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

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

Reference number
ISO 9050 : 1990 (E)

Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

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Annex A of this International Standard is for information only.

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INTERNATIONAL STANDARD **ISO 9050 : 1990 (E)**

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

1 Scope

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

This International Standard applies both to conventional glazing units and to absorbing or reflecting solar-control glazing units, used as vertical or horizontal glazed apertures. The appropriate formulae for single, double and triple glazing units are given.

This International Standard accordingly applies 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 plastics sheets.

Materials with light-scattering properties for incident radiation are dealt with as conventional transparent materials under certain conditions (see 2.2).

2 Determination of characteristic parameters

2.1 General

The characteristic parameters are determined for quasi-parallel, almost normal radiation incidence (see [6]), using the radiation distribution of illuminant D_{65} (see table 1), solar radiation according to table 2 or 3 and ultraviolet (UV) radiation according to table 4.

The characteristic parameters are as follows :

- the spectral transmittance $\tau(\lambda)$ and the spectral reflectance $\varrho(\lambda)$ in the wavelength range of 280 nm to 2 500 nm,
- the light transmittance τ_v and the light reflectance ϱ_v for illuminant D_{65},
- 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 (in accordance with [2]).

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

If nothing else is stated, the published characteristic parameters should be determined using the standard conditions given in 2.2 to 2.6.

2.2 Light transmittance

The light transmittance τ_v of glazing units may be calculated using the formula :

$$\tau_v = \frac{\int_{\lambda = 380\text{ nm}}^{780\text{ nm}} D_\lambda \tau(\lambda) V(\lambda) \mathrm{d}\lambda}{\int_{\lambda = 380\text{ nm}}^{780\text{ nm}} D_\lambda V(\lambda) \mathrm{d}\lambda} \approx \frac{\sum_{\lambda = 380\text{ nm}}^{780\text{ nm}} D_\lambda \tau(\lambda) V(\lambda) \Delta\lambda}{\sum_{\lambda = 380\text{ nm}}^{780\text{ nm}} D_\lambda V(\lambda) \Delta\lambda} \qquad \text{...(1)}$$

where

D_λ is the relative spectral power distribution of illuminant D_{65} (see [3]);

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

$V(\lambda)$ is the photopic luminous efficiency function defining the standard observer for photometry (see [3]).

Table 1 indicates the values for $D_\lambda V(\lambda) \Delta\lambda$ for intervals of 10 nm. The table has been drawn up in such a way that $\sum D_\lambda V(\lambda) \Delta\lambda = 100$. In the case of multiple glazing, the spectral transmittance $\tau(\lambda)$ can be calculated from the spectral transmittance and reflectance of the individual components as follows.

For double glazing units :

$$\tau(\lambda) = \frac{\tau_1(\lambda)\tau_2(\lambda)}{1 - \varrho'_1(\lambda)\varrho_2(\lambda)} \qquad \text{...(2)}$$

where

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

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

$\varrho_1(\lambda)$ is the spectral reflectance of the outer sheet, measured in the direction of incident radiation;

$\varrho_1'(\lambda)$ is the spectral reflectance of the outer sheet, measured in the opposite direction to the incident radiation;

$\varrho_2(\lambda)$ is the spectral reflectance of the second sheet, measured in the direction of the incident radiation.

For triple glazing :

$$\tau(\lambda) = \frac{\tau_1(\lambda)\tau_2(\lambda)\tau_3(\lambda)}{[1-\varrho_1'(\lambda)\varrho_2(\lambda)] \times [1-\varrho_2'(\lambda)\varrho_3(\lambda)] - \tau_2^2(\lambda)\varrho_1'(\lambda)\varrho_3(\lambda)} \qquad \ldots(3)$$

where

$\tau_1(\lambda)$, $\tau_2(\lambda)$, $\varrho_1(\lambda)$, $\varrho_1'(\lambda)$ and $\varrho_2(\lambda)$ are as defined in equation (2);

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

$\varrho_2'(\lambda)$ is the spectral reflectance of the second sheet, measured in the opposite direction to the incident radiation;

$\varrho_3(\lambda)$ is the spectral reflectance of the third sheet, measured in the direction of the incident radiation.

For glazing with more than three components, similar relations to (2) and (3) can be found to calculate $\tau(\lambda)$ of such units from the spectral factors of the individual components. As an example, glazing composed of five components may be treated as follows:

a) first consider the first three components as a triple glazing unit and calculate the factors of this unit;

b) next, run the same procedure for the next two components as a double glazing unit;

c) then calculate $\tau(\lambda)$ for the five component unit, considering it as a double glazing unit with the spectral components of the two preceding units.

NOTES

1 The spectral transmittance $\tau(\lambda)$ of any multiple glazing may also be obtained by measurements on the complete unit.

2 In the case of oblique incidence of light, i.e. in general cases where glazed apertures are lit by the sun, a clear or overcast sky and by light reflected off the ground and buildings, the transmittance is smaller than with light of perpendicular incidence. In the design therefore, with the application of appropriate corrections, somewhat larger glazed apertures result than on the basis of the transmittance determined for quasi-parallel and almost normal incident light (see [7]).

3 Daylight calculations are based on [4].

4 The use of an integrating sphere is recommended when light-scattering materials are tested. In this case the size of the sphere and its aperture should be big enough to collect all possible stray light and to obtain fair average values when surface patterns are irregularly distributed.

2.3 Light reflectance

The light reflectance of glazing ϱ_v may be calculated using the following formula :

$$\varrho_v = \frac{\int_{\lambda = 380\text{ nm}}^{780\text{ nm}} D_\lambda \varrho(\lambda) V(\lambda) d\lambda}{\int_{\lambda = 380\text{ nm}}^{780\text{ nm}} D_\lambda V(\lambda) d\lambda} \approx \frac{\sum_{\lambda = 380\text{ nm}}^{780\text{ nm}} D_\lambda \varrho(\lambda) V(\lambda) \Delta\lambda}{\sum_{\lambda = 380\text{ nm}}^{780\text{ nm}} D_\lambda V(\lambda) \Delta\lambda} \qquad \ldots(4)$$

where

D_λ and $V(\lambda)$ are as defined in 2.2;

$\varrho(\lambda)$ is the spectral reflectance of the glazing.

In the case of multiple glazing, the spectral reflectance $\varrho(\lambda)$ may be calculated from the spectral transmittance and the spectral reflectance of the individual components as follows (for definitions of symbols, see 2.2).

For double glazing units :

$$\varrho(\lambda) = \varrho_1(\lambda) + \frac{\tau_1^2(\lambda)\varrho_2(\lambda)}{1 - \varrho_1'(\lambda)\varrho_2(\lambda)} \qquad \ldots(5)$$

For triple glazing units :

$$\varrho(\lambda) = \varrho_1(\lambda) + \\ + \frac{\tau_1^2(\lambda)\varrho_2(\lambda)[1 - \varrho_2'(\lambda)\varrho_3(\lambda)] + \tau_1^2(\lambda)\tau_2^2(\lambda)\varrho_3(\lambda)}{[1 - \varrho_1'(\lambda)\varrho_2(\lambda)] \times [1 - \varrho_2'(\lambda)\varrho_3(\lambda)] - \tau_2^2(\lambda)\varrho_1'(\lambda)\varrho_3(\lambda)} \qquad \ldots(6)$$

For glazing with more than three elements the same method as described in 2.2 can be used.

2.4 Total solar energy transmittance (solar factor)

2.4.1 Definitions

The total solar energy transmittance g is the sum of the solar direct transmittance τ_e and of the secondary heat transfer factor q_i of the glazing towards the inside (see 2.4.3 and 2.4.6), 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 :

$$g = \tau_e + q_i \qquad \ldots(7)$$

2.4.2 Division of incident solar radiation

The incident solar radiation ϕ_e is divided into the following three parts (see figure 1) :

- the transmitted part, $\tau_e \phi_e$
- the reflected part, $\varrho_e \phi_e$
- the absorbed part, $\alpha_e \phi_e$

where

τ_e is the solar direct transmittance (see 2.4.3);

ϱ_e is the solar direct reflectance (see 2.4.4);

α_e is the solar direct absorptance (see 2.4.5).

Dimensions in millimetres

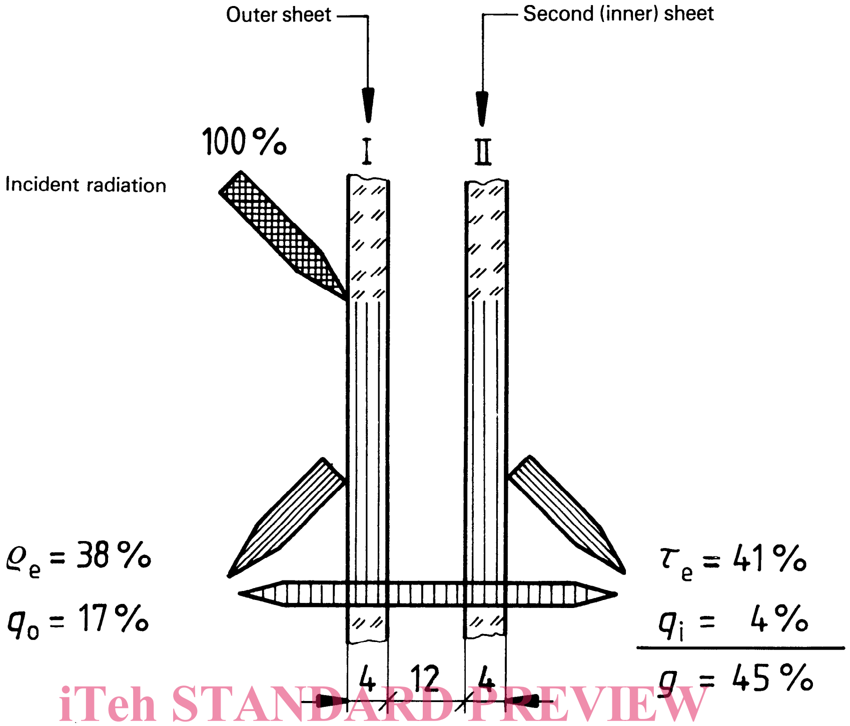

Figure 1 — Example of division of the incident solar radiation

The relation between the three factors is

$$\tau_e + \varrho_e + \alpha_e = 1 \qquad \ldots(8)$$

The absorbed part $\alpha_e \phi_e$ is subsequently split into two parts $q_i \phi_e$ and $q_o \phi_e$ which are energies transferred to the inside and outside respectively :

$$\alpha_e = q_i + q_o \qquad \ldots(9)$$

where

q_i is the secondary heat transfer factor of the glazing towards the inside;

q_o is the secondary heat transfer factor of the glazing towards the outside.

2.4.3 Solar direct transmittance

The solar direct transmittance τ_e of the glazing may be calculated using the following equation :

$$\tau_e = \frac{\int\limits_{\lambda=0}^{\infty} S_\lambda \tau(\lambda) d\lambda}{\int\limits_{\lambda=0}^{\infty} S_\lambda d\lambda} \approx \frac{\sum\limits_{\lambda=0}^{\infty} S_\lambda \tau(\lambda) \Delta\lambda}{\sum\limits_{\lambda=0}^{\infty} S_\lambda \Delta\lambda} \qquad \ldots(10)$$

where

S_λ is the spectral distribution of the solar radiation (see tables 2 and 3);

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

In the case of multiple glazing, the spectral transmittance $\tau(\lambda)$ can be calculated in accordance with 2.2.

Worldwide, two spectral distributions S_λ are used to calculate the solar direct transmittance, one according to [5] and the other according to the curve of P. Moon [8] for air mass 2. The corresponding values $S_\lambda \Delta\lambda$ are given in tables 2 and 3. The tables have been drawn up in such a way that $\Sigma\, S_\lambda \Delta\lambda = 1$. Other spectral distributions, S_λ, meeting special climatic conditions may also be used.

In most cases the differences in the solar direct transmittance obtained with these distributions can be neglected. Only for glazing materials with considerable differences in the transmittance over the whole spectral region may noticeable deviations come out. For all technical glazing materials, these differences may amount to only a few percent.

Which distribution is used for the calculation of the characteristic energy values shall be indicated.

NOTES

1 Contrary to real situations, it is always assumed, for simplification, that the spectral distribution of the solar radiation (tables 2 and 3) is not dependent upon atmospheric conditions (e.g. dust, mist, moisture content) and that the solar radiation strikes the glazing as a beam and almost normally. The resulting errors are very small.

2 In the case of oblique incidence of radiation, the solar direct transmittance of the glazing and the total solar energy transmittance are both reduced, as explained in 2.2, note 2. The solar control effect becomes greater in the case of oblique incidence of radiation.

2.4.4 Solar direct reflectance

The solar direct reflectance ϱ_e of the glazing can be calculated using the following equation :

$$\varrho_e = \frac{\int_{\lambda=0}^{\infty} S_\lambda \varrho(\lambda) \mathrm{d}\lambda}{\int_{\lambda=0}^{\infty} S_\lambda \mathrm{d}\lambda} \approx \frac{\sum_{\lambda=0}^{\infty} S_\lambda \varrho(\lambda) \Delta\lambda}{\sum_{\lambda=0}^{\infty} S_\lambda \Delta\lambda} \qquad \ldots(11)$$

where

S_λ is the spectral distribution of the solar radiation (see tables 2 and 3);

$\varrho(\lambda)$ is the spectral reflectance of the glazing.

In the case of multiple glazing, the spectral reflectance $\varrho(\lambda)$ can be calculated in accordance with 2.3.

2.4.5 Solar direct absorptance

The solar direct absorptance α_e can be calculated using equation (8).

2.4.6 Secondary heat transfer factor towards the inside

2.4.6.1 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.

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

- position of the glazing : vertical;
- outside surface : wind velocity : approximately 4 m/s, hemispherical emissivity = 0,83;
- inside surface : natural convection, emissivity optional.

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

$$h_e = 23 \text{ W/(m}^2\text{.K)}$$

$$h_i = 3{,}6 + \frac{4{,}4\,\varepsilon_i}{0{,}83} \text{ W/(m}^2\text{.K)}$$

where ε_i is the hemispherical emissivity [for normal glass $\varepsilon_i = 0{,}83$ and $h_i = 8 \text{ W/(m}^2\text{.K)}$].

If other heat transfer coefficients are used to calculate the secondary heat transfer factor in order to meet special boundary conditions, this shall be indicated.

NOTE — Lower values than 0,83 for ε_i (due to surface coatings with higher reflection in the far infra-red) are only to be taken into account if water condensation on the coated surface can be excluded.

2.4.6.2 Single glazing

The secondary heat transfer factor of a single glazing unit towards the inside q_i can be calculated using the following formula:

$$q_i = \alpha_e \frac{h_i}{h_e + h_i} \qquad \ldots(12)$$

where

α_e is the solar direct absorptance in accordance with 2.4.5;

h_i and h_e are the heat transfer factors towards the inside and outside respectively in accordance with 2.4.6.1.

2.4.6.3 Double glazing

The secondary heat transfer factor of double glazing units towards the inside q_i can be calculated using the following formula:

$$q_i = \left(\frac{\alpha_{e1} + \alpha_{e2}}{h_e} + \frac{\alpha_{e2}}{\Lambda} \right) \Big/ \left(\frac{1}{h_i} + \frac{1}{h_e} + \frac{1}{\Lambda} \right) \qquad \ldots(13)$$

where

α_{e1} is the solar absorptance of the outer sheet within the double glazing unit;

α_{e2} is the solar absorptance of the second sheet within the double glazing unit;

Λ is the thermal conductance between the outer and second sheet of the double glazing.

Coefficients α_{e1} and α_{e2} are calculated as follows :

$$\alpha_{e1} = \frac{\int_{\lambda=0}^{\infty} S_\lambda \left\{ \alpha_1(\lambda) + \frac{\alpha_1'(\lambda)\tau_1(\lambda)\varrho_2(\lambda)}{1 - \varrho_1'(\lambda)\varrho_2(\lambda)} \right\} \mathrm{d}\lambda}{\int_{\lambda=0}^{\infty} S_\lambda \mathrm{d}\lambda} \qquad \ldots(14)$$

$$\alpha_{e2} = \frac{\int_{\lambda=0}^{\infty} S_\lambda \left\{ \frac{\alpha_2(\lambda)\tau_1(\lambda)}{1 - \varrho_1'(\lambda)\varrho_2(\lambda)} \right\} \mathrm{d}\lambda}{\int_{\lambda=0}^{\infty} S_\lambda \mathrm{d}\lambda} \qquad \ldots(15)$$

where

$\alpha_1(\lambda)$ is the spectral absorptance of the outer sheet, measured in the direction of the incident radiation, given by the relation

$$\alpha_1(\lambda) = 1 - \tau_1(\lambda) - \varrho_1(\lambda) \qquad \ldots(16)$$

$\alpha'_1(\lambda)$ is the spectral absorptance of the outer sheet, measured in the opposite direction to the incident radiation, given by the relation

$$\alpha'_1(\lambda) = 1 - \tau_1(\lambda) - \varrho'_1(\lambda) \qquad \ldots(17)$$

$\alpha_2(\lambda)$ is the spectral absorptance of the second sheet, measured in the direction of the incident radation, given by the relation

$$\alpha_2(\lambda) = 1 - \tau_2(\lambda) - \varrho_2(\lambda) \qquad \ldots(18)$$

NOTE — The thermal conductance Λ is determined by the calculation method whenever possible or measuring methods (for example guarded hot plate method [1]). Corresponding International Standards are in preparation. The determinations are carried out with the sample vertical, the temperature difference across the sample being approximately 15 °C. The values are given for a mean sample temperature of 10 °C. Variations of these temperatures have practically no influence on the values of q_i.

2.4.6.4 Triple glazing

The secondary heat transfer factor of triple glazing towards the inside q_i may be calculated using the following formula :

$$q_i = \left(\frac{\alpha_{e3}}{\Lambda_{23}} + \frac{\alpha_{e3} + \alpha_{e2}}{\Lambda_{12}} + \frac{\alpha_{e3} + \alpha_{e2} + \alpha_{e1}}{h_e} \right) \Big/ \left(\frac{1}{h_i} + \frac{1}{h_e} + \frac{1}{\Lambda_{12}} + \frac{1}{\Lambda_{23}} \right) \qquad \ldots(19)$$

where

α_{e1} is the solar direct absorptance of the outer sheet within the triple glazing;

α_{e2} is the solar direct absorptance of the second sheet within the triple glazing;

α_{e3} is the solar direct absorptance of the third sheet within the triple glazing;

Λ_{12} is the thermal conductance between the outer and second sheet;

Λ_{23} is the thermal conductance between the second and third sheet.

Coefficients α_{e1}, α_{e2} and α_{e3} are calculated as follows :

$$\alpha_{e1} = \frac{\displaystyle\int_{\lambda=0}^{\infty} S_\lambda \left\{ \alpha_1(\lambda) + \frac{\tau_1(\lambda)\alpha'_1(\lambda)\varrho_2(\lambda)[1 - \varrho'_2(\lambda)\varrho_3(\lambda)] + \tau_1(\lambda)\tau_2^2(\lambda)\alpha'_1(\lambda)\varrho_3(\lambda)}{[1 - \varrho'_1(\lambda)\varrho_2(\lambda)] \times [1 - \varrho'_2(\lambda)\varrho_3(\lambda)] - \tau_2^2(\lambda)\varrho'_1(\lambda)\varrho_3(\lambda)} \right\} d\lambda}{\displaystyle\int_{\lambda=0}^{\infty} S_\lambda d\lambda} \qquad \ldots(20)$$

$$\alpha_{e2} = \frac{\displaystyle\int_{\lambda=0}^{\infty} S_\lambda \frac{\tau_1(\lambda)\alpha_2(\lambda)[1 - \varrho'_2(\lambda)\varrho_3(\lambda)] + \tau_1(\lambda)\tau_2(\lambda)\alpha'_2(\lambda)\varrho_3(\lambda)}{[1 - \varrho'_1(\lambda)\varrho_2(\lambda)] \times [1 - \varrho'_2(\lambda)\varrho_3(\lambda)] - \tau_2^2(\lambda)\varrho'_1(\lambda)\varrho_3(\lambda)} d\lambda}{\displaystyle\int_{\lambda=0}^{\infty} S_\lambda d\lambda} \qquad \ldots(21)$$

$$\alpha_{e3} = \frac{\displaystyle\int_{\lambda=0}^{\infty} S_\lambda \frac{\tau_1(\lambda)\tau_2(\lambda)\alpha_3(\lambda)}{[1 - \varrho'_1(\lambda)\varrho_2(\lambda)] \times [1 - \varrho'_2(\lambda)\varrho_3(\lambda)] - \tau_2^2(\lambda)\varrho'_1(\lambda)\varrho_3(\lambda)} d\lambda}{\displaystyle\int_{\lambda=0}^{\infty} S_\lambda d\lambda} \qquad \ldots(22)$$

where

$\alpha_1(\lambda)$, $\alpha'_1(\lambda)$ and $\alpha_2(\lambda)$ are as defined in 2.4.6.3;

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

$$\alpha'_2(\lambda) = 1 - \tau_2(\lambda) - \varrho'_2(\lambda) \qquad \ldots(23)$$

$\alpha_3(\lambda)$ is the spectral absorptance of the third sheet, measured in the direction of the incident radiation, given by the relation

$$\alpha_3(\lambda) = 1 - \tau_3(\lambda) - \varrho_3(\lambda) \qquad \ldots(24)$$

The thermal conductances Λ_{12} and Λ_{23} are determined according to the note in 2.4.6.3.

2.4.7 Total solar energy transmitted

The total solar energy transmitted into the room per unit area of glazing ϕ_{ei} is given by the relation

$$\phi_{ei} = \phi_e g \qquad \text{...(25)}$$

where ϕ_e is the flux of the incident solar radiation. ϕ_e-values can be obtained from appropriate tables in meteorological literature.

2.4.8 Additional heat transfer

If the room temperature T_i differs from the outside temperature T_o, another heat transfer occurs in addition to ϕ_{ei}. This additional heat flow q_z is independent of solar radiation and can be calculated as follows :

$$q_z = U(T_o - T_i) \qquad \text{...(26)}$$

where U is the thermal transmittance of the glazing.

2.5 UV-transmittance

In the UV-range, the global radiation of the sun only contains components in the UVB-range (280 nm to 315 nm) and the UVA (315 nm to 380 nm). A standard distribution for the UV part of the global radiation has been found (see [9]). Table 4 gives the values $U_\lambda \Delta\lambda$ for intervals of 5 nm in the range of UVA and UVB. The table has been drawn up with relative values in such a way that $\Sigma\, U_\lambda \Delta\lambda = 1$ for the total UV-range.

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

$$\tau_{UV} = \frac{\int_{\lambda = 280\ \text{nm}}^{380\ \text{nm}} U_\lambda \tau(\lambda) d\lambda}{\int_{\lambda = 280\ \text{nm}}^{380\ \text{nm}} U_\lambda d\lambda} \approx \frac{\sum_{\lambda = 280\ \text{nm}}^{380\ \text{nm}} U_\lambda \tau(\lambda) \Delta\lambda}{\sum_{\lambda = 280\ \text{nm}}^{380\ \text{nm}} U_\lambda \Delta\lambda} \qquad \text{...(27)}$$

where $\tau(\lambda)$ is the spectral transmittance of the glazing (see 2.2).

NOTE — If statements are made about the UV-transmittance of glazing units, it is in most cases sufficient to give τ_{UV}, the transmittance for the total UV-radiation contained in the global radiation. Only in special cases would there be any interest in the transmittance for the sub-ranges UVA and UVB.

2.6 Colour rendering

The colour rendering properties of the transmitted daylight are given by the general colour rendering index R_a. It is calculated according to the test colour method which has been established by the International Commission of Illumination (CIE) as the recommended method of measuring and specifying colour rendering properties of light sources (see [2]).

To determine the general colour rendering index R_a of glazing in transmission, D_{65} is given as a reference illuminant and the relative spectral distribution $D_\lambda \tau(\lambda)$ corresponds to the light source to be investigated.

R_a may reach a maximum value of 100. This will be achieved for glazing the spectral transmittance of which 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.

Table 1 — Relative spectral power distribution D_λ of illuminant D_{65} multiplied by the spectral sensitivity of the human eye $V(\lambda)$ and the spectral bandwidth $\Delta\lambda$

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

Table 2 — Relative spectral distribution of global solar radiation (direct and diffuse) S_λ (see [5]) for air mass 1 multiplied by the spectral bandwidth $\Delta\lambda$

λ nm	$S_\lambda \Delta\lambda$	λ nm	$S_\lambda \Delta\lambda$
300	0,005	700	0,046
340	0,024	740	0,041
380	0,032	780	0,037
420	0,050	900	0,139
460	0,065	1 100	0,097
500	0,063	1 300	0,058
540	0,058	1 500	0,039
580	0,054	1 700	0,026
620	0,055	1 900	0,018
660	0,049	2 500	0,044

Table 3 — Relative spectral distribution of direct solar radiation S_λ according to P. Moon [8] for air mass 2 multiplied by the spectral bandwidth $\Delta\lambda$

λ nm	$S_\lambda \Delta\lambda$
350	0,012 8
400	0,035 3
450	0,066 5
500	0,081 3
550	0,080 2
600	0,078 8
650	0,079 1
700	0,069 4
750	0,059 5
800	0,056 6
850	0,056 4
900	0,030 3
950	0,029 1
1 000	0,042 6
1 050	0,037 7
1 100	0,019 9
1 150	0,014 5
1 200	0,025 6
1 250	0,024 7
1 300	0,018 5
1 350	0,002 6
1 400	0,000 1
1 450	0,001 6
1 500	0,010 3
1 550	0,014 8
1 600	0,013 6
1 650	0,011 8
1 700	0,008 9
1 750	0,005 1
1 800	0,000 3
1 850	0,000 0
1 900	0,000 0
1 950	0,001 3
2 000	0,001 3
2 050	0,003 8
2 100	0,005 8

Table 4 — Relative spectral distribution of the UV part of the global radiation U_λ multiplied by the spectral bandwidth $\Delta\lambda$

λ nm	$U_\lambda \Delta\lambda$
282,5	0,000 00
287,5	0,000 00
292,5	0,000 00
297,5	0,000 82
302,5	0,004 61
307,5	0,013 73
312,5	0,027 46
317,5	0,041 20
322,5	0,055 91
327,5	0,065 72
332,5	0,070 62
337,5	0,072 58
342,5	0,074 54
347,5	0,076 01
352,5	0,077 00
357,5	0,078 96
362,5	0,080 43
367,5	0,083 37
372,5	0,086 31
377,5	0,090 73