

BS EN 410:2011



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

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee B/520/4, Properties and glazing methods.

A list of organizations represented on this committee can be obtained on request to its secretary.

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EUROPEAN STANDARD
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EN 410

February 2011

ICS 81.040.20

Supersedes EN 410:1998

English Version

**Glass in building - Determination of luminous and solar
characteristics of glazing**

Verre dans la construction - Détermination des
caractéristiques lumineuses et solaires des vitrages

Glas im Bauwesen - Bestimmung der lichttechnischen und
strahlungsphysikalischen Kenngrößen von Verglasungen

This European Standard was approved by CEN on 2 January 2011.

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Foreword

This document (EN 410:2011) has been prepared by Technical Committee CEN/TC 129 "Glass in building", the secretariat of which is held by NBN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2011, and conflicting national standards shall be withdrawn at the latest by August 2011.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 410:1998.

The main changes compared to the previous edition are:

- a) A procedure is provided for the calculation of the spectral properties of laminated glass.
- b) A formula is introduced for determining the total shading coefficient.
- c) Table 3 has been updated to make it more practical.
- d) Table 6 has been updated in line with the 2004 edition of the publication CIE No 15.
- e) The external and internal heat transfer coefficients have been amended slightly to reflect changes to EN 673.
- f) Guidance is also given on how to determine the spectral characteristics of screen printed glass.
- g) New drawings have been introduced for improved clarity and to conform with CEN rules.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

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Introduction

While this European 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 European 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 European 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).

1 Scope

This European Standard 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 European Standard 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.

This European Standard 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 5.2).

Angular light and solar properties of glass in building are excluded from this standard. However, research work in this area is summarised in Bibliography [1], [2] and [3].

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.

EN 673, *Glass in building — Determination of thermal transmittance (U value) — Calculation method*

EN 674, *Glass in building — Determination of thermal transmittance (U value) — Guarded hot plate method*

EN 675, *Glass in building — Determination of thermal transmittance (U value) — Heat flow meter method*

EN 12898, *Glass in building — Determination of the emissivity*

3 Terms and definitions

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

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 Normal emissivity is determined in accordance with EN 12898.
- 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)

4 Symbols

Sym.	Deutsch/German/Allemand	Englisch/English/Anglais	Französisch/French/Français
D65	Normlichtart D65	standard illuminant D65	illuminant normalisé D65
UV	Ultravioletter Strahlungsbereich	ultraviolet radiation	rayonnement ultraviolet
τ_{UV}	Ultravioletter Transmissionsgrad	ultraviolet transmittance	facteur de transmission de l'ultraviolet
$\tau(\lambda)$	Spektraler Transmissionsgrad	spectral transmittance	facteur de transmission spectrale
$\rho(\lambda)$	Spektraler Reflexionsgrad	spectral reflectance	facteur de réflexion spectrale
τ_v	Lichttransmissionsgrad	light transmittance	facteur de transmission lumineuse
ρ_v	Lichtreflexionsgrad	light reflectance	facteur de réflexion lumineuse
τ_e	direkter Strahlungstransmissionsgrad	solar direct transmittance	facteur de transmission directe de l'énergie solaire
ρ_e	direkter Strahlungsreflexionsgrad	solar direct reflectance	facteur de réflexion directe de l'énergie solaire

g	Gesamtenergiedurchlaß- grad	total solar energy transmittance (solar factor)	facteur de transmission totale de l'énergie solaire ou facteur solaire
R_a	allgemeiner Farbwiedergabeindex	general colour rendering index	indice général de rendu des couleurs
D_λ	relative spektrale Verteilung der Normlichtart D65	relative spectral distribution of illuminant D65	répartition spectrale relative de l'illuminant normalisé D65
$V(\lambda)$	spektraler Hellempfindlichkeitsgrad	spectral luminous efficiency	efficacité lumineuse relative spectrale
α_e	direkter Strahlungsabsorptionsgrad	solar direct absorptance	facteur d'absorption directe de l'énergie solaire
ϕ_e	Strahlungsleistung (Strahlungsfluß)	incident solar radiant flux	flux énergétique solaire incident
q_i	sekundärer Wärmeabgabegrad nach innen	secondary internal heat transfer factor	facteur de réémission thermique vers l'intérieur
q_e	sekundärer Wärmeabgabegrad nach außen	secondary external heat transfer factor	facteur de réémission thermique vers l'extérieur
S_λ	relative spektrale Verteilung der Sonnenstrahlung	relative spectral distribution of solar radiation	répartition spectrale relative du rayonnement solaire
h_e	Wärmeübergangskoeffizient nach außen	external heat transfer coefficient	coefficient d'échange thermique extérieur
h_i	Wärmeübergangskoeffizient nach innen	internal heat transfer coefficient	coefficient d'échange thermique intérieur
$\mathcal{E}$	korrigierter Emissionsgrad	corrected emissivity	émissivité corrigée
$\mathcal{E}_n$	normaler Emissionsgrad	normal emissivity	émissivité normale
A	Wärmedurchlaßkoeffizient	thermal conductance	conductance thermique
λ	Wellenlänge	wavelength	longueur d'onde
$\Delta\lambda$	Wellenlängenintervall	wavelength interval	intervalle de longueur d'onde
U_λ	relative spektrale Verteilung der UV-Strahlung der Sonne	relative spectral distribution of UV in solar radiation	répartition spectrale relative du rayonnement ultraviolet solaire
SC	Durchlassfaktor	shading coefficient	coefficient d'ombrage

