within the triple glazing in accordance with 5.4;
- $\alpha_{e,3}$ is the solar direct absorptance of the third pane within the triple glazing in accordance with 5.4;
- h_e and h_i are the heat transfer coefficients towards the outside and inside respectively in accordance with 5.5.3.1;
- Λ_{12} is the thermal conductance between the outer surface of the first pane and the centre of the second pane (see Figure 5);
- Λ_{23} is the thermal conductance between the centre of the second pane and the innermost surface of the third pane (see Figure 5).

The thermal conductances Λ_{12} and Λ_{23} are determined in accordance with 5.5.3.3.

**Key**

- 1 pane 1
- 2 pane 2
- 3 pane 3
- 4 outside
- 5 inside

Figure 5 — Illustration of the meaning of the thermal conductances Λ_{12} and Λ_{23}

5.5.3.5 Quadruple glazing

The secondary internal heat transfer factor of quadruple glazing can be determined by reference to the g value calculation in [Annex D](#).

5.6 Shading coefficient

The shading coefficient, SC, is given as the total solar energy transmittance of the glazing, divided by the total solar energy transmittance of 3 mm or 4 mm clear float.

NOTE 1 In some countries, SC may be specifically referred to as total shading coefficient.

NOTE 2 The value of the total solar energy transmittance of a clear float glass of 3 mm to 4 mm nominal thickness traditionally assumed as 0,87.

The value that is actually used as the total solar energy transmittance for the clear float glass pane should be stated.

5.7 UV transmittance

A standard relative spectral distribution for the UV part of the global solar radiation, U_λ , is given (see Bibliography, [7]). [Table 3](#) gives the values of $U_\lambda \cdot \Delta\lambda$ for wavelength intervals of 5 nm in the UV range. The table has been drawn up with relative values in such a way that $\sum U_\lambda \cdot \Delta\lambda = 1$ for the total UV range.

The UV-transmittance τ_{uv} is calculated as follows:

$$\tau_{uv} = \frac{\sum_{\lambda=300 \text{ nm}}^{380 \text{ nm}} U_\lambda \tau(\lambda) \Delta\lambda}{\sum_{\lambda=300 \text{ nm}}^{380 \text{ nm}} U_\lambda \Delta\lambda} \quad (32)$$

where

$\tau(\lambda)$ is the spectral direct transmittance of the glazing (see 5.2);

U_λ is the relative distribution of the UV part of global solar radiation;

$\Delta\lambda$ is the wavelength interval.

NOTE If statements are made about the UV transmission of glazing, in most cases it is sufficient to give τ_{UV} , the transmittance for the total UV radiation contained in global solar radiation.

5.8 CIE damage factor

The CIE damage factor τ_{df} (see reference [8]) is calculated according to the following formulae:

$$\tau_{\text{df}} = \frac{\sum_{\lambda=300 \text{ nm}}^{600 \text{ nm}} \sum_{\lambda=300 \text{ nm}}^{600 \text{ nm}} \tau(\lambda) C_\lambda S_\lambda \Delta\lambda}{\sum_{\lambda=300 \text{ nm}}^{600 \text{ nm}} \sum_{\lambda=300 \text{ nm}}^{600 \text{ nm}} C_\lambda S_\lambda \Delta\lambda} \quad (33)$$

$$C_\lambda = e^{-0,012\lambda} \quad (\text{with } \lambda \text{ in nm}) \quad (34)$$

where

S_λ is the relative spectral distribution of solar radiation;

$\tau(\lambda)$ is the spectral transmittance of the glazing (see 3.3);

$\Delta\lambda$ and the integration procedure are the same as in 3.3 except that the data points shall be chosen at the wavelengths given in Table 4.

Table 4 gives the values of $C_\lambda S_\lambda \Delta\lambda$. This table has been drawn up with relative values in such a way that $\sum C_\lambda S_\lambda \Delta\lambda = 1$ for the range from 300 nm to 600 nm.

This average extends over the UV and part of the visible portions of the solar spectrum, which may contribute to the solar radiation damage of materials.

5.9 Skin damage factor

The skin damage factor F_{sd} (see reference [9]) is calculated according to the following formula:

$$F_{\text{sd}} = \frac{\sum_{\lambda=300 \text{ nm}}^{400 \text{ nm}} \tau(\lambda) E_\lambda S_\lambda \Delta\lambda}{\sum_{\lambda=300 \text{ nm}}^{400 \text{ nm}} E_\lambda S_\lambda \Delta\lambda} \quad (35)$$

where

S_λ is the relative spectral distribution of solar radiation;

E_λ is the CIE erythral effectiveness spectrum;

$\tau(\lambda)$ is the spectral transmittance of the glazing (see 3.3);

$\Delta\lambda$ and the integration procedure are the same as in 3.3 except that the data points shall be chosen at the wavelengths given in Table 5.

Table 5 gives the values of $E_\lambda S_\lambda \Delta\lambda$. This table has been drawn up with relative values in such a way that $\sum E_\lambda S_\lambda \Delta\lambda = 1$ for the range from 300 nm to 400 nm.

This average extends over the UV and part of the visible portions of the solar spectrum, which may contribute to the solar radiation damage of skin.

5.10 Colour rendering

The colour rendering properties of glazing in transmission are expressed by the general colour rendering index R_a . This index enables to express synthetically a quantitative evaluation of the differences in colour between eight test colours lighted directly by the reference illuminant D65 and by the same illuminant transmitted through the glazing (see [10]).

The test colours are defined by their spectral reflectance $\beta_i(\lambda)$ (i from 1 to 8), reported in Table 6 (see [10]). The relative spectral energy distribution of illuminant D65 is reported in Table 7 (see [5]).

The procedure to determine the general colour rendering index is the following.

Calculate the tristimulus values X_t , Y_t , Z_t of the light transmitted by the glazing:

$$X_t = \sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} \frac{d\Phi_e}{d\lambda} \cdot \tau(\lambda) \cdot \bar{x}(\lambda) \cdot \Delta\lambda \quad (36)$$

$$Y_t = \sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} \frac{d\Phi_e}{d\lambda} \cdot \tau(\lambda) \cdot \bar{y}(\lambda) \cdot \Delta\lambda \quad (37)$$

$$Z_t = \sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} \frac{d\Phi_e}{d\lambda} \cdot \tau(\lambda) \cdot \bar{z}(\lambda) \cdot \Delta\lambda \quad (38)$$

where

$\frac{d\Phi_e}{d\lambda} \cdot \Delta\lambda$ is the relative spectral energy distribution of illuminant D65 reported in Table 7 (see [5]);

$\tau(\lambda)$ is the spectral transmittance of the glazing;

$\bar{x}(\lambda)$, $\bar{y}(\lambda)$ and $\bar{z}(\lambda)$ are the spectral tristimulus values for the CIE 1931 colorimetric standard observer reported in Table 8 (see [5]).

Calculate the tristimulus values of the light transmitted by the glazing and reflected by each of the eight test colours:

$$X_{t,i} = \sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} \frac{d\Phi_e}{d\lambda} \cdot \tau(\lambda) \cdot \beta_i(\lambda) \cdot \bar{x}(\lambda) \cdot \Delta\lambda \quad (39)$$

$$Y_{t,i} = \sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} \frac{d\Phi_e}{d\lambda} \cdot \tau(\lambda) \cdot \beta_i(\lambda) \cdot \bar{y}(\lambda) \cdot \Delta\lambda \quad (40)$$

$$Z_{t,i} = \sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} \frac{d\Phi_e}{d\lambda} \cdot \tau(\lambda) \cdot \beta_i(\lambda) \cdot \bar{z}(\lambda) \cdot \Delta\lambda \quad (41)$$

where $\beta_i(\lambda)$ is the spectral reflectance of each test colour i (i from 1 to 8).

Calculate the trichromatic coordinates in the CIE 1960 uniform chromaticity diagram. The following formulae shall be used:

— for transmitted light:

$$u_t = \frac{4X_t}{X_t + 15Y_t + 3Z_t} \quad (42)$$

$$v_t = \frac{6Y_t}{X_t + 15Y_t + 3Z_t} \quad (43)$$

— for light transmitted then reflected by the test colour i :

$$u_{t,i} = \frac{4X_{t,i}}{X_{t,i} + 15Y_{t,i} + 3Z_{t,i}} \quad (44)$$

$$v_{t,i} = \frac{6Y_{t,i}}{X_{t,i} + 15Y_{t,i} + 3Z_{t,i}} \quad (45)$$

Calculate the trichromatic coordinates corrected in terms of distortion by chromatic adaptation, for the eight test colours illuminated by the transmitted light according to:

$$u'_{t,i} = \frac{10,872 + 0,8802 \frac{c_{t,i}}{c_t} - 8,2544 \frac{d_{t,i}}{d_t}}{16,518 + 3,2267 \frac{c_{t,i}}{c_t} - 2,0636 \frac{d_{t,i}}{d_t}} \quad (46)$$

$$v'_{t,i} = \frac{5,520}{16,518 + 3,2267 \frac{c_{t,i}}{c_t} - 2,0636 \frac{d_{t,i}}{d_t}} \quad (47)$$

with c_t , d_t for the transmitted light, $c_{t,i}$, $d_{t,i}$ for each test colour i , expressed by the formulae:

— for transmitted light:

$$c_t = \frac{1}{v_t} (4 - u_t - 10 v_t) \quad (48)$$

$$d_t = \frac{1}{v_t} (1,708 v_t + 0,404 - 1,48 u_t) \quad (49)$$

— for light transmitted, then reflected by the test colour i :

$$c_{t,i} = \frac{1}{v_{t,i}} (4 - u_{t,i} - 10 v_{t,i}) \quad (50)$$

$$d_{t,i} = \frac{1}{v_{t,i}} (1,708 v_{t,i} + 0,404 - 1,48 u_{t,i}) \quad (51)$$

Conversion into the CIE 1964 uniform colour space system: for each of the test colours the conversion is worked out using the formulae:

$$W_{t,i}^* = 25 \left(\frac{100Y_{t,i}}{Y_t} \right)^{\frac{1}{3}} - 17 \quad (52)$$

$$U_{t,i}^* = 13 W_{t,i}^* (u'_{t,i} - 0,1978) \quad (53)$$

$$V_{t,i}^* = 13 W_{t,i}^* (v'_{t,i} - 0,3122) \quad (54)$$

Determination of the total distortion of the colour i . For each test colour i :

$$\Delta E_i = \sqrt{(U_{t,i}^* - U_{r,i}^*)^2 + (V_{t,i}^* - V_{r,i}^*)^2 + (W_{t,i}^* - W_{r,i}^*)^2} \quad (55)$$

The values of $U_{r,i}^*$, $V_{r,i}^*$, $W_{r,i}^*$, calculated for the test colours, lighted by the standard illuminant D65 without the glazing being interposed, are given in [Table 9](#) (see [8]).

Calculate the specific colour rendering index for each test colour i :

$$R_i = 100 - 4,6 \Delta E_i \quad (56)$$

Calculate the general colour rendering index:

$$R_a = \frac{1}{8} \sum_{i=1}^8 R_i \quad (57)$$

The general colour rendering index R_a may attain a maximum value of 100. This will be achieved for glazing whose spectral transmittance is completely constant in the visible spectral range. In the technique of illumination, general colour rendering indices $R_a > 90$ characterize a very good and values $R_a > 80$ a good colour rendering.

An example of calculation of R_a is given in [Annex F](#).

6 Expression of results

The general colour rendering index R_a shall be quoted to two significant figures. All the other characteristics shall be quoted to two decimal places. Intermediate values shall not be rounded.

7 Test report

The test report shall state the following:

- the number and thickness of panes in the glazing;
- the type and position of panes (for the case of multiple glazing) designated as outer pane, second pane, third pane, etc.;
- the position of the coating (for the case of coated glass) designating the faces of the panes as 1, 2, 3 etc., starting from the outer surface of the outer pane;
- the results for the required characteristics;
- the type of instrument used (specifying, if used, the reflectance accessory or integrating sphere and the reference material for reflectance).

Table 1 — Normalized relative spectral distribution D_λ of illuminant D65 multiplied by the spectral luminous efficiency $V(\lambda)$ and by the wavelength interval $\Delta\lambda$

λ nm	$D_\lambda V(\lambda) \Delta\lambda \cdot 10^2$
380	0,000 0
390	0,000 5
400	0,003 0
410	0,010 3
420	0,035 2
430	0,094 8
440	0,227 4
450	0,419 2
460	0,666 3
470	0,985 0
480	1,518 9
490	2,133 6
500	3,349 1
510	5,139 3
520	7,052 3
530	8,799 0
540	9,442 7
550	9,807 7
560	9,430 6
570	8,689 1
580	7,899 4
590	6,330 6
600	5,354 2
610	4,249 1
620	3,150 2
630	2,081 2
640	1,381 0
650	0,807 0
660	0,461 2
670	0,248 5
680	0,125 5
690	0,053 6
700	0,027 6
710	0,014 6
720	0,005 7
730	0,003 5
740	0,002 1
750	0,000 8
760	0,000 1
770	0,000 0
780	0,000 0

Table 2 — Normalized relative spectral distribution of global solar radiation S_λ multiplied by the wavelength interval $\Delta\lambda$ (Based on CIE 85Table 4 at 10 nm intervals)

λ nm	$S_\lambda \Delta\lambda^a$
300	0,000 108
310	0,001 308
320	0,003 382
330	0,005 537
340	0,006 091
350	0,006 544
360	0,007 075
370	0,008 421
380	0,008 897
390	0,009 285
400	0,011 966
410	0,013 515
420	0,013 567
430	0,012 769
440	0,014 703
450	0,016 780
460	0,017 251
470	0,017 050
480	0,017 142
490	0,016 375
500	0,016 278
510	0,016 359
520	0,015 651
530	0,016 115
540	0,016 015
550	0,015 974
560	0,015 609
570	0,015 176
580	0,014 699
590	0,014 306
600	0,014 462
610	0,014 642
620	0,014 427
630	0,014 165
640	0,014 013
650	0,013 866
660	0,013 643
670	0,013 296
680	0,012 278
690	0,011 379

^a The relative spectral distribution of global solar radiation (direct and diffuse) is calculated from the values given in Bibliography [6], for air mass = 1; water content = 1,42 cm precipitable water; ozone content = 0,34 cm at standard temperature and pressure; albedo of earth surface = 0,2; spectral optical depth of aerosol extinction (at $\lambda = 500$ nm) = 0,1.