INTERNATIONAL STANDARD

ISO 9050

Second edition
2003-08-15

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

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Verre dans la construction — Détermination de la transmission lumineuse, de la transmission solaire directe, de la transmission énergétique solaire totale, de la transmission de l'ultraviolet et des facteurs dérivés des vitrages

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Reference number
ISO 9050:2003(E)

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Published in Switzerland

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 9050 was prepared by Technical Committee ISO/TC 160, *Glass in building*, Subcommittee SC 2, *Use considerations*.

This second edition cancels and replaces the first edition (ISO 9050:1990), which has been technically revised.

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

1 Scope

This International Standard specifies methods of determining light and energy transmittance of solar radiation for glazing in buildings. These characteristic data can serve as a basis for light, heating and ventilation calculations of rooms and can permit comparison between different types of glazing.

This International Standard is applicable both to conventional glazing units and to absorbing or reflecting solar-control glazing, used as glazed apertures. The appropriate formulae for single, double and triple glazing are given. Furthermore, the general calculation procedures for units consisting of more than components are established.

This International Standard is applicable to all transparent materials. One exception is the treatment of the secondary heat transfer factor and the total solar energy factor for those materials that show significant transmittance in the wavelength region of ambient temperature radiation (5 µm to 50 µm), such as certain plastic sheets.

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NOTE For multiple glazing including elements with light-scattering properties, the more detailed procedures of ISO 15099 can be used. For daylighting calculations, procedures can be found in reference [1].

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2 Normative references

The following referenced documents are indispensable for the application 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 9845-1:1992, *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 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 10526:1999/CIE S005:1998, *CIE standard illuminants for colorimetry*

ISO/CIE 10527:1991, *CIE standard colorimetric observers*

CIE 13.3:1995, *Technical report — Method of measuring and specifying colour rendering properties of light source*

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3 Determination of characteristic parameters

3.1 General

The characteristic parameters are determined for quasi-parallel, almost normal radiation incidence. For the measurements, the samples shall be irradiated by a beam whose axis is at an angle not exceeding 10° from the normal to the surface. The angle between the axis and any ray of the illuminating beam shall not exceed 5° (see reference [2]).

The characteristic parameters are as follows:

— the spectral transmittance $\tau(\lambda)$, the spectral external reflectance $\rho_o(\lambda)$ and the spectral internal reflectance $\rho_i(\lambda)$ in the wavelength range of 300 nm to 2 500 nm;

— the light transmittance τ_v, the external light reflectance $\rho_{v,o}$ and the internal light reflectance $\rho_{v,i}$ 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.

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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 glass substrates, it may be obtained by calculation (see Annex A).

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If nothing else is stated, the published characteristic parameters shall be determined using the standard conditions given in 3.3 to 3.7. Other optional conditions given in Clause 4 shall be stated.

When calculating the characteristic parameters of multiple glazing, the spectral data of each glass component instead of integrated data shall be used.

3.2 Performance of optical measurements

Optical measurements in transmission and reflection require special care and much experimental experience to achieve an accuracy in transmittance and reflectance of about ± 0,01.

Commercial spectrophotometers (with or without integrating spheres) are affected by various sources of inaccuracy when used for reflectance and transmittance measurements on flat glass for building.

The wavelength calibration and the photometric linearity of commercial spectrophotometers shall be checked periodically using reference materials obtained from metrological laboratories.

The wavelength calibration shall be performed by measuring glass plates or solutions which feature relatively sharp absorption bands at specified wavelengths; the photometric linearity shall be checked using grey filters with a certified transmittance.

For reflectance measurements, reference materials having a reflection behaviour (i.e. reflectance level and ratio of diffuse and direct reflectance) similar to the unknown sample shall be selected.

Thick samples (e.g. laminated glass or insulating units) can modify the optical path of the instrument’s beam as compared to the path in air and therefore the sample beam hits an area of the detector having a different responsivity.

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A similar source of inaccuracy occurs in case of samples with significant wedge angles which deflect the transmitted (and reflected) beams. It is recommended to check the reproducibility by repeating the measurement after rotating the sample.

Additionally, in the case of reflectance measurements, glass sheets cause a lateral shear of the beam reflected by the second surface, causing reflectance losses (whose extent is particulary evident in the case of thick and/or wedged samples). This source of inaccuracy shall be taken into account particularly in the case of reflectance measurements through the uncoated side. In order to quantify and correct systematic errors, it is recommended to use calibrated reflectance standards with a thickness similar to the unknown sample.

In the case of diffusing samples (or samples with a non-negligible diffusing component or wedged samples), transmittance and reflectance measurements shall be performed using integrating spheres whose openings are sufficiently large to collect all the diffusely transmitted or reflected beam. The sphere diameter shall be adequate and the internal surface adequately coated with a highly diffusing reflectance material, so that the internal area can provide the necessary multiple reflections. Reference materials with characteristics similar to the unknown sample as specified above shall be used.

If the transmittance or reflectance curve recorded by the spectrometer exhibits a high level of noise for some wavelengths, the values to be considered for those wavelengths should be obtained after a smoothing of the noise.

In this International Standard, these requirements are not all treated in detail. For more information, see reference [3] which gives comprehensive and detailed information on how to perform optical measurements.

3.3 Light transmittance

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The light transmittance τ_{v} of glazing shall be calculated using the following formula:

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$$\tau_{\mathrm{v}} = \frac{\sum\limits_{\lambda = 380\ \mathrm{nm}}^{780\ \mathrm{nm}} \tau(\lambda) D_{\lambda} V(\lambda) \Delta\lambda}{\sum\limits_{\lambda = 380\ \mathrm{nm}}^{780\ \mathrm{nm}} D_{\lambda} V(\lambda) \Delta\lambda} \tag{1}$$

where

D_{λ} is the relative spectral distribution of illuminant D65 (see ISO/CIE 10526),

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

$V(\lambda)$ is the spectral luminous efficiency for photopic vision defining the standard observer for photometry (see ISO/CIE 10527);

$\Delta\lambda$ is the wavelength interval.

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

In the case of multiple glazing, the spectral transmittance $\tau(\lambda)$ shall be obtained by calculation from the spectral characteristics of the individual components. Alternatively measurements on non-diffusing multiple units may be performed using an integrating sphere. This may be achieved after reducing the interspaces under conditions that allow the collection of the whole transmitted beam (see 3.2).

The calculation of the spectral transmittance $\tau(\lambda)$ shall be performed using methods such as algebraic manipulation, the embedding technique of reference [4] or by recursion techniques (e.g. according to reference [5]). Any algorithm that can be shown to yield consistently the correct solution is acceptable.

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For the calculation of $\tau(\lambda)$ as well as for the calculation of spectral reflectance (see 3.4), the following symbols for the spectral transmittance and spectral reflectance of the individual components are used:

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

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

$\tau_n(\lambda)$ is the spectral transmittance of the nth (inner) pane (e.g. for triple glazing $n = 3$);

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

$\rho'_1(\lambda)$ is the spectral reflectance of the outer (first) pane measured in the opposite direction of incident radiation;

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

$\rho'_2(\lambda)$ is the spectral reflectance of the second pane measured in the opposite direction of incident radiation;

$\rho_n(\lambda)$ is the spectral reflectance of the nth (inner) pane measured in the direction of incident radiation;

$\rho'_n(\lambda)$ is the spectral reflectance of the nth (inner) pane measured in the opposite direction of incident radiation.

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For the spectral transmittance $\tau(\lambda)$ as a function of the spectral characteristics of the individual components of the unit, the following formulae are obtained:

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a) For double glazing:

$$\tau(\lambda) = \frac{\tau_1(\lambda)\,\tau_2(\lambda)}{1 - \rho'_1(\lambda)\,\rho_2(\lambda)} \qquad (2)$$

b) For triple glazing:

$$\tau(\lambda) = \frac{\tau_1(\lambda)\,\tau_2(\lambda)\,\tau_3(\lambda)}{\left[1 - \rho'_1(\lambda)\,\rho_2(\lambda)\right]\cdot\left[1 - \rho'_2(\lambda)\,\rho_3(\lambda)\right] - \tau_2^2(\lambda)\,\rho'_1(\lambda)\,\rho_3(\lambda)} \qquad (3)$$

For multiple glazing with more than three components, relationships similar to Equations (2) and (3) are found to calculate $\tau(\lambda)$ of such glazing from the spectral characteristics of the individual components. As these formulae become very complex, they are not given here.

As an example for calculating $\tau(\lambda)$ according to the procedures of this International Standard, a 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.

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3.4 Light reflectance

3.4.1 External light reflectance of glazing

The external light reflectance of glazing $\rho_{v,o}$ shall be calculated using the following formula:

$$\rho_{v,o} = \frac{\sum_{\lambda = 380\text{ nm}}^{780\text{ nm}} \rho_o(\lambda)\, D_\lambda\, V(\lambda)\, \Delta\lambda}{\sum_{\lambda = 380\text{ nm}}^{780\text{ nm}} D_\lambda\, V(\lambda)\, \Delta\lambda} \quad (4)$$

where $\rho_o(\lambda)$ is the spectral external reflectance of glazing, and D_λ, $V(\lambda)$, $\Delta\lambda$ and the integration procedure are as defined in 3.3

For multiple glazing, the calculation of the spectral external reflectance $\rho_o(\lambda)$ shall be performed using the same methods as given in 3.3 for the calculation of the spectral transmittance $\tau(\lambda)$.

For the spectral external reflectance $\rho_o(\lambda)$ as a function of the spectral characteristics of the individual components of the unit, the following formulae are applied.

a) For double glazing:

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$$\rho_o(\lambda) = \rho_1(\lambda) + \frac{\tau_1^2(\lambda)\, \rho_2(\lambda)}{1 - \rho_1'(\lambda)\, \rho_2(\lambda)} \quad (5)$$

b) For triple glazing:

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$$\rho_o(\lambda) = \rho_1(\lambda) + \frac{\tau_1^2(\lambda)\, \rho_2(\lambda)\left[1 - \rho_2'(\lambda)\, \rho_3(\lambda)\right] + \tau_1^2(\lambda)\, \tau_2^2(\lambda)\, \rho_3(\lambda)}{\left[1 - \rho_1'(\lambda)\, \rho_2(\lambda)\right] \cdot \left[1 - \rho_2'(\lambda)\, \rho_3(\lambda)\right] - \tau_2^2(\lambda)\, \rho_1'(\lambda)\, \rho_3(\lambda)} \quad (6)$$

For multiple glazing with more than three components, relationships similar to Equations (5) and (6) are found to calculate $\rho_o(\lambda)$ of such glazing from the spectral characteristics of the individual components. As these formulae become very complex, they are not given here.

As an example for calculating $\rho_o(\lambda)$, a glazing composed of five components may be treated in the same way as described in 3.3.

3.4.2 Internal light reflectance of glazing

The internal light reflectance of glazing $\rho_{v,i}$ shall be calculated using the following formula:

$$\rho_{v,i} = \frac{\sum_{\lambda = 380\text{ nm}}^{780\text{ nm}} \rho_i(\lambda)\, D_\lambda\, V(\lambda)\, \Delta\lambda}{\sum_{\lambda = 380\text{ nm}}^{780\text{ nm}} D_\lambda\, V(\lambda)\, \Delta\lambda} \quad (7)$$

where $\rho_i\,(\lambda)$ is the spectral internal reflectance of glazing, and D_λ, $V(\lambda)$, $\Delta\lambda$ and the integration procedure are as defined in 3.3.

For multiple glazing, the calculation of the spectral internal reflectance $\rho_i(\lambda)$ shall be performed using the same methods as given in 3.3 for the calculation of the spectral transmittance $\tau(\lambda)$.

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For the spectral internal reflectance $\rho_i(\lambda)$ as a function of the spectral characteristics of the individual components of the unit, the following formulae are applied.

a) For double glazing:

$$\rho_i(\lambda) = \rho'_2(\lambda) + \frac{\tau_2^2(\lambda)\,\rho'_1(\lambda)}{1 - \rho'_1(\lambda)\quad \rho_2(\lambda)} \tag{8}$$

b) For triple glazing:

$$\rho_i(\lambda) = \rho'_3(\lambda) + \frac{\tau_3^2(\lambda)\,\rho'_2(\lambda)\left[1 - \rho_2(\lambda)\,\rho'_1(\lambda)\right] + \tau_3^2(\lambda)\,\tau_2^2(\lambda)\,\rho'_1(\lambda)}{\left[1 - \rho_3(\lambda)\,\rho'_2(\lambda)\right]\cdot\left[1 - \rho_2(\lambda)\,\rho'_1(\lambda)\right] - \tau_2^2(\lambda)\,\rho_3(\lambda)\,\rho'_1(\lambda)} \tag{9}$$

For multiple glazing with more than three components, relationships similar to Equations (8) and (9) are found to calculate $\rho_i(\lambda)$ of such glazing from the spectral characteristics of the individual components. As these formulae are very complex, they are not given here.

As an example for calculating $\rho_i(\lambda)$, a glazing composed of five components may be treated in the same way as described in 3.3.

3.5 Total solar energy transmittance (solar factor)

3.5.1 General

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The total solar energy transmittance g is the sum of the solar direct transmittance τ_e and the secondary heat transfer factor q_i towards the inside (see 3.5.3 and 3.5.6), 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:

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$$g = \tau_e + q_i \tag{10}$$

3.5.2 Division of incident solar radiation flux

The incident solar radiant flux per unit area ϕ_e is divided into the following three parts (see Figure 1):

— the transmitted part $\tau_e\phi_e$;

— the reflected part $\rho_e\phi_e$;

— the absorbed part $\alpha_e\phi_e$;

where

τ_e is the solar direct transmittance (see 3.5.3);

ρ_e is the solar direct reflectance (see 3.5.4);

α_e is the solar direct absorptance (see 3.5.5).

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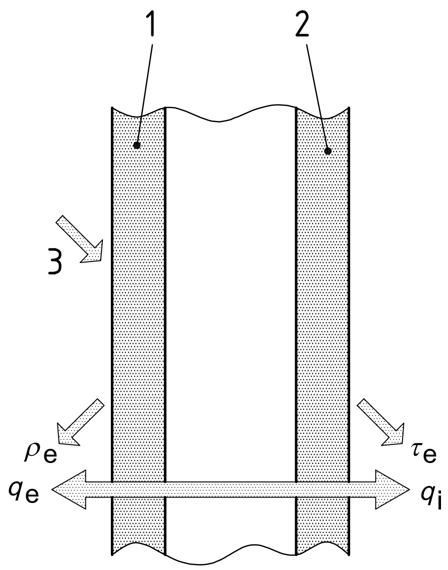

Key

1 outer pane

2 second inner pane

3 unit incident radiant flux

$\rho_e = 0{,}38$; $q_e = 0{,}17$

$\tau_e = 0{,}41$; $q_i = 0{,}04$; therefore $g = 0{,}45$

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Figure 1 — Division of the incident radiant flux for a double glazing unit

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The relationship between the three characteristics is

$$\tau_e + \rho_e + \alpha_e = 1 \tag{11}$$

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

$$\alpha_e = q_i + q_e \tag{12}$$

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.

3.5.3 Solar direct transmittance

The solar direct transmittance τ_e of glazing shall be calculated using the following formula:

$$\tau_e = \frac{\sum_{\lambda = 300\text{ nm}}^{2\,500\text{ nm}} \tau(\lambda) S_\lambda \, \Delta\lambda}{\sum_{\lambda = 300\text{ nm}}^{2\,500\text{ nm}} S_\lambda \Delta\lambda} \tag{13}$$

where

S_λ is the relative spectral distribution of the solar radiation;

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

$\Delta\lambda$ 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 2.

The relative spectral distribution, S_λ, used to calculate the solar direct transmittance τ_e, is derived from the global solar irradiance given in ISO 9845-1:1992, Table 1, column 5. The corresponding values $S_\lambda \Delta\lambda$ are given in Table 2. This table is drawn up in such a way that $\Sigma\, S_\lambda \Delta\lambda = 1$.

In the case of multiple glazing, the spectral transmittance $\tau(\lambda)$ is calculated in accordance with 3.3.

NOTE Contrary to real situations, it is always assumed, for simplification, that the solar radiation strikes the glazing as a beam and almost at normal incidence. In the case of oblique incidence of radiation, the solar direct transmittance of glazing and the total solar energy transmittance are both somewhat reduced. The solar control effect becomes greater in the case of oblique incidence of radiation.

3.5.4 Solar direct reflectance

The solar direct reflectance ρ_e of the glazing shall be calculated using the following formula:

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$$\rho_e = \frac{\sum_{\lambda = 300\ \text{nm}}^{2\,500\ \text{nm}} \rho_o(\lambda)\, S_\lambda\, \Delta\lambda}{\sum_{\lambda = 300\ \text{nm}}^{2\,500\ \text{nm}} S_\lambda\, \Delta\lambda} \qquad (14)$$

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where

S_λ is the relative spectral distribution of the solar radiation (see 3.5.3);

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

$\Delta\lambda$ 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 2.

In the case of multiple glazing, the spectral external reflectance $\rho_o(\lambda)$ is calculated in accordance with 3.4.1.

3.5.5 Solar direct absorptance

The solar direct absorptance α_e shall be calculated from Equation (11).

3.5.6 Secondary heat transfer factor towards the inside

3.5.6.1 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.

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