5 Determination of characteristics

5.1 General

The characteristics are determined for quasi-parallel, near normal radiation incidence (see Bibliography, [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 2500 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.

5.2 Light transmittance

The light transmittance τ_v of the glazing is calculated using the following formula:

$$\tau_v = \frac{\sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} D_\lambda \tau(\lambda) V(\lambda) \Delta\lambda}{\sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} D_\lambda V(\lambda) \Delta\lambda} \quad (1)$$

where

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

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

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

$\Delta\lambda$ 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 $\sum D_{\lambda} V(\lambda) \Delta\lambda = 1$.

In the case of multiple glazing, the spectral transmittances $\tau(\lambda)$ are calculated from the spectral transmittances and reflectances of the individual components as follows :

For double glazing:

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

where

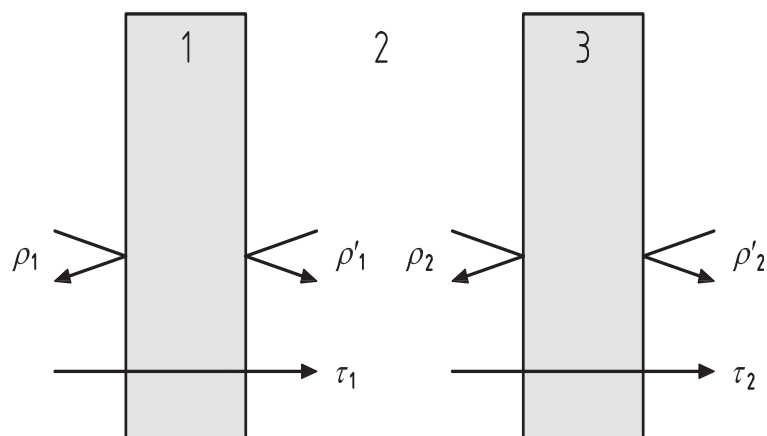
$\tau_1(\lambda)$ is the spectral transmittance of the first (outer) pane;

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

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

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

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:

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

where

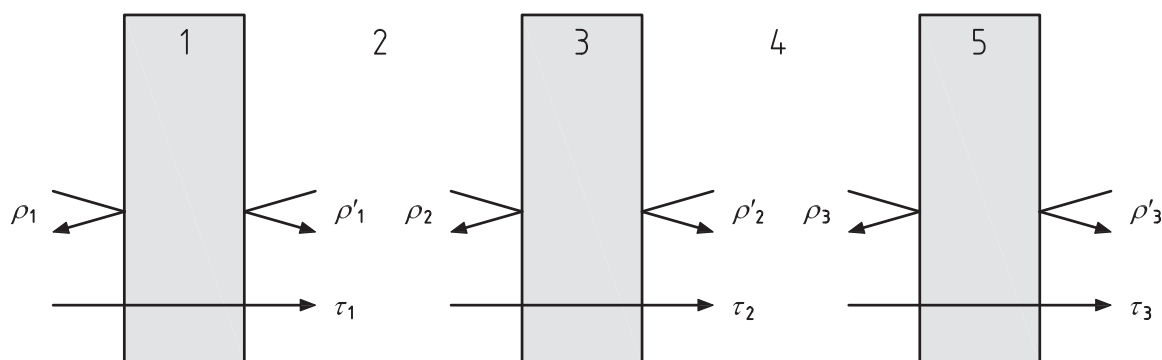
$\tau_1(\lambda)$, $\tau_2(\lambda)$, $\rho'_1(\lambda)$ and $\rho_2(\lambda)$ are as explained in Equation (2);

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

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

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

The above is illustrated in Figure 2.

**Key**

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

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

For glazing with more than three components, formulae similar to Equations (2) and (3) 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:

- a) first consider the first three components as triple glazing and calculate the spectral characteristics of this combination;
- b) next, run the same procedure for the next two components as double glazing;
- c) then calculate $\tau(\lambda)$ for the five component glazing, considering it as double glazing consisting of the preceding triple and double glazing.

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 reflectance

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

$$\rho_v = \frac{\sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} D_\lambda \rho(\lambda) V(\lambda) \Delta\lambda}{\sum_{\lambda=380 \text{ nm}}^{780 \text{ nm}} D_\lambda V(\lambda) \Delta\lambda} \quad (4)$$

where

D_λ , $V(\lambda)$ and $\Delta\lambda$ are as explained in 5.2;

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

In the case of multiple glazing, the spectral reflectance $\rho(\lambda)$ is calculated from the spectral transmittances and the spectral reflectances of the individual components as follows.

For double glazing, the external light reflectance of the glazing is calculated as follows:

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

where

$\tau_1(\lambda)$, $\rho_2(\lambda)$ and $\rho_1'(\lambda)$ are as explained in 5.2;

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

A corresponding equation can also be derived for calculating the internal light reflectance.

For triple glazing, the external light reflectance of the glazing is calculated as follows:

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

where

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

$\tau_1(\lambda)$, $\tau_2(\lambda)$, $\rho_1(\lambda)$, $\rho_2(\lambda)$, $\rho_1'(\lambda)$ and $\rho_2'(\lambda)$ are as defined in 5.2 and 5.3.

A corresponding equation the internal light reflectance of triple glazing can also be derived.

For glazing with more than three elements the same method as described in 5.2 is used.

5.4 Total solar energy transmittance (solar factor)

5.4.1 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 5.4.3 and 5.4.6), 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:

$$g = \tau_e + q_i \quad (7)$$

5.4.2 Division of incident solar radiant flux

The incident solar radiant flux ϕ_e is divided into the following three parts (see Figure 3):

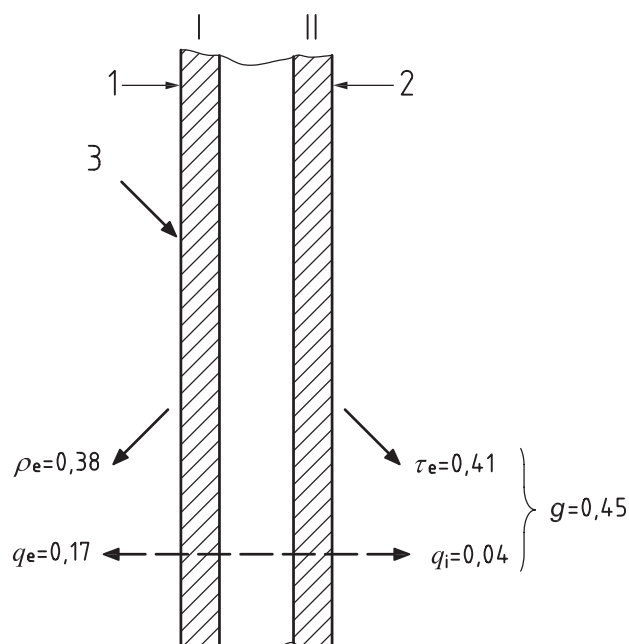
- a) the transmitted part, $\tau_e \phi_e$;
- b) the reflected part, $\rho_e \phi_e$;
- c) the absorbed part, $\alpha_e \phi_e$;

where

τ_e is the solar direct transmittance (see 5.4.3);

ρ_e is the solar direct reflectance (see 5.4.4);

α_e is the solar direct absorptance (see 5.4.5).



Key

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

Figure 3 — Example of division of the incident radiant flux

The relation between the three characteristics is:

$$\tau_e + \rho_e + \alpha_e = 1 \quad (8)$$

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:

$$\alpha_e = q_i + q_e \quad (9)$$

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.

5.4.3 Solar direct transmittance

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

$$\tau_e = \frac{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \tau(\lambda) \Delta\lambda}{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \Delta\lambda} \quad (10)$$

where

S_{λ} is the relative spectral distribution of the solar radiation (see Table 2);

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

$\Delta\lambda$ is the wavelength interval.

In the case of multiple glazing, the spectral transmittance $\tau(\lambda)$ is 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 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.

5.4.4 Solar direct reflectance

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

$$\rho_e = \frac{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \rho(\lambda) \Delta\lambda}{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \Delta\lambda} \quad (11)$$

where

S_{λ} is the relative spectral distribution of the solar radiation (see Table 2);

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

$\Delta\lambda$ is the wavelength interval.

In the case of multiple glazing, the spectral reflectance $\rho(\lambda)$ is calculated in accordance with 5.3.

5.4.5 Solar direct absorptance

The solar direct absorptance α_e is calculated from Equation (8) in 5.4.2.

5.4.6 Secondary heat transfer factor towards the inside

5.4.6.1 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 standard 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:

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

$$h_i = 3,6 + \frac{4,1\varepsilon_i}{0,837} \text{ W/(m}^2\cdot\text{K)}$$

where

ε_i is the corrected emissivity of the inside surface.

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

The corrected emissivity shall be defined and measured in accordance with EN 12898.

NOTE Values lower than 0,837 for ε_i (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.

5.4.6.2 Single glazing

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

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

where

α_e is the solar direct absorptance in accordance with 5.4.5;

h_e and h_i are the heat transfer coefficients towards the outside and inside respectively in accordance with 5.4.6.1.

5.4.6.3 Double glazing

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

$$q_i = \frac{\left[\frac{\alpha_{e1} + \alpha_{e2}}{h_e} + \frac{\alpha_{e2}}{A} \right]}{\left[\frac{1}{h_i} + \frac{1}{h_e} + \frac{1}{A} \right]} \quad (13)$$

where

h_e and h_i are the heat transfer coefficients towards the outside and inside respectively in accordance with 5.4.6.1;

α_{e1} is the solar direct absorptance of the outer pane within the double glazing;

α_{e2} is the solar direct absorptance of the second pane within the double glazing;

A is the thermal conductance between the outer surface and the innermost surface of the double glazing (see Figure 4).

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

$$\alpha_{e1} = \frac{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \left\{ \alpha_1(\lambda) + \frac{\alpha'_1(\lambda)\tau_1(\lambda)\rho_2(\lambda)}{1-\rho'_1(\lambda)\rho_2(\lambda)} \right\} \Delta\lambda}{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \Delta\lambda} \quad (14)$$

$$\alpha_{e2} = \frac{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \left\{ \frac{\alpha_2(\lambda)\tau_1(\lambda)}{1-\rho'_1(\lambda)\rho_2(\lambda)} \right\} \Delta\lambda}{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \Delta\lambda} \quad (15)$$

where

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

$$\alpha_1(\lambda) = 1 - \tau_1(\lambda) - \rho_1(\lambda) \quad (16)$$

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

$$\alpha'_1(\lambda) = 1 - \tau_1(\lambda) - \rho'_1(\lambda) \quad (17)$$

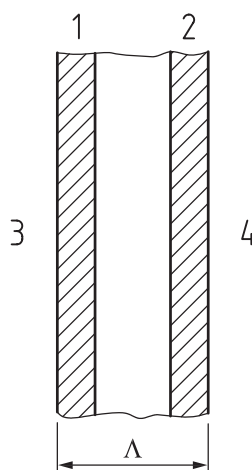
$\alpha_2(\lambda)$ is the spectral direct absorptance of the second pane, measured in the direction of the incident radiation, given by the formula:

$$\alpha_2(\lambda) = 1 - \tau_2(\lambda) - \rho_2(\lambda) \quad (18)$$

S_{λ} and $\Delta\lambda$ are as defined in 5.4.3;

$\tau_1(\lambda)$, $\rho_2(\lambda)$ and $\rho'_1(\lambda)$ are as defined in 5.2.

The thermal conductance A is determined by the calculation method in accordance with EN 673 whenever possible or by measuring methods in accordance with EN 674 or EN 675.



Key

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

Figure 4 — Illustration of the meaning of thermal conductance Λ

5.4.6.4 Triple glazing

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

$$q_i = \frac{\left[\frac{\alpha_{e3}}{A_{23}} + \frac{\alpha_{e3} + \alpha_{e2}}{A_{12}} + \frac{\alpha_{e3} + \alpha_{e2} + \alpha_{e1}}{h_e} \right]}{\left[\frac{1}{h_i} + \frac{1}{h_e} + \frac{1}{A_{12}} + \frac{1}{A_{23}} \right]} \quad (19)$$

where

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

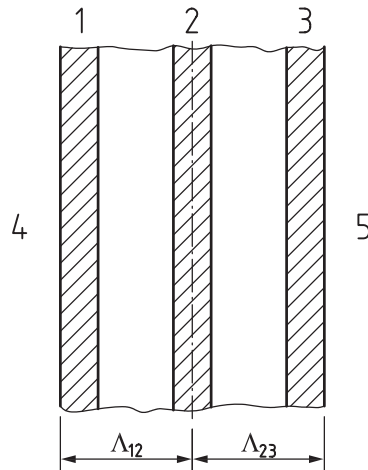
α_{e2} is the solar direct absorptance of the second pane within the triple glazing;

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

h_e and h_i are the heat transfer coefficients towards the outside and inside respectively in accordance with 5.4.6.1;

A_{12} is the thermal conductance between the outer surface of the first pane and the centre of the second pane (see Figure 5);

A_{23} is the thermal conductance between the centre of the second pane and the innermost surface of the third pane (see Figure 5).



Key

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

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

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

$$\alpha_{e1} = \frac{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \left\{ \alpha_1(\lambda) + \frac{\tau_1(\lambda) \alpha'_1(\lambda) \rho_2(\lambda) [1 - \rho'_2(\lambda) \rho_3(\lambda)] + \tau_1(\lambda) \tau_2^2(\lambda) \alpha'_1(\lambda) \rho_3(\lambda)}{[1 - \rho'_1(\lambda) \rho_2(\lambda)] \times [1 - \rho'_2(\lambda) \rho_3(\lambda)] - \tau_2^2(\lambda) \rho'_1(\lambda) \rho_3(\lambda)} \right\} \Delta \lambda}{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \Delta \lambda} \quad (20)$$

$$\alpha_{e2} = \frac{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \left\{ \frac{\tau_1(\lambda) \alpha_2(\lambda) [1 - \rho'_2(\lambda) \rho_3(\lambda)] + \tau_1(\lambda) \tau_2(\lambda) \alpha'_2(\lambda) \rho_3(\lambda)}{[1 - \rho'_1(\lambda) \rho_2(\lambda)] \times [1 - \rho'_2(\lambda) \rho_3(\lambda)] - \tau_2^2(\lambda) \rho'_1(\lambda) \rho_3(\lambda)} \right\} \Delta \lambda}{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \Delta \lambda} \quad (21)$$

$$\alpha_{e3} = \frac{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \left\{ \frac{\tau_1(\lambda) \tau_2(\lambda) \alpha_3(\lambda)}{[1 - \rho'_1(\lambda) \rho_2(\lambda)] \times [1 - \rho'_2(\lambda) \rho_3(\lambda)] - \tau_2^2(\lambda) \rho'_1(\lambda) \rho_3(\lambda)} \right\} \Delta \lambda}{\sum_{\lambda=300 \text{ nm}}^{2500 \text{ nm}} S_{\lambda} \Delta \lambda} \quad (22)$$

where

$\alpha_1(\lambda)$, $\alpha'_1(\lambda)$ and $\alpha_2(\lambda)$ are as defined in 5.4.6.3;

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

$$\alpha'_2(\lambda) = 1 - \tau_2(\lambda) - \rho'_2(\lambda) \quad (23)$$

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

$$\alpha_3(\lambda) = 1 - \tau_3(\lambda) - \rho_3(\lambda) \quad (24)$$

S_λ and $\Delta\lambda$ are as defined in 5.4.3.

The thermal conductances A_{12} and A_{23} are determined in accordance with 5.4.6.3.

5.5 UV-transmittance

In the UV range, the global radiation of the sun contains components in the UV-B range 280 nm to 315 nm and the UV-A range 315 nm to 380 nm. 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 $U_\lambda \Delta\lambda$ for wavelength intervals of 5 nm in the UV range. The table has been drawn up with relative values in such a way that $\sum U_\lambda \Delta\lambda = 1$ for the total UV range.

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

$$\tau_{uv} = \frac{\sum_{\lambda=280 \text{ nm}}^{380 \text{ nm}} U_\lambda \tau(\lambda) \Delta\lambda}{\sum_{\lambda=280 \text{ nm}}^{380 \text{ nm}} U_\lambda \Delta\lambda} \quad (25)$$

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. Only in special cases would there be any interest in the transmittances for the sub-ranges UV-A and UV-B.

5.6 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 Bibliography, [8]).

NOTE Bibliography, [8] suggests to determine the colour rendering index with the help of a diskette. The user should be aware of the fact that the program contained in the diskette automatically compares the light filtered by a given glazing with the illuminant having the nearest colour temperature, rather than with D65.

The test colours are defined by their spectral reflectance $\beta_i(\lambda)$ (i from 1 to 8), reported in Table 4 (see Bibliography, [8]). The relative spectral energy distribution of illuminant D65 is reported in Table 5 (see Bibliography, [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